Pesticide Use on Fruits and Vegetables in Himachal Pradesh, India

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by
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ABSTRACT

This project researched stakeholder knowledge about pesticides in Himachal Pradesh, as well as pesticide use on farms in the region. We documented perceptions of farmers, government officials, and vendors, investigated relevant policies, documented application practices, and applied a method to test for chemicals in market produce. Our findings indicated the presence of pesticides on sampled fruit and vegetables, many of which have been banned in other countries. Moreover, farmers were not always aware of dangers and regulations.

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EXECUTIVE SUMMARY

A Transition Toward Pesticides in Himachal Pradesh

Pesticide use in rural and remote locations can be difficult to measure in India, where local practices vary and are where there is limited educational outreach to inform small farmers. Himachal Pradesh faces such challenges. Located in the northwestern foothills of the Himalayan region, Himachal Pradesh is dotted with small farms, despite its hilly terrain. The state is largely rural and agrarian, with approximately 70% of jobs in agriculture (Himachal Pradesh, 2012).

Figure 1. Small plots for lettuce cultivation

Despite their small size, strategically placed agricultural plots supply local families and regional markets with a wide range of produce, including apples, tomatoes, carrots, radishes, cauliflower, and several different kinds of lettuce. Through preliminary discussions with our IIT mentors, we learned that farmers are turning to pesticides to raise crop production, and some rely on chemicals that have been banned in other countries. These practices limit the possibilities for export and also raise questions about the toxicity of the produce and risks to those that consume it. The shift toward pesticide use has led to internal controversy and debate as to whether or not these pesticides should be banned in India as well (Centre in Favour of Manufacture of Endosulfan, 2014).

It has proven difficult for India to determine a policy on pesticide limits because key stakeholders—farmers, consumers, and the government—cannot agree on the numbers. It is even more challenging to gather information about how much each of these groups knows about pesticides because many may be unfamiliar with the effects they have on both the environment and humans. Preliminary discussions with our mentors at IIT suggested that local farmers are even unsure of the meaning of the term *pesticide*, which makes it difficult to gather consistent information through the use of direct questioning. Beyond this, the government has not taken a firm stance on the matter because of conflicting information on the pros and cons associated with pesticides (Pesticide Regulations, 2014).

> The goal of this project was to understand pesticide use on small fruit and vegetable farms in Himachal Pradesh and to determine the knowledge farmers, vendors, consumers, and government officials have about pesticides.

Focused research on pesticide use will inform ongoing debates and public policies. Therefore, the goal of this project was to understand pesticide use on small fruit and vegetable farms in Himachal Pradesh and to determine the knowledge farmers, vendors, consumers, and government officials have about pesticides. In order to meet this goal, we documented perceptions that these key stakeholders had about pesticides, investigated government policies, documented pesticide application practices, and identified pesticides present in a sample of local market fruits and vegetables. Based on this data, we recommended that government offices supply information to farmers about safe practices and promote safer alternatives to pesticide-based practices.

The Dangers of Pesticide Reliance

Various fruits, vegetables, grains, and legumes are grown throughout Himachal Pradesh (Agricultural Informatics Division, n.d.). Because of the uneven terrain, crops are typically grown on small farms throughout the state. In order to maximize crop production and combat pests and blight, farmers have begun using pesticides which are sold in local markets. Local crops are sold in local markets, either through vendors who sell on behalf of the farmers or by the farmers themselves. Market streets in Mandi and small surrounding villages are lined with vendor stands. Most of the produce comes from local farms, but some items out of season or not grown locally may be imported. Through preliminary discussion with our IIT mentors, we learned that local villagers rely on these markets for their produce unless they farm their own plots of land. Because of this reliance, it is especially dangerous if farmers are not conscious of the effects of pesticides.

The majority of pesticides used on crops in Himachal Pradesh fall under the category of insecticides (Abhilash, & Singh, 2009). The most commonly used chemicals have been identified as organochlorine insecticides (OCs), known for “their low cost and versatility against various pests” (ibid.). Although OCs have been banned in many countries due to their “potential for bioaccumulation and biological effects” as well as their resistance to degradation, these chemicals are still manufactured and used on a large scale across India (ibid.). While it is assumed that pesticide use is common, it is less clear which pesticides farmers are using sincedocumentation of regional practices is scarce.

Pesticides have been incorporated into farming practices to increase profits. By using pesticides, crops are less likely to be damaged from pests or blight. Studies have shown, however, that communities, farmworkers, and consumers can suffer unintended negative consequences from pesticide exposure. Advocacy groups fear serious health and environmental effects that could emerge from chemicals not yet controlled in India (Centre in Favour of Manufacture of Endosulfan, 2014). The ability of pesticides to travel easily through various domains, such as air, water, soil, and the food chain, enables bioaccumulation in plants and animals. Numerous studies, including one from the University of Toronto, have found consistent positive associations between pesticide exposure and neurologic, reproductive, and genotoxic deficiencies in exposed subjects (Sanborn, 2007). The World Health Organization estimates one million severe unintentional poisonings each year and three million unreported poisonings (Jeyaratnam, 1990).

From an environmental standpoint, pesticides tend to have long half-lives, and can remain in the ecosystem for years. Some undergo chemical reactions in the environment, often creating even more dangerous and persistent chemicals. For example, endosulfan, a pesticide used commonly in India, can transform into three different isomers, all with large half-lives. According to the Agency for Toxic Substances and Disease Registry, the half-life of alpha-endosulfan in soil is about 37–67 days, and the half-life for beta-endosulfan in soil is 104–265 days, while the half-life of endosulfan diol in water is approximately one month (ATSDR, 2013). During this time, the chemicals interact with their surroundings and escalate the effects of the pesticide on the ecosystem. Some of the ways pesticides can be spread through a community are highlighted in Figure 2.

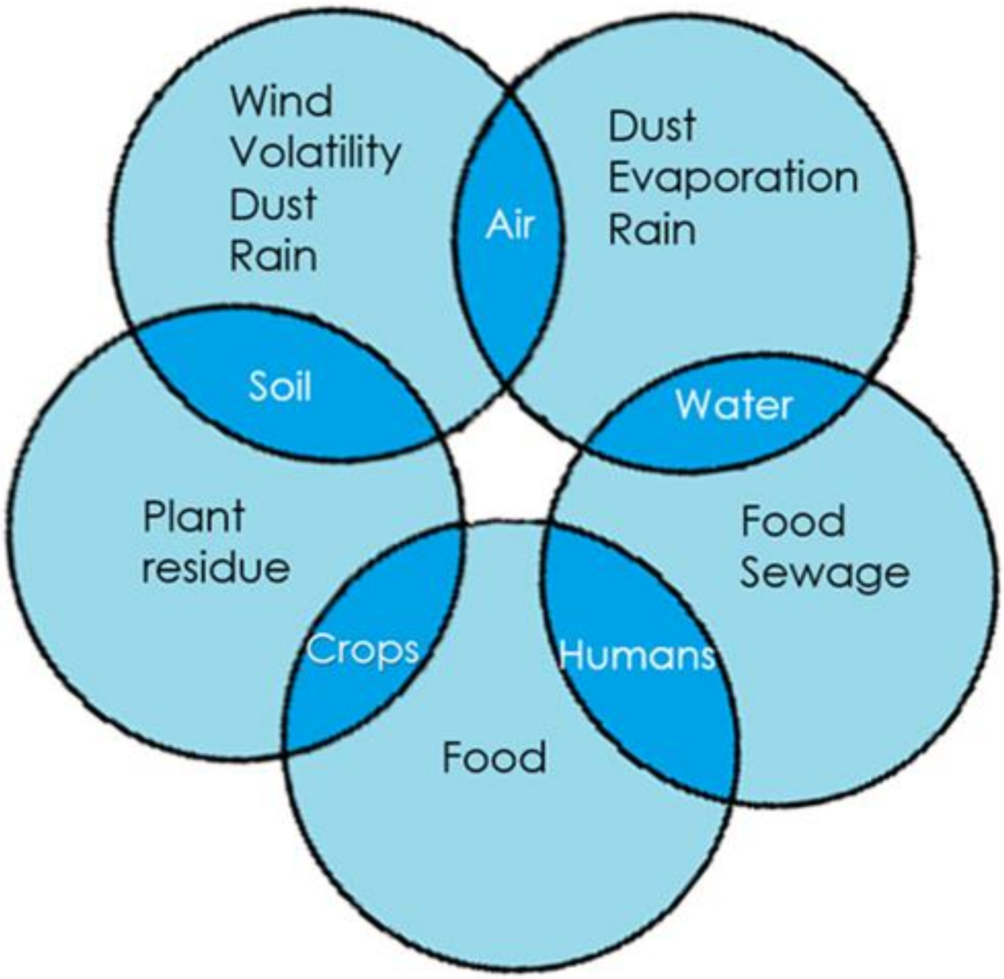

Figure 2. Pathways for transport of pesticides (adapted from Fenik, Tankiewicz, & Biziuk, 2011).

Clearly, there is a need to document current agricultural spraying practices: how much, how often, and what kinds of chemicals are being used. It is also important to determine how much consumers, farmers, and vendors know about these practices and their effects. Spreading information about pesticides will make farmers, vendors, and consumers make informed choices and be more aware of the dangers that these harsh chemicals pose when used excessively.

Methodology: A Hands-on Approach

The goal of this project was to understand pesticide use on small fruit and vegetable farms and determine the knowledge farmers, vendors, consumers, and government officials have about pesticides. In order to accomplish this goal, we established the following objectives and approach.

Table 1. Objectives and Methodological Strategies

Objective	Methods
1 Collect perceptions of key stakeholders about pesticides (farmers, produce vendors, and pesticide vendors)	Site map of Mandi town market Unstandardized interviews: farmers, produce vendors, pesticide vendors
2 Compile government policies	Archival research on laws Semi-standardized interview with Department of Agriculture Officer
3 Document pesticide application practices	Informal site assessment of farms Unstandardized interviews: farmers Semi-standardized interviews: Department of Agriculture Officer
4 Identify pesticide levels in market fruits and vegetables	Research banned chemical compositions (U.S. and India) Acquire samples from local market Extract pesticide residues, using ethyl acetate and analysis via mass spectrometry

Objective 1: Collect Perceptions of Key Stakeholders about Pesticides

The first step in completing this objective was to identify the location of produce markets so that we could interview vendors. We used a site assessment strategy in Mandi town to help us gauge the flow of the market and informally map vendor locations. This also allowed us to see the options available to local consumers for purchasing produce.

Once the site assessment was completed, we planned to conduct unstandardized interviews with fruit and vegetable vendors. Unstandardized interviews allow researchers to "develop, adapt, and generate questions and follow-up probes appropriate to each given situation and the central purpose of the investigation" (Berg, 2012, p. 111). The interviews were designed to determine specific attributes vendors looked for in high quality crops and to see if any particular farms executed their standards better than others, allowing us to uncover farms that we could visit for future interviews.

We also interviewed pesticide vendors to determine the kind of information they provide farmers when selling chemicals to them. Because we were unfamiliar with the markets in Mandi, we were unsure of where we would find pesticide vendors and how many would be willing to speak with us. Since our IIT team members were more familiar with the markets, we relied on them to determine an appropriate sample size.

Throughout the interview and site visit processes, we introduced ourselves as students interested in learning about high quality farming practices and the success of small farms in Himachal Pradesh. Interviews were conducted in Hindi by IIT members of our team and translated to English. Responses were recorded on questionnaire sheets and on voice recorders. All data was stored in a password protected laptop, and any identifying materials were destroyed upon the completion of the project.

Objective 2: Compile Government Policies

We used archival research from government websites to compile state and national policies on pesticide use with regards to farming and food quality in Himachal Pradesh so that we would know which pesticides are banned, the maximum limits of detection for pesticides when it came time to test produce, and how the government enforces these laws. We also interviewed the Department of Agriculture Officer for Mandi District to gain deeper insight on these laws. This semi-standardized interview focused on laws regarding food quality and best and safe practices in farming. We probed to find the current attitude towards public health with regards to food safety and the presence of unwanted chemicals in market produce. This also helped us to determine whether government officials were aware of actual farming practices used in the region.

Objective 3: Document Pesticide Application Practices

We traveled to ten farms to learn about pesticide practices on local crops. We asked farmers if they could give us a tour of their farms so that we could gain some insight on the types of crops being grown (Figure 3).

Figure 3. Team members conducting an interview with a farmer in Kullu.

We also conducted unstandardized interviews with farmers to inquire about quality measures on their farms, chronic threats in terms of pests or blights that they face on a regular basis, and how they address these problems. When pesticide use was brought up in the natural flow of the conversation, we were able to ask about the application process and any safety precautions taken before spraying. Unstandardized interviews allowed a more relaxed rapport with the farmers, making it possible for our team to inquire about pesticide use without being forward.

Because we learned from the Department of Agriculture that the government and not vendors are responsible for teaching farmers proper application practices, we chose to incorporate further questions about pesticide application into our interview with the Department of Agriculture Officer. This allowed us to gather information on the resources available for farmers in regards to application training.

Objective 4: Identify Pesticides Present in Market Fruits and Vegetables

While conducting interviews with farmers and pesticide vendors, we asked what different brands of pesticides the interviewees used. We determined the chemical compositions of the pesticides from the labels and compiled them into a list. We checked each chemical's status in India as well as the United States. Then we determined their molecular weights by drawing the chemicals in Chem Draw Ultra 8.0 and running a chemical analysis within the program.

We originally selected five fruits and five vegetables for testing based on our mentors' recommendations for commonly sold produce: apples, oranges, bananas, grapes, mangos, carrots, spinach, cabbage, cauliflower, and tomatoes. Due to time constraints and seasonal availability, we tested apples, bananas, grapes, mangos, cucumbers, carrots, tomatoes, and eggplant instead. All samples came from stands selling produce grown locally in Himachal Pradesh and were collected the day before they were tested to maintain freshness. Samples were individually placed in plastic zip-lock bags, which were labeled with the date and time of collection as well as the stand information in order to differentiate among the different stands. The produce was brought to the IIT – Mandi Chemistry Lab for testing, using ethyl acetate to extract the pesticide residues and water to extract the sugars from our samples. This mixture was then put into a separation funnel, agitated, and left so that the water and ethyl acetate could separate into two layers. Once two layers could be seen, the water layer, which was located at the bottom, was taken out and the top layer of ethyl acetate was collected and dried with sodium sulfate. This dried ethyl acetate was then put in a round bottom flask and was put into a rotary evaporator in order to remove the ethyl acetate solvent and to collect the pesticide residues. Mass spectrometry was then used in order to determine the pesticides found in the residues. A detailed laboratory procedure is located in supplemental materials for methods section. We compared the chemicals we detected with the list of banned chemicals and their exact molecular weights that we created prior to testing.

Results and Discussion

Our fieldwork and lab research yielded the following results.

Objective 1: Stakeholder Perceptions

We interviewed ten farmers from the Kullu and Mandi districts, all of whom said they used pesticides. None of the farmers knew which, if any, pesticides were banned. Of these ten farmers, five were asked[1] if they take any precautions while spraying. Two indicated they wear gloves and a mask, one said he wears gloves and washes his hands after, one said he takes a bath and washes his clothes after, and one said he has to wear a mask or cover his head else it is harmful. When directly prompted about specific protective measures, however, all five said they cover water supplies, keep animals away, store pesticides separately, and dispose of empty containers; however, they only indicated these measures after they were specifically asked, suggesting they may have been lead by our prompts. Further discussion with all ten farmers revealed that that they buy pesticides when needed instead of in bulk. One of the most important pieces of information that we gathered was that none of the farmers wash their produce before selling it because they say it will degrade the quality; they do wait an average of ten days after spraying before selling. These interviews suggest inconsistencies among farmers concerning the poper approach to safety precautions, a lack of knowledge about banned chemicals, and erroneous assumptions that harmful effects of pesticides can be washed off or can diminish after waiting a period of days.

KEY FINDING:
None of the farmers interviewed wash their produce before selling it because they say it will degrade the quality.

Produce vendors were not willing to speak with us even after we offered to return after they closed for the evening.

We visted six pesticide vendors in Mandi town, but only three were willing to be interviewed. They did allow us to look around their shop and photograph their products. When speaking to the pesticide vendors in Mandi town, all three said they depend on manufacturers to provide high quality pesticides. All vendors reported that their customers come to restock once in a quarter and that they sell on average 4-5 kg per month. One of the most important things we learned was that most vendors were also unaware of which pesticides are banned in India, but they assumed the ones provided by manufacturers were legal.

Objective 2: Government Policies

Per request of our IIT mentor, we compared India's pesticide regulations to the United States' pesticide regulations. Our research on government websites revealed vast differences between the two countries. A simple internet search for a list of banned

[1] We initially planned to ask all ten, but our interviewers were confused about this plan due to translation issues.

KEY FINDING:
The CIBRC website's list of registered products gives the names of all registered chemicals, but no maximum residue levels or crop specifications, making it difficult for farmers and those who distribute the chemicals to know the limits and proper uses for each chemical.

pesticides in the United States brings up the Environmental Protection Agency's website with links to lists of registered pesticides and restricted pesticides. The same search in India leads to a downloadable document listing a significantly smaller number of banned and restricted pesticides. Though the document was created by India's Central Insecticide Board & Registration Committee, it has not been updated since January 1, 2014. Only after clicking through links in the document were we able to locate the website from which the list originates. Beyond the sheer size of the lists, the registry systems are different. The EPA provides a list of registered chemicals, products, and their maximum residue level (MRL), which is the greatest amount of a chemical that can be present in a food. In addition to this, a link to query forms helps users look up the federal status of any pesticide. The EPA also makes a point to say that if a pesticide is not registered, it cannot be used legally. Furthermore, the website states that it is illegal to use a registered pesticide on a crop for which its registration is not approved. Pesticide regulations are not as explicit on the Central Insecticide Board & Registration Committee's website. After navigating through the links to the homepage, we were able to download more documents to gather information. The website's list of registered products gives the names of all registered chemicals, but no maximum residue levels or crop specifications, making it difficult for farmers and those who distribute the chemicals to know the limits and proper uses for each chemical.

Further research on this website revealed India's policies regarding pesticides and food quality. India's Insecticide Act of 1968 requires the government to monitor the use, manufacture, distribution, sale, and transport of insecticides (Pesticide Regulations, 2014). To build on this act, the Government created Insecticide Rules in 1971. According to these rules, anyone who desires to use pesticides with restrictions must apply to be a pest control officer. To obtain this license, the applicant "should be at least a graduate in Agriculture or in Science with Chemistry as a subject with a certificate of minimum 15 days training from [a list of authorized institutions]" (Central Government of India, 1971). We learned that there is a pesticide law in place which sets standards for food quality in every food item available in markets, and that an updated version is currently pending in parliament. After learining about this law regarding food quality standards, we continued searching for maximum residue levels for India, but we were still unable to locate them.

According to the Department of Agriculture Officer of Mandi, these laws are enforced by frequent checking done by the Department itself. Through the use of mobile testing vehicles, the Department is able to test fruits and vegetables at stands and stores in the markets throughout Himachal Pradesh. There are also informants outside the department which notify the department if any of the laws are broken. An interesting fact that we discovered was that if any of the laws regarding pesticides are broken, farmers are not held accountable. Instead, the pesticide dealers suffer the penalties according to which law was broken. In order to make sure that the policies are enforced, the Department of Agriculture organizes training camps for farmers and pesticide vendors as well as a subsidy in order to ensure that farmers are able to attend. As an extension of the training camps, government officers at block level as well as soil conservation officers make various trips to different villages to make sure policies regarding pesticides and proper application are enforced, meaning that masks and gloves are used, animals are kept away, water supplies are covered during application, pesticides are stored separately, and empty containers are disposed of after use.

Objective 3: Pesticide Application Practices

The Department of Agriculture Officer had valuable information about policies on pesticide application practices. Our fieldwork also revealed valuable insight into farming practices and use of pesticides in the Kullu and Mandi Districts. Though our IIT mentors mentioned that many local farmers use manure or ash to protect crops, when those we interviewed were asked how high quality is ensured in their crops, every farmer admitted to using pesticides, with seven of the ten also saying they used hybrid seeds. Farmers typically get their information about pesticides from television advertisements or word of mouth from other farmers. Only one farmer had attended a training camp and received information about pesticides from the government. Farmers use various types of pesticides based on what is available in the markets. Pesticides are selected based solely on the pest, not the type of crop or size of farm, suggesting that dosages and targeted application to crop are not taken into consideration when farmers are applying pesticides. Farmers showed us the various pesticides they use and allowed us to note down the active chemicals. A list of the 24 active chemicals can be found in the supplementary materials section of our WPI report.

Objective 4: Pesticides Present in Market Fruits and Vegetables

Of the 24 active ingredients in the pesticides we found on farms and in pesticide shops, 21 have no restrictions according to the Central Insecticide Board & Registration Committee, but we did note some violations: one chemical, Methyl parathion, is banned for use in India, and two are only permitted for use when applied by a trained pest control operator. As indicated earlier, only one of the farmers we interviewed had attended a training camp where these trainings take place. Of these 24 chemicals, 17 are registered as fully restricted (banned) by the US EPA, five have some EPA restrictions on use, and two are not in the United States' registry, meaning that they too are banned in the United States (California Department of Pesticide Regulation, 2013). These statistics are represented in Figures 4 and 5.

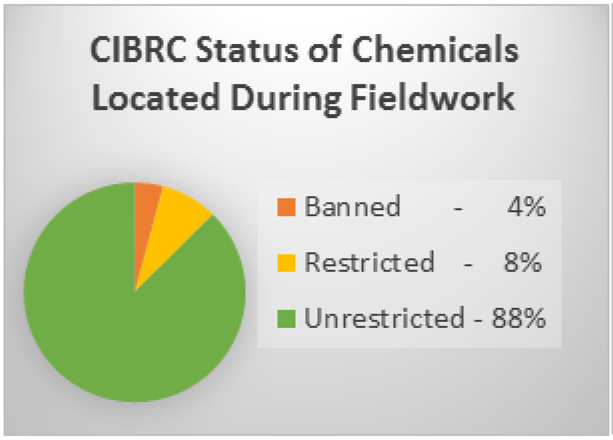

Figure 4. CIBRC Status of Chemicals Located During Fieldwork.

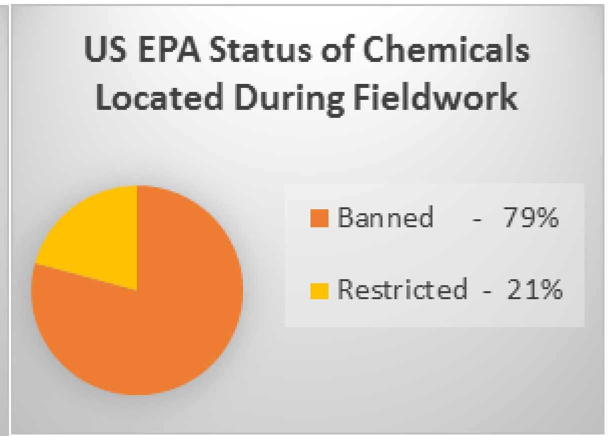

Figure 5. US EPA Status of Chemicals Located During Fieldwork.

In sum, 12% of the chemicals we found are banned or restricted in India; nearly 80% of these are banned in the US, with the remaining chemicals having restrictions on use in the United States.

The list of pesticides that we found was used throughout our testing process in the lab. We wanted to see if these same chemicals were present on actual produce we sampled from markets. The results of the mass spectrometry analysis are given in Table 2.

Table 2. Chemicals Detected on Sample Produce via Mass Spectrometry

Chemical	Number of Samples Detected in	US EPA Status of Chemical	CIBRC Status of Chemical
Pyrazosulfuronethyl	13	None*	None
Methyl parathion	5	Fully Restricted	Banned
Glyphosate	0	Fully Restricted	None
Dichlorvos	1	Fully Restricted	None
Quizalofop-ethyl	10	Fully Restricted	None
Deltamethrin	6	Fully Restricted	None
Oxyfluorfen	4	Fully Restricted	None
Ethephon	0	Fully Restricted	None
Acetamiprid	0	Fully Restricted	None
Validamycin	8	None*	None
Paraquat dichloride	8	Restrictions on Use	None
Carbendazim	2	Fully Restricted	None
Mancozeb	6	Fully Restricted	None
Boron	0	Fully Restricted	None
Thiophanate methyl	17	Fully Restricted	None
Chlorpyriphos	11	Fully Restricted	None

Cypermethrin	9	Fully Restricted	Restrictions on Use
Thiamethoxam	6	Restrictions on Use	None
Propiconazole	15	Fully Restricted	None
Copper oxychloride	9	Fully Restricted	None
Aluminium phosphide	0	Restrictions on Use	Restrictions on Use
Lambdacyhalothrin	9	Restrictions on Use	None
Triazophos	7	Fully Restricted	None
Imidacloprid	3	Restrictions on Use	None

Chemicals with no status in the US EPA registry are considered to be fully restricted or banned by the US EPA.

In sum, 19 of the 24 chemicals found on farms and in pesticide vendor shops were detected in our samples, one of which, Methyl parathion, is fully banned in India. This chemical appeared in five of our 18 samples. Another chemical, Cypermethrin, has restrictions on its use in India; this was present in nine of 18 samples. The mass peaks of the chemicals were considered a match when accuracy to three significant figures was observed via comparison with the masses calculated in Chem Draw Ultra 8.0.

Discussion

The data revealed both expected and surprising results. Our biggest challenge with data collection was presented by the language barrier. Our Hindi interviewers sometimes did not ask a general question about spraying precautions but skipped right to specific prompts about recommended practices, which may have been leading; thus, we only analyzed data from the five who were asked the general question first. None of these mentioned covering water tanks, keeping animals away, storing pesticides separately, and disposing of empty containers until they were prompted to. The responses that were given, such as simply covering one's head, waiting ten days to eat or sell the produce, or washing up afterwards, suggest the farmers may not fully understand the dangers and how to reduce risks.

We expected it to be difficult to get farmers to open up about using pesticides, but all farmers were open about their use. This made it easy to gather information on the chemicals used. Perhaps the most surprising piece of information gathered was that both farmers and pesticide vendors stated that they had no knowledge about which pesticides were banned in India. Though farmers are not held legally responsible for breaking laws regarding pesticides, the pesticide vendors are. They reported that they trust the manufacturers to produce high quality products within governmental standards, regardless of the fact that they themselves will face serious consequences (e.g., loss of license) for violations if they sell banned or restricted pesticides to farmers.

After learning that the Department of Agriculture holds training camps for farmers and frequently visits villages to check on them, we expected farmers to be well aware of pesticide use policies. When we spoke to the farmers, we were surprised to learn that only one of ten had ever attended a government training camp. The farmers said these training camps were not advertised to them. Even without training, some of these farmers are still using restricted pesticides, which require the training noted in the Insecticide Rules of

1971. These discrepancies imply a disconnect between the availability of training resources and farmer's use of those resources, and they suggest violations of government policies.

Our laboratory testing identified the presence of many chemicals on local produce we sampled. Because of delayed repairs in lab equipment during our seven week research stay India, our team only tested for presence of chemicals as opposed to maximum residue levels; however, our IIT counterparts plan to continue with the research in subsequent weeks. The full results will be available on the IIT-Mandi ISTP webpage: http://www.iitmandi.ac.in/istp/projects.html. Even though we only saw evidence of the banned chemical Methyl parathion in one container on one farm during our fieldwork, we detected it in five of the 18 samples we took from local markets, suggesting wider use. Cypermethrin and Aluminum phosphide have restrictions on use, but we found only Cypermethrin in our samples. Nine of the samples had this chemical present. The detection of both banned and restricted chemicals further supports farmers' statements that they are uninformed about pesticide restrictions or unaware of what they are being sold. These detections also suggest that the improvement of government testing strategies could help to control pesticide use.

KEY FINDING:
Even without training, farmers are still using pesticides; however, Insecticide Rules of 1971 require pesticides with restrictions to be applied only by those with extensive training.

Project Outcomes

Based our data, we made recommendations to the Central Government of India as well as to local consumers.

Recommendations

- The Central Insecticides Board & Registration committee might address some of the misperceptions and misuse of pesticides that we found in Himachal Pradesh by making their official website more accessible and navigable. As seen in Figure 6, farmers commonly confer with each other for help; only one participated in government training, and none discussed literature dispersed by the government, either on websites or in hard copy form. An easily navigable website that clearly outlines registered, banned, and restricted pesticides and includes maximum residue levels for these pesticides will help. An online database of commonly used pesticides, their active ingredients and status, and an explanation of crops for which the pesticides are most effective would make it easier for farmers and vendors to verify that their products and practices are in line with government standards. This database would make it easy to confirm the information pesticide vendors receive from manufacturers.

Figure 6. A group of neighboring farmers sharing knowledge and farming techniques in Kullu.

- The Central Insecticides Board & Registration Committee might also add a section to the website that outlines possible alternatives to pesticide use for farming. This section could outline traditional organic farming practices that reduce the risk of insects, mold and other diseases as well as safer alternatives that have been developed in recent years.

- The Department of Agriculture might consider supplementing or replacing poorly attended training camps with informational booklets that can be updated annually with information about pesticides and their effects. These booklets would contain the same information as the online database as well as pictures of common pesticide containers to make it easier for farmers to identify potentially dangerous pesticides. Since the Department of Agriculture already holds training camps in various blocks, they would be able to determine the most appropriate language for the bookletsto be written in for each block. In addition to this, Himachal Pradesh has a high literacy rate, so we assume most farmers will be able to read the booklets.

- The Department of Agriculture might also benefit from altering their testing method used in their mobile testing vehicles. The procedure used was adapted from a study done in Switzerland and was very successful for detecting the presence of pesticides, easy to follow, and inexpensive. All necessary chemicals and equipment were readily available at the IIT – Mandi. A detailed procedure can be found in the supplemental materials section for project outcomes.

- Finally, given the widespread presence of these chemicals on most of the common fruits and vegetables we sampled, we recommend that our IIT counterparts share their continued research with the local media to spread awareness to consumers. Since farmers do not wash fruits and vegetables before selling them, the pesticides are not being removed before arriving at the markets. If consumers do not wash their produce with soap and water before consumption, the nonpolar pesticides will not be removed because water is polar.

Conclusion

As pesticides become more prevalent in farming practices in Himachal Pradesh, farmers need to develop a deeper understanding of their proper application and effects. Our research, though limited, suggests that stakeholders may not be fully informed about the laws. Moreover, they may not always realize the damage that can be done to health and the environment. It is more likely that laws regarding pesticide regulations will be followed by farmers if they are provided this information on websites, in brochures, and in training workshops that are convenient for them to attend. These changes might help make fruits and vegetables safer and healthier for their own and other communities. The effects of pesticide use are not contained within the boundaries of Himachal Pradesh; drift affects surrounding states as well. When research is done locally, farmers, produce vendors, pesticide vendors, consumers, and government officials feel more connected to the issue and become more aware of the impact pesticides they use might have nationally. If pesticide presence and levels are high in the produce of Himachal Pradesh, typically considered an organic farming state, then investigating their use in other states seems equally important. The process we followed is just a possible first step in extending that research.

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Supplementary Materials

The following materials further support and document information in this report .

Materials for Background Section

Stakeholders:

- Produce farmers
- Produce vendors
- Pesticide vendors
- Government officials
- Consumers

Materials for Methods Section

Unstandardized Interview Questions for Famers

What type of crops do you grow in ravi season? In Kharif season?

Do you grow multiple crops at the same time?

Which crops sell the most?

How do you ensure high quality in your crops?

Are there any farming practices which you prefer or find to be most effective?

Have you ever encountered issues with pests or blight?

How do you manage pests?

Do you use any pesticides or insecticides?

What pesticides are used at what stage of crop growth?

How do you protect yourself when applying pesticides and insecticides?

Do you cover nearby water tank and containers when spraying?

Where do you store the pesticides and insecticides?

Do you keep your pets and animals away while spraying?

Are empty pesticide containers used for anything else when they are empty? If yes, then what?

How have your farming practices changed (if at all) over the past ten years?

Have you noticed an increase in crop production since using pesticides?

Unstandardized Interview Questions for Produce Vendors

What attributes do you look for in high quality produce?

Are there any particular farms/farmers that excel in these standards?

Are there key steps in the farming or transportation processes that help achieve higher quality?

Have any changes made over the past ten years helped to produce higher quality fruits and vegetables?

For Pesticide Vendors

What attributes do you look for in high quality produce?

How can these standards be achieved?

Are there key steps in the farming or transportation processes that help achieve higher quality?

Do you have any products that you recommend to help achieve these high standards?

Which pesticides do you sell the most of?

How many kilograms of pesticides do you sell each month?

How often do people typically come back for refills?

Do you know of any banned pesticides?

Semistandardized Interview Questions for Government Officials

Is there any legislation or laws that set standards for food quality?

Specifically for food sold in markets or produce in general?

How are these laws enforced?

Are there any laws that specify what chemicals can or cannot be used on crops or as pesticides?

How are these policies enforced?

What actions are taken if pesticide laws are broken?

Is there a separate department that deals with pesticides specifically?

How do you relay information about pesticide laws to the public?

Do you have any suggestions for ways that community members can relay this information to other locals?

Materials for Results Section

Pesticides Located During Fieldwork and Their Restriction Statuses

Chemical	Use	Located	Status in United States	Status in India
Pyrazosulfuronethyl 10%	Systemic herbicide	Farm	None*	None
Methyl parathion 2% DP	Insecticide	Farm	Fully Restricted	Banned
Glyphosate 41% SL	Herbicide	Farm, Vendor	Fully Restricted	None
Dichlorvos 76% EC	Insecticide	Vendor	Fully Restricted	None
Quizalofop-ethyl 5% EC	Herbicide	Vendor	Fully Restricted	None
Deltamethrin 2.8% EC	Insecticide	Vendor	Fully Restricted	None
Oxyfluorfen 23.5% EC	Herbicide	Vendor	Fully Restricted	None
Ethephon 39% SL	Plant growth regulator	Vendor	Fully Restricted	None
Acetamiprid 20% SP	Insecticide	Vendor	Fully Restricted	None
Validamycin 3% L	Antibiotic and fungicide	Vendor	None*	None
Paraquat dichloride 24% SL	Non-selective contact herbicide	Vendor	Restrictions on Use	None
Carbendazim 12% + Mancozeb 63% WP	Protective and curative fungicide	Vendor	Both Fully Restricted	None
Imidacloprid 17.8% SL	Systemic insecticide	Farm, Vendor	Restrictions on Use	None
20% Boron (Min)	Micronutrient fertilizer	Vendor	Fully Restricted	None
Copper oxychloride 50% WP	Contact fungicide	Farm, Vendor	Fully Restricted	None
Thiophanate methyl 70% WP	Systemic fungicide	Vendor	Fully Restricted	None

Chlorpyriphos + Cypermethrin (50% + 5%)-EC	Insecticide	Vendor	Both Fully Restricted	Restrictions on Use of Cypermethrin, None for Chlorpyriphos
Cypermethrin 25% EC	Insecticide	Vendor	Fully Restricted	Restrictions on Use
Thiamethoxam 25% WG	Broad spectrum systemic insecticide	Vendor	Restrictions on Use	None
Propiconazole 25% EC	Systemic fungicide	Vendor	Fully Restricted	None
Aluminium phosphide 56%	Fumigant powder for control of stored grain pests, rodenticide, insecticide	Vendor	Restrictions on Use	Restrictions on Use
Chlorpyriphos 50% EC	Insecticide	Vendor	Fully Restricted	None
Carbendazim 50% WP	Fungicide	Farm	Fully Restricted	None
Mancozeb 75% WP	Contact fungicide	Farm	Fully Restricted	None
Lambdacyhalothrin 5%	Insecticide	Farm	Restrictions on Use	None
Deltamethrin 1.25% EC	Insecticide	Farm	Fully Restricted	None
Triazophos 35% + Deltamethrin 1% EC	Insecticide	Farm	Both Fully Restricted	None

****Chemicals with no status in the US EPA registry are considered to be fully restricted by the US EPA.***

Below is an example of the Excel Spreadsheets used while analysing the results from the mass spectrometer. Numbers highlighted in yellow differed by one (example: 415 instead of the mass spectrometry peak's value of 414) and were not considered substansial evidence for proof of presence. Numbers highlishted in blue differ one place after the decimal point (ex: 415.3 instead of 415.8). Numbers highlighted in purple differ two places after the decimal point (ex: 415.82 instead of 415.87). Numbers highlightd in red differ three places after the decimal point (ex: 415.873 instead of 415.871) . Any chemical with a match highlighted in blue, purple, or red was considered to show substansial evidence for presence.

Chemical	Molecular Weight	Molecular Weight with H+	Molecular Weight with K+	Molecular Weight with Na+
Pyrazosulfuronethyl	414.3937	415.4011	453.4915	437.3829
Methyl parathion	263.2075	264.2149	302.3052	286.1967
Glyphosate	169.0731	170.0805	208.1708	192.0623
Dichlorvos	220.9757	221.9831	260.0735	243.965
Quizalofop-ethyl	344.7491	345.7565	383.8469	367.7383
Deltamethrin	505.1992	506.2066	544.2969	528.1884
Oxyfluorfen	361.7003	362.7077	400.7981	384.6896
Ethephon	144.494	145.5014	183.5918	167.4832
Acetamiprid	221.6861	222.6935	260.7838	244.6753
Validamycin	497.4908	498.4982	536.5886	520.48
Paraquat dichloride	257.159	258.1664	296.2567	280.1482
Carbendazim	191.1867	192.1941	230.2844	214.1759
Mancozeb	345.7264	346.7338	384.8242	368.7156
Boron	10.811	11.8184	49.9088	33.8002
Thiophanate methyl	398.5003	343.4008	381.4912	365.3832
Chlorpyriphos	350.5863	351.5937	389.6841	373.5755
Cypermethrin	414.3243	417.3046	455.3949	439.2864
Thiamethoxam	291.7147	292.7221	330.8125	314.7039
Propiconazole	342.2204	343.2278	381.3181	365.2096
Copper oxychloride	427.134	428.1414	466.2318	450.1233
Aluminium phosphide	57.9553	58.9627	97.0531	80.9445
Lambdacyhalothrin	449.8501	450.8575	488.9478	472.8393
Triazophos	313.3125	314.3199	352.4103	336.3017
Imidacloprid	224.69	225.6974	263.7878	247.6792

Materials for Project Outcomes Section

Lab Procedure Used for Sample Testing
Extraction:

- From each fruit/vegetable, two 20 g samples were taken.
- One of the samples was not crushed and the other was crushed using a mortar and pestle.
- Each sample was placed into its own Erlenmeyer flask to which 40 mL of Ethyl acetate were added, and each flask was then agitated by hand for 10 minutes.
- Between 20 and 30 mL of distilled water, as needed for clear separation, were then added to the Erlenmeyer flask.
- For uncrushed samples, the liquid was simply poured into a separatory funnel. However, for crushed samples, the liquid was collected into another Erlenmeyer flask through vacuum filtration.
- Once the liquid was poured into the separatory funnel, it was then agitated for approximately 2 to 3 minutes. Gas from funnel was released every 10 to 15 seconds in order to avoid buildup.
- A clamp was then used to hold the separatory funnel in place while separation into two layers was taking place.
- Once the two layers were clearly visible, each layer was collected into its own Erlenmeyer flask.
- The bottom layer collected initially was then placed into the separatory funnel again, and enough Ethyl acetate was added to ensure clear separation.
- This mixture was also agitated for approximately 2 to 3 minutes. Gas from funnel was released every 10 to 15 seconds in order to avoid buildup.
- The bottom aqueous layer was again collected into an Erlenmeyer flask, but the top Ethyl acetate layer was combined with the previously collected Ethyl acetate layer.
- Enough Sodium sulfate was then added to the flask containing the Ethyl acetate in order to ensure that all of the water was absorbed.
- Once all of the water had been absorbed by the Sodium sulfate, the liquid was transferred into a 100 mL round bottom flask and a rotary evaporator was used to evaporate the liquid and to collect our extracted sample.

Preparation from Mass Spectrometer:

- 1 mL of Ethyl acetate was used to dissolve the extracted sample so that it could be transferred into 5 mL vials.
- Cotton was then used to close the vial, and the vials were then left over night in order to ensure that all of the Ethyl acetate was evaporated.
- Once the samples were completely dry, 3 mL of Methanol and 1 mL of Acetonitrile (ratio of 75% Methanol to 25% Acetonitrile) were added to each flask.
- The flasks were then agitated until the samples were well dissolved.
- 1 mL from each sample was collected using a syringe. The needle from the syringe was then replaced with a filter, which allowed for a clear sample to be put into the MS testing vials.

- The samples were then given to a MS operator, who ran the samples through the machine.