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Alison Clune　　　　　　　　　　Date

A cross-sectional study of knowledge and practices related to use of pesticides among vegetable and rice growers in Bangladesh

By

Alison Clune

Master of Public Health

Global Environmental Health

Dana Boyd Barr

Committee Chair

Paige Tolbert

Committee Member

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Alison Clune

Bachelor of Science

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Thesis Committee Chair: Dana Boyd Barr, PhD

An abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
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Abstract

A cross-sectional study of knowledge and practices related to use of pesticides among vegetable and rice growers in Bangladesh

By Alison Clune

Background: Several studies suggest that poor pesticide application practices contribute to adverse health effects associated with pesticide poisoning.

Purpose: To investigate whether better knowledge of safe pesticide application and storage is associated with safer application and storage practices among farmers in Bangladesh.

Methods: Interviews were conducted with 72 farmers including kitchen gardeners, local farmers, and city/regional farmers. A standardized questionnaire was used to collect information about farmers' practices, knowledge, and attitudes about pesticide application and storage. Practice, knowledge, and attitude scores were used to summarize questionnaire data. Multiple linear regression and mapping were used to explore the relationship between knowledge and practice of safe pesticide application and storage. Informal focus groups were conducted separately to supplement questionnaire data.

Results: None of the interviewed farmers had formal training on pesticide application or storage, and 89% received pesticide application and storage information from other farmers. A marginally significant association was found between pesticide knowledge and application and storage practices in the final multiple linear regression model ($p=0.0863$). The level of knowledge about such practices was higher and less varied in southwest districts than in central districts, and the relationship between knowledge and practice was similarly reflected in the mapping analysis. The association between pesticide knowledge and practice was about four times greater when a farm was located in a town compared to a village, municipality, or slum. The strength of association also increased with the number of pesticide information sources reported by the farmer. Conversely, farmers who grew beans exhibited a weaker association between pesticide knowledge and practice than those who did not grow beans, likely because beans require high pesticide inputs.

Conclusions: Greater pesticide knowledge may lead to safer application and storage practices, and the best way to disseminate information about pesticides is through word-of-mouth.

Recommendations: Based on these results, it will be possible to develop community-based training on pesticide application and storage that encourages word-of-mouth knowledge dissemination to mitigate occupational hazards associated with pesticide application and storage.

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I. INTRODUCTION

Without current crop protection methods, as much as 80% of potential yield in some crops would be lost to agricultural pests. These methods, which rely heavily on synthetic chemical pesticides, can prevent more than half of potential crop loss due to pests *(1)*. While the benefits of synthetic pesticide use are clear, negative health and environmental consequences of their use are also apparent. One to five million pesticide poisonings occur worldwide each year *(2)*. Although developing countries account for only about 25% of global pesticide use, they experience around 99% of pesticide related deaths, most occurring among farmworkers *(2)*. In Bangladesh, the World Bank estimates that organophosphate (OP) insecticide poisonings alone occur with an incidence as high as 900/100,000 population *(3)*. As of 2004, OP insecticides, a class of cholinesterase-inhibiting compounds, were the pesticides most often sold in Bangladesh *(4)*.

In an effort to feed a growing population, the Government of Bangladesh (GOB) has encouraged the use of pesticides. The GOB provided pesticides free of cost to farmers until 1974 when the subsidy was reduced to 50% and finally eliminated in 1979 when the pesticide market was handed over to the private sector *(5)*. Even without such financial encouragement, the amount of pesticides used in Bangladesh between 1992 and 2001 more than doubled *(4)*. Carbosulfan, diazinon, and carbofuran, all World Health Organization (WHO) Class II (moderately hazardous) or higher, have been found to be frequently used among Bangladeshi farmers *(6)*; in fact, many GOB recommendations (Appendix 1) call for moderately or highly hazardous pesticides according to the WHO classification system *(7, 8)*. No active pesticide ingredients are produced in Bangladesh, although some companies formulate final pesticide products. There were 31 registered companies marketing pesticides in 1989 *(9)*, and 96 registered pesticides in 2002 in Bangladesh *(5)*. Although the GOB does not currently register internationally banned pesticides, there is evidence that some of these persistent pesticides are still applied. A high *p,p'*-DDT/∑DDT ratio[1] in a sample of serum from men and women in several occupations indicates that DDT is still in use in Bangladesh *(10)*, while survey evidence suggests that heptachlor and endrin, both internationally banned pesticides, are also in use *(4)*. In addition to the use of highly hazardous pesticides, a 2003 World Bank study in Bangladesh *(11)* found that pesticide overapplication was widespread among the 820 participating male farmers, and was influenced by income, farm ownership, the toxicity of pesticides used, crop produced, and geographic location. Rates of overapplicaton were highest for bean and eggplant farmers and in Chapainawabganj, Chittagong, Comilla, Jessore, Narshingdi, Rajshahi and Rangpur districts.

Figure 1 describes knowledge transmission that may lead to poor application practices. Primary information sources for Bangladeshi farmers tend to be manufacturers and retailers, the Ministry of Agriculture and personal knowledge *(11)*. The role of pesticide labeling on overapplication is not well understood. Some studies suggest that lower knowledge of pesticide exposure hazards is associated with fewer safe application practices *(12-14)*, while other studies suggest that there is no relationship *(15-17)*. In addition, experience indicates that the anticipation of flooding may also affect when and how much pesticide is applied in Bangladesh (Bilqis Hoque, personal communication).

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[1] *p,p'*-DDT/∑DDT ratios describe the present level of the parent compound (DDT) relative to environmental degradation products of the parent compound (DDE, DDD). High ratios indicate recent use of DDT whereas low ratios indicate past use of DDT and degradation of DDT into DDE and DDD.

Regardless of other factors surrounding pesticide use, poor practices have been associated with symptoms of pesticide poisoning *(14, 15, 18)*.

In previous studies, farmers reported low levels of training (4% in one study in 2003 *(11)*, 8 out of 26, about 30%, in another study in 2007 *(6)*), and those who did receive training frequently forgot alternative strategies they had learned or rationalized improper practices later on *(6)*. Many farmers appear to believe that using pesticides before a pest attack, as many retailers recommend *(19)*, can prevent all losses in yield, although they also perceive benefits from applying after a pest attack arises, as is generally considered the correct practice *(6)*. Some farmers may also incorrectly use pesticides as a substitute for fertilizers when fertilizer prices rise *(20)*.

Although farmers generally perceive negative health impacts from using pesticides, they do not often use any personal protective equipment (PPE). A study of the general population of Bangladesh suggests that they blame pesticides and chemical fertilizers for a perceived increase in adult mortality, claiming that the increased use of such farm chemicals is due to a production shift from self-consumption to market-consumption *(21)*. In a study in 2003, 87% of Bangladeshi farmers took no protective measures even though about half reported acute pesticide-related health effects *(11)*. Education may improve the use of PPE because of improved literacy or awareness of possible routes of pesticide exposure. However in a tropical climate, PPE is hot and uncomfortable, so personal preference and the alternative risk of heat stress may also discourage farmers from using protective measures *(22)*.

The physical manifestations of acute pesticide poisoning are generally well characterized in humans. Symptoms of acute pesticide poisoning include fatigue, dizziness, blurred vision, nausea, dry throat, difficulty breathing, stinging eyes, itchy skin, burning nose, muscle stiffness and weakness, and death *(22)*, but vary according to the mechanism of action of the individual pesticide. The primary routes of exposure in an occupational setting are dermal absorption and inhalation *(16)*. However non-dietary ingestion may also be an important exposure route in developing countries where workers smoke or eat in the fields, and many parents must bring children to the fields with them until they are old enough to attend school. Because children take in more food, water, and soil per body weight than adults, they may be exposed to higher pesticide doses than their parents *(22)*. Furthermore, malnutrition and dehydration, common problems in developing countries, may intensify the effects of acute pesticide poisoning *(22)*.

While the acute effects of pesticide poisoning are well known, the health effects of long-term, low-dose exposures are not clear. There is some evidence from animal studies of developmental and reproductive abnormalities, endocrine disruption, neurobehavioral disabilities or developmental disorders, carcinogenesis, and immunological damage. Some epidemiological evidence also supports carcinogenesis as a result of long-term pesticide exposure *(22, 23)*, or as a result of exposure to chlorinated dioxin impurities that form as byproducts during the production of some pesticides *(23)*. A study in Argentina also found that agricultural workers, both pesticide applicators and non-applicators who had all been occupationally exposed to two or more pesticides, had significantly more DNA damage and significantly impaired ability to resist DNA damage in lymphocytes compared to controls with no exposure to potentially genotoxic substances *(24)*. Such damage may be a marker of early effect for cancers caused by pesticides.

Farmers also perceive negative environmental consequences of using pesticides, but generally only those consequences that directly affect their livelihood such as increased soil compaction, fewer fish caught in rice paddies, and more frequent pest attacks. Effects on water quality, for example, are not as well understood *(25)*, probably because they do not directly impact yields; in response to such market failure, it has been suggested that farmers who internalize such costs by using integrated pest management (IPM) practices should receive subsidies or other incentives to continue such practices *(26)*. An increasing body of evidence suggests that pesticides have in fact caused environmental damage in Bangladesh, as 1800 metric tons annually runoff into the Bay of Bengal *(27)* where they accumulate in fish and other seafood, potentially decreasing the fish population in the bay *(28, 29)*.

Despite knowledge of the environmental and health risks, farmers probably continue to use pesticides because they are less labor intensive than IPM *(6)*. Sustainable agricultural practice, including IPM, aims to optimize the use of natural capital ("environmental goods and services" *(26)*) without harming these resources. This includes integrating biological and ecological systems into the production process, minimizing harmful inputs, and utilizing and improving farmers' skills to solve problems *(26)*. IPM training has been available through the Bangladesh Department of Agriculture Extension (DAE) since 1981 *(19)*. Farmers who have adopted IPM practices have reported lower pesticide usage (0.77 kg/acre for IPM farmers compared to 2.33 kg/acre for conventional farmers *(19)*), and many report higher crop yields (52% of IPM farmers in 11 districts *(19)*) and improved environmental conditions (70% of IPM farmers in 11 districts *(19)*). Evidence suggests that successful IPM adoption is associated with a shift in inputs rather than a decrease in outputs *(26)*, implying that IPM farms can successfully compete with conventional farms. However it is important that IPM training be administered at the community level and emphasize collective benefits, as pesticides are often carried on the wind (known as pesticide “drift”) or otherwise deposited on the land of neighboring farms *(19, 26)*.

The GOB has embraced the community-based IPM approach; through the Agriculture Sector Programme Support (ASPS) partnership with the Danish International Development Agency (DANIDA), DAE officers currently run Farmer Field Schools (FFS) that initially train communities of farmers using an interactive, participatory approach. In addition to pest and disease management techniques, farmers are introduced to a holistic crop management process including seed selection, land preparation, raising a nursery, fertilizer management, water management, and additional income generating activities such as aquaculture in rice paddies. Through these trainings, some farmers have reported using fewer pesticides and increasing crop yields. At the conclusion of the FFS, IPM clubs are created as a permanent fixture in the agricultural communities that participate in IPM training. Such clubs seek to maintain enthusiasm for IPM techniques, while also spreading IPM knowledge by contracting out services to member and non-member farmers to raise money for club functions. Between September 2002 and February 2006, 8029 FFS and 6938 IPM clubs were established, with an additional 471 FFS and 862 IPM clubs slated to be formed by the end of the program in June 2006 *(30)*. Despite the impressive number of FFS and IPM clubs formed in this period, many farmers remain to be reached considering that about 45% of the labor force, approximately 32.56 million people, are employed in agriculture in Bangladesh *(31)*.

However, the Ministry of Agriculture seems committed to continue reducing pesticide use, advertising “Use less pesticides to save life and the environment” on the homepage of their website *(32)*.

The Environment and Population Research Center (EPRC), a non-profit non-government organization (NGO) based in Dhaka, Bangladesh, works to serve the poorest of the poor in Bangladesh through research, education, training and networking programs that address issues in environment, education, public health, agriculture and food security, and related social and policy issues. EPRC is currently conducting several research and educational projects through its SAFE (Sustainable Agriculture, Food and Environment) Initiative with other member organizations of the Global Applied Research Network, South Asia (GARNET-SA). These projects aim to reduce poverty and improve food security among participating farmers.

Farmers’ reasons for using pesticides and poor pesticide application practices are well established in Bangladesh, but few studies have examined whether knowledge of safe pesticide use for rice and vegetable production is associated with safe pesticide practices among farmers in Bangladesh**.** The impacts of incorrect pesticide use on women and children working on or near farms especially have not been adequately addressed in previous studies in developing countries. The purpose of this study was to determine whether better knowledge of safe pesticide use is associated with safe practices among farmers in Bangladesh. Here “farmer” refers to (i) kitchen gardeners, serving only the immediate compound near their vegetable garden, (ii) local farmers who grow rice or vegetables to sell in local markets, although some produce may be consumed by the grower, and (iii) city or regional farmers who grow rice or vegetables to sell in distant markets, or sell produce to a trader who sells in a distant market. Based on these findings, recommendations of simple, practical measures to manage pesticides were identified and presented to EPRC in order to develop occupational hazard mitigation strategies for farmers in Bangladesh.

II. METHODS

i. Hypothesis

Knowledge and safe practices of pesticide application and storage were expected to be low, but with enough variation to detect trends in the relationship between knowledge and practice variables. Farmers with more knowledge of safe practices were expected to exhibit safer practices.

ii. Data Collection

This study was conducted in the districts of Dhaka, Gazipur, Narayanganj, Satkhira, and Jessore (Figure 2) during June, July and August 2010. The study objectives, methods, and consent forms were reviewed and approved by Emory University's Institutional Review Board (EUIRB) prior to beginning fieldwork. Twenty-four kitchen gardens, 36 local market farms, and 12 regional market farms were selected for a total of 72 farms. Because a record of existing farms in Bangladesh was not available, farms were selected by walking through the study areas, visually identifying farms, and approaching every third farm for an interview. A waiver of written informed consent was obtained from the EUIRB. Participating farmers provided oral informed consent, and were allowed to terminate interviews, leave focus groups, or drop out of the study at any time. A single person, usually the main pesticide applicator and/or owner of the farm, was interviewed. Farms were considered eligible for the study if the interviewee was over 18 years of age and the farm grew one of the following crops sometime in the past year: rice (*aman* or *boro* varieties), tomato, eggplant, okra, pumpkin, bitter gourd, potato, sweet gourd, bean or long bean, spinach, *pui shaak* (a type of leafy vegetable), cauliflower, and cabbage.

A standardized questionnaire, adapted from DeFeo *(33)* and Dasgupta *(34)*, was used to interview farmers about their knowledge, attitudes, and practices related to pesticide use. The farmers were also asked about their level of education and income using a set of standardized questions from previous EPRC studies. The size and ownership of the farm, crops produced, and ultimate market for the produced vegetables were also determined. A Garmin eTrex Legend GPS device (Garmin, Ltd., Olathe, Kansas) was used to record the latitude and longitude of each farm, defined as the point of the interviewer's entry to the farm. All interviews were conducted in Bengali by one of three interviewers. If an interview could not be completed in a single session, the interviewer returned to complete the interview at a later time with the farmer's permission. No interview was returned incomplete. During training, interviewers were asked to review the questionnaire and clarify the meaning of any confusing questions with a colleague at EPRC. All project staff completed the Family Health International ethical training for researchers to introduce the principles of research ethics and explain how to obtain informed consent from subjects. To pilot test the survey, interviewers practiced using the questionnaire with six farmers in Dhaka who were not included in the study results. Based on these interviews, the clarity and appropriateness of the questions were assessed and the questionnaire was edited accordingly. The questionnaire was originally developed in English, then edited and finalized in Bengali, and finally translated again into English. A standardized code plan was used by the interviewers to code Bengali answers for data entry in English. Responses and comments that could not be coded were translated individually by one of two translators. All responses and comments were entered in a Microsoft Excel spreadsheet and each entry was double checked by the principal investigator (A. Clune).

To evaluate farmers' safe pesticide practice, farmers were asked about their application practices during the past year (including pesticide name, crop, application rate, quantity, method, product mixing, and number of applications), disposal of empty pesticide bottles, use of PPE, precautions taken after application (including posting warnings of a recent spray, cleaning spraying equipment far from drinking water sources, and washing hands and clothes after spraying), and whether they follow application instructions given on a label, information sheet, or by a retailer. While pesticide retailers, manufacturers, government officials or NGOs provide printed information, many farmers are illiterate, so the questionnaire addressed how farmers read printed instructions. Questions also addressed whether other family members or laborers worked in the field and how children were kept away from recently sprayed crops. Whenever possible or appropriate, farmers were asked to show materials and equipment to the interviewer or demonstrate their practices in order to avoid dishonest answers. Where visual evidence could not be obtained, questions were first posed indirectly, and then each question and/or answer choice was reviewed with the farmer to confirm his/her response. The questions about pesticide application practices preceded the questions about knowledge during the interview so that farmers would not be tempted to claim that they maintain certain practices they know to be correct, even if they do not in fact maintain these practices. Farmers were asked to show their pesticide storage area to the interviewer. The interviewer then completed a simple observation checklist, adapted from Defeo *(33)*, to further evaluate the farmer's safe pesticide storage and accident preparedness.

To evaluate farmers' knowledge of safe pesticide use, the interviewer asked farmers about their previous pesticide safety training, including who conducted the training and its scope. Questions about their knowledge of routes of exposure, poisoning symptoms, common safety instructions, and IPM were also included to gauge the extent of their knowledge. Farmers were asked about perceived health or environmental effects of pesticides, and their opinions about the responsibilities of pesticide applicators and vendors to explore other factors that may allow them to rationalize practices they know to be incorrect.

Two informal focus groups were also conducted during the study to aid in the interpretation of farmers' questionnaire responses and allow farmers to share any other information they felt would contribute to the study's aims. One focus group was conducted in Narail district with 25 farmers, and the other was conducted in Dhaka district with 20 farmers. Local leaders were asked to help recruit farmers to participate in the focus groups, and the elected representative from the two participating unions participated in the focus groups. All focus group participants were male and represented each of the three types of farmers. Some had participated in interviews, while others had not. Focus groups were asked about how they decide which pesticides to apply, how much to apply, and when to apply them; how their pesticide application practices have changed over time; how they interact with government agriculture officials and pesticide retailers; and any health or environmental effects of pesticide use that they have noticed.

Discussion topics were agreed upon by the principal and co-investigators, and focus groups were facilitated in Bengali by the co-investigator (B. Hoque). The co-investigator took notes during the focus group discussions and later translated the notes to English for the principal investigator.

iii. *Data Analysis*

De-identified survey and observation checklist data were returned to the United States and analyzed using SAS 9.2 (SAS Institute, Cary, NC). To assess the relationships between knowledge and practices, knowledge, attitude, and practice scores for each farmer were calculated using methods adapted from Sam et al. *(13)*, Rahman *(25)*, Dasgupta et al. *(11)*, Salameh et al. *(12)*, and Goldman et al. *(35)*. For knowledge and practice questions with correct/incorrect responses, correct responses were scored as 1 and incorrect or missing responses were scored as 0. If a partially correct response was possible, it was scored as 0.5. For questions with multiple correct responses, such as identifying the routes of pesticide exposure, the score was the proportion of correct responses out of the number of possible correct responses. Specific information about pesticide application, including the name of the crop and pesticide, the dosage, and the time between application and re-entry into the field (re-entry period), was compared to government, label, or retailer recommended doses, crops and re-entry periods. Many farmers did not know the correct name of the pesticide formulations they used, and did not have labeled pesticide containers. In these cases, interviewers checked pesticide labels when possible, visited local pesticide retailers, and/or used knowledge from their personal experience in agriculture to determine the name of the pesticide formulation and the recommended instructions, if not specified in government recommendations. One pesticide formulation was identified by consultation with a pesticide company official, and two pesticides could not be identified. One famer reported using sex pheromone as a pesticide; this was excluded because the application of sex pheromones is considered an IPM technique. The scores for the three pesticide-specific application practices (overapplication, use on prescribed crop, and sufficient re-entry period) were then the proportion of crop-pesticide combinations that met official recommendations, out of the total number of crop-pesticide combinations reported by each farmer. Pesticide formulations were also categorized according to the WHO Classification of their active ingredient(s) *(8)*, and the proportion of pesticides with active ingredients in WHO Class II or higher was calculated for each farmer. One active ingredient was not included in the WHO Classification system. The proportion of WHO Class II or higher pesticides was not included in the practice score because, as noted previously, government recommendations frequently include such pesticides. Correct or incorrect knowledge and practices were determined based on Food and Agriculture Organization (FAO) or International Labor Organization (ILO) guidelines, or from other authoritative sources in Bangladesh *(7, 9, 36-43)*. Attitude questions were rated according to the level of responsibility for pesticide related hazards demonstrated by the farmer's response. Appendix 2 presents the details of scoring assignments and sources. Overall scores for knowledge, attitudes, and practices were calculated by summing the scores for each farmer and dividing by the number of non-missing score components.

Descriptive statistics and bivariate analyses were calculated using data from all 72 farmers interviewed. Selected bivariate analyses were carried out to explore differences in practice, knowledge, and attitude scores, overapplication, and proportion of WHO

Class II and higher pesticides used by training, farm type, sex, income, years working on the farm, information sources, and district. Statistical tests were chosen for these analyses based on variable types and normality of continuous variables; the name of the statistical test used is listed with the result of each test.

Knowledge and practice scores were analyzed using multiple linear regression to characterize the relationship of pesticide knowledge and attitudes, farm characteristics (such as size, location, and crop), and respondent demographics (such as age, education and income) with pesticide practices. Practice scores were normally distributed (Kolmogorov-Smirnov D=0.072525, p>0.1500; Appendix 4, Table 1, Figures 1-2), therefore no transformation was applied to the scores. Candidate predictor variables considered for inclusion in the model were selected based on information in the literature and/or the plausibility of a relationship between that variable and practice and knowledge scores. Bivariate associations, including Pearson correlation coefficients for each continuous variable with knowledge and practice, Student's t-tests for each dichotomous variable with knowledge and practice, and one-way ANOVA tests for each categorical variable with knowledge and practice, were examined to indicate strong predictors and possible confounders within the linear regression model. Those strongly associated with both knowledge and practice (p<0.1) were included in the initial model. Interaction terms between each of these variables and knowledge were tested for significance using manual backward elimination. Possible confounders in the resulting model were removed one at a time and the change in coefficients of knowledge and significant interaction terms were examined. The F statistic, r^2, adjusted r^2, residuals and influential points were examined to assess fit and modeling assumptions. The significance level was α=0.05.

GPS data were analyzed using ArcGIS 9.3 (ESRI, Redlands, CA). Shapefiles of administrative boundaries in Bangladesh (e.g. districts, upazilas[2], etc.) were downloaded from the internet *(44)*. Using the GPS data, a set of maps were created that depicted farmers' reported information sources at the time of the study, knowledge scores, and practice scores. To improve visual clarity, values were pooled by upazila and averaged, and districts were divided into central districts (Dhaka, Gazipur, and Narayanganj) and southwest districts (Jessore, Narail, and Satkhira; Figure 2). Cutoff values for knowledge and practice score map symbols were determined using the quantile option in ArcGIS with four levels. Spatial patterns were identified visually.

III. RESULTS

i. Descriptive statistics

Demographic characteristics of the study participants and their farms are shown in Table 1. Participants tended to be older and included proportionately more males than the general population. Reported income among these farmers was about seven times that of the general population of agricultural laborers in Bangladesh. Not surprisingly, a larger proportion of the study population primarily worked in agriculture compared to the general population, however a lesser proportion of the study population considered their incomes sufficient to meet their families' basic needs than the general population. A lower proportion of participants owned their agricultural land compared to all farmers in Bangladesh, however the area of the farms was comparable between participants and the

[2] Districts in Bangladesh are divided into subdistricts called upazilas, similar to a county in the United States.

general population of farmers. None of the farmers in the study had any training in the use of pesticides, and few reported having access to training (Table 2). The number of farmers who grew each crop is shown in Table 3. Sweet gourd and eggplant were the most common crops, while cabbage and spinach were the least common. None of the participating farmers grew potatoes. Farmers applied pesticides to their crops throughout the year, and the number of formulations applied peaked in July (Figure 3). Farmers tended to use a high proportion of WHO Class II and higher active ingredients (Figure 4; Appendix 3, Table 1).

On average 53.66% (SD 33.47%) of farmers reported correct application practices (Appendix 3, Table 2). Most farmers reported using two items of PPE (Figure 5; Appendix 3, Table 3), and these were most often long pants or a full-length lungi[3] and long sleeves (Appendix 3, Table 4). No farmer reported using every item of PPE listed because many farmers found individual PPE items inappropriate; however a few items were reported to be unavailable (Appendix 3, Table 5). Overapplication was extremely common, while using pesticides for crops specified on the label and allowing a sufficient re-entry period were highly uncommon (Table 4; Appendix 3, Figures 1-3). Almost every farmer stored pesticides separately from food, drinks and medicine, and had a means of communication near the storage place. Interestingly, none of the farmers had a fire extinguisher near the pesticide storage place (Table 5). Most farmers took measures to prevent children's exposure to pesticides (Table 6).

About three-quarters of farmers had knowledge of pesticide application and post-application instructions, but understanding of exposure routes, pathways, symptoms, and

[3] A lungi is a clothing item traditionally worn by men in Bangladesh. It is a tube-shaped piece of cloth tied around the waist, and the length can be adjusted from above the knees to near the ankles.

IPM techniques was less common (Appendix 3, Table 6). Only four farmers had heard of IPM techniques (listed in Appendix 3, Table 7), and most identified less than half of the routes, pathways, and symptoms of acute exposure (Appendix 3, Figures 4-6). Most farmers reported hearing application and post-application instructions from at least one source (Appendix 3, Figure 7), with word-of-mouth being by far the most common means of receiving instructions (Table 7). Farmers in the southwest districts tended to report more sources than those in the central districts (Figure 6), and pesticide companies were a more common source in the southwest districts than in the central districts (Appendix 3, Figures 8-9). Farmers generally felt that everyone using pesticides was responsible for their safe use, although a similar proportion also felt that pesticides were only effective if their effect could be seen soon after spraying (Table 8).

Descriptive statistics for practice, knowledge, and attitude scores are shown in Appendix 3, Table 8. Practice scores were approximately normally distributed with a mean of about 0.5 (Figure 7). Knowledge scores appeared bi-modal such that farmers were separated into a group with a broad range of knowledge scores below 0.5, and a group with a narrow range of knowledge scores approximately centered around 0.8 (Figure 8). The largest proportion of farmers had an attitude score of 0.25 (Figure 9). Descriptive statistics for the number of missing practice, knowledge, and attitude score components are shown in Appendix 3, Table 9. With a few extreme exceptions, practice scores were missing fewer than five components (Appendix 3, Figure 10), knowledge scores were missing fewer than 4 components (Appendix 3, Figure 11), and one attitude score was missing one component (Appendix 3, Figure 12).

ii. *Bivariate analyses*

Interestingly, pesticide overapplication was not associated with income (p=0.7452, Spearman Correlation Coefficient). Farmers who have worked on the farm longer did not have better knowledge scores (p=0.4510, Spearman Correlation Coefficient) and did not use a lower proportion of WHO Class II or higher pesticides (p=0.7465, Spearman Correlation Coefficient). Similarly, farmers who used a higher proportion of WHO Class II or higher pesticides did not identify more symptoms of acute pesticide poisoning (p=0.9626, Spearman Correlation Coefficient).

Farmers who received any pesticide information from NGO or Ministry of Agriculture officials had similar knowledge scores (p=0.0679, Wilcoxon Two-Sample Test), but significantly higher practice scores (p=0.0005, Student's T-test) than those who did not receive information from one of these sources. Farmers who received any pesticide information from NGO or Ministry of Agriculture officials did not report hearing about IPM practices more or less often than those who did not receive information from one of these sources (p=1.0000, Fischer's Exact Test).

Practice and knowledge scores did not differ by sex (p=0.4120, Student's t-test; p=0.2111, Wilcoxon Two-Sample Test; respectively) or farm type (p=0.5457, one-way ANOVA; p=0.8235, Kruskal-Wallis ANOVA; respectively. See Figures 10-11; Appendix 3, Table 10). Similarly, farmers from different farm types did not differ in pesticide overapplication (p=0.4413, Kruskal-Wallis ANOVA). However attitude scores were significantly higher in men (p=0.0268, Student's t-test) and differed significantly by farmer's farm type (p=0.0066, one-way ANOVA; Figure 12; Appendix 3, Table 10). Conversely, practice and knowledge scores differed significantly according to the location of the farm ($p=0.0207$, Figure 13; $p<0.0001$, Figure 14; respectively), with farmers in towns having the lowest scores in both cases. Attitude scores did not differ significantly by farm location ($p=0.3213$, Appendix 3, Figure 13). Farmers with more education had significantly higher practice scores ($r=0.2389$, $p=0.0433$, Spearman Correlation Coefficient), but knowledge and attitude scores were not associated with education ($p=0.1406$ and $p=0.0510$, respectively, Spearman Correlation Coefficient). Surprisingly, among farmers with access to pesticide training ($n=9$), attitude scores did not differ between those who planned to get training and those who did not ($p=0.5613$, Wilcoxon Two-Sample Test). Practice, knowledge, and attitude scores did not consistently vary according to whether farmers grew each crop (Appendix 3, Table 11).

Practice scores did not differ significantly by district ($p=0.4157$, one-way ANOVA; Table 9; Appendix 3, Figure 14), but knowledge and attitude scores did differ significantly ($p=0.0047$, Kruskal-Wallis ANOVA; $p<0.0001$, one-way ANOVA; respectively, Table 9). Both knowledge (Figure 14) and attitude scores (Appendix 3, Figure 15) tended to be lower and more variable in the central districts and higher and less variable in the southwest districts. When practice and knowledge scores were mapped by upazila, upazilas with knowledge scores in higher quartiles often had practice scores in higher quartiles as well (Figure 15). This relationship also held when practice scores were plotted against knowledge scores, and the relationship appeared to be approximately linear ($r^2=0.29$; Figure 16).

iii. Multiple linear regression

Multiple linear regression analysis was used to examine the impact of other variables on the relationship between practice scores and knowledge scores. Appendix 4,

Table 2 lists the candidate predictor variables considered in the modeling process and the number of missing values and outliers for each variable. Appendix 4, Tables 3 and 4 show the results of bivariate tests of association between candidate predictor variables and practice and knowledge scores. Based on these tests, the following variables were included in the model: number of information sources, farm grows beans, farm location, and pesticide applicator. When the frequency distributions of these variables were examined, the distributions of the number of information sources and farms that grow beans appeared balanced enough to be informative in the regression analysis. However one level in both the farm location and pesticide applicator distributions contained only one respondent (Appendix 4, Table 5). For the farm location, the one farm that was located in a slum[4] was combined with those farms in a municipality because these locations have similar characteristics. For the pesticide applicator variable, the levels of the variable were redefined as the respondent applied pesticides, or anyone else applied pesticides. The bivariate tests of association in Appendix 4, Table 4 reflect these variable definitions, and the associations of each re-defined variable with practice and knowledge remained significant at the p=0.1 level. The variance inflation factors of all of the variables selected for inclusion in the model were less than ten (Appendix 4, Table 6), suggesting that multicollinearity was not present among these variables. The base model then included practice score as the outcome; knowledge score as the predictor of interest; number of information sources, farm grows beans, farm location, and pesticide applicator as potential effect modifiers or confounders; and the set of four interaction terms created

[4] A slum was defined as a densely populated area characterized by informal, single-story structures, and lack of water, sanitation, and electrical infrastructure. Slums were generally located within a municipality.

by the interaction with these four variables and knowledge score. Sixty-nine observations were used in the regression analysis.

A chunk test of interaction terms indicated that at least one interaction term was significant (p=0.001; Appendix 4, Table 7). Manual backward elimination resulted in the removal of the interaction term knowledge x pesticide applicator (Appendix 4, Table 8). In order to maintain a hierarchically well-formulated model, only the single variable pesticide applicator was tested for confounding. Pesticide applicator was not removed from the model because it meaningfully changed the coefficient of the knowledge score under several interaction scenarios (Appendix 4, Table 9).

In the final model, the relationship between knowledge and practice scores was marginally significant (p=0.0863, Table 10). The model intercept was significantly different than zero (p<0.0001, Table 10), suggesting that even with no knowledge of safe pesticide application practices, farmers in this study had a basic level of safe pesticide practices. The strength of the association between knowledge and practice scores decreased on farms where beans were grown, but increased based on farm location and the number of information sources reported by the respondent (Table 11). When a farm was located in a town, the association between knowledge and practice scores was about four times that of farms located in a village, municipality, or slum. The strength of the association between knowledge and practice scores increased with the number of information sources reported by the respondent, with the strength of association among farmers reporting three information sources being about four times that of farmers reporting no information sources.

The final model explained at least half of the variation in practice scores (r^2=0.59, adjusted r^2=0.52), and appeared to fit the observed practice scores well (F=8.30, p<0.0001; Appendix 4, Figure 3). Residual analysis suggested that the model satisfied the assumption of having approximately normally distributed residuals (Appendix 4, Table 10, Figures 4-6), however the residuals exhibited some fanning when plotted against predicted practice scores (Appendix 4, Figure 7); this indicates that the residuals may not have had constant variance. Still, the appearance of fanning is strongly influenced by a small number of points with large residuals located among the most common predicted practice score values; thus the apparent fanning may be due to chance rather than true non-constant variance in the residuals. Residual plots suggested some non-constant variance based on values of the variable town and the interaction knowledge x town (Appendix 4, Figures 12 and 17), but this is most likely due to the relatively small number of farms located in a town (n=7). Residual plots with other variables did not suggest non-constant variance (Appendix 4, Figures 8-11 and 13-16).

iv. *Focus groups*

During the focus group discussion in Narail district, farmers expressed concerns about a lack of control over the types of pesticides they used, an increased need for pesticide application, and a lack of access to information about pesticides. Farmers reported being limited to the small number of pesticides available in the local market, and said that these pesticides changed every year. Many felt that pesticide formulations were progressively less “powerful” each year, leading them to apply larger quantities more frequently. In the past, farmers had applied pesticides once just before their crops flowered, but at the time of the focus group they had to apply pesticides beginning seven days after planting. They applied pesticides again when they noticed shriveled leaves or a change in the color of their crops. Farmers were spraying pesticides so frequently that they had stopped warning their neighbors before a pesticide application, although both flags and verbal warnings were common in the past. This was considered acceptable because farmers observed that fewer chickens died from pesticide poisoning and so perceived current pesticides as less “powerful” than before. Hybrid seeds were generally viewed as the reason for the increased need for pesticides. Farmers noted that more pest attacks occurred during the summer, speculating that lower temperatures and fog might prevent insects from reproducing in the winter months. They said that the local retailer was their best source of pesticide information, but felt that retailers tended to recommend pesticides that would give them the highest commission. The DAE block supervisor, on the other hand, often recommended pesticides that were not available in the local market, had little or out-of-date training, and was rarely available. Farmers said they did not read labels for several reasons, including illiteracy, “laziness”, and an inability to understand the technical terminology on the label. Due to their lack of knowledge about pesticides, the farmers felt controlled by the market and expressed some mistrust of the information they received from pesticide companies, despite claiming that the retailers were the best pesticide information source. Farmers in Narail had no training in IPM practices, although they claimed to have used such practices in the past. They were also unaware of most environmental impacts of pesticide use, and expressed surprise when the facilitator explained that pesticides can contaminate groundwater and surface waters. When asked about measures taken to protect themselves while spraying, some farmers said they wear shoes or slippers during the rainy season to keep their feet dry, but not because they are concerned about pesticide exposure.

Farmers who participated in the Dhaka district focus group had significantly different experiences. In this area, women never applied pesticides because it was considered a man's job. Pesticides were usually applied to fully grown plants in this area, but beans, tomatoes, and eggplant required pesticides starting with the "baby" plants. Farmers applied pesticides three times per week to beans, and two times per week to eggplant and tomatoes from the early stages of their growth; pesticides were applied to other crops two times per week after they flowered or produced fruit. Although farmers had been cautious about using large amounts of pesticides in the past, they applied more now because the pesticide residues kept the vegetables looking nice and extended their shelf life. Farmers generally agreed to stop applying pesticides three days before the regional market day each week because the "power" of the "medicines" lasted only 24 hours and would be gone by the time anyone consumed the crops. The 24-hour guideline was suggested by DAE block supervisor. These farmers did not express the same concerns about the limitations of the local market, but still said that local retailers were a primary source of pesticide information. Local retailers sometimes had training, but not always. They seemed to rely on a chart of pests, crops and pesticides supplied by pesticide companies to make recommendations about which pesticides to use. The DAE block supervisor for the area played a larger role than in Narail because this area supplies a large amount of vegetables to the city of Dhaka. The block supervisor usually visited the area once or twice each week, and sought the advice of his supervisor when necessary to make reliable recommendations of which pesticides to use. Environmental impacts were also poorly understood here, and farmers felt strongly that the government should be responsible for training them in this area and for properly disposing of their empty pesticide containers. At the time farmers simply threw empty containers away in the field, but they said they were willing to collect the containers if the government would pick them up and dispose of them.

IV. DISCUSSION

i. Major findings

Among the farmers interviewed, training on pesticide application and storage was exceedingly rare, and most pesticide-related information was gained from other farmers by word-of-mouth. Pesticide-related knowledge was higher in the southwest districts than in the central districts, and knowledge scores in the central districts had a wider spread. Knowledge of safe pesticide application and storage practices showed a marginally significant association with safe practices, and this relationship was reflected geographically when knowledge and practice scores were mapped by upazila. The relationship between knowledge and practice was influenced by three effect modifiers, including the farm location, growing beans on the farm, and the number of reported information sources, and one confounder, the pesticide applicator.

Previous studies have consistently found that pesticide training was rare *(6, 11, 45)*. Similarly, word-of-mouth has often been found to be a common source of pesticide-related information *(6, 12, 45)*. The focus groups conducted during this study provide some evidence for why word-of-mouth is such an important source of information. First, farmers in both focus groups expressed distrust toward pesticide retailers, which may explain why retailers were not a primary source of information in the interviews, in contrast to previous findings *(3, 6, 46)*. Interestingly, farmers reported getting information from pesticide retailers in both focus groups, although this was not reflected in the interview responses. In the Narail focus group, the DAE block supervisor was unavailable or did not provide useful information. Similar sentiments arose among focus groups in another study where Bangladeshi farmers expressed a preference for gaining information from retailers and other farmers because they did not have to be sought out *(6)*. Second, farmers reported low literacy, with 50% reporting that they had not completed any formal education. In focus group discussions, farmers said that they either could not read at all, or could not understand the terminology on pesticide labels, so they did not read the labels. Being unable to read the labels, it is not surprising that farmers rely on verbal communication with people at a similar educational level for pesticide information. However, responsible use of pesticides under current conditions requires the abilty to read and follow label instructions, both of which are often beyond the ability or control of the applicator in low-resource settings *(47)*.

The finding that pesticide-related knowledge was higher and less varied in the southwest districts from the interviews was contradictory to the feelings expressed in the focus groups: the southwest focus group in Narail perceived a greater need for pesticide training, implying poorer pesticide knowledge, than the central focus group in Dhaka. This difference may be a result of differences in sample size between the central and southwest districts in the quantitative analysis, or a result of including non-interviewees in the focus groups; because names were not collected from focus group members, it was not possible to determine how large of an influence non-interviewees might have had on focus group discussions. Moreover, the specific villages in which focus groups were conducted may not have been representative of all villages in which farmers were interviewed in the southwest or central districts. As noted by the farmers in the Dhaka focus group, the block supervisor visited often, and the area was considered a key producer for the city of Dhaka. Perhaps these farmers received more attention and better information because the block supervisor had identified this area as a priority. Currently, activities in the ASPS partnership are limited to 32 districts, which includes Dhaka, but none of the southwest districts *(48)*. Therefore FFS and IPM clubs, and consequently better pesticide knowledge, are expected to be more common in the central districts. It is also possible that farmers in Narail had truly higher pesticide knowledge, and were consequently more aware of gaps in their knowledge, whereas farmers in Dhaka were less aware of such gaps. Based on the available information, it remains unclear whether the interview findings or focus group findings were a more accurate reflection of the true distribution of knowledge among farmers in Bangladesh.

The marginally significant association between knowledge and practice scores observed here reflects the uncertainty about this relationship in the literature. Few studies have carried out formal statistical tests of the relationship between knowledge of safe pesticide application and storage and safe practices. Salameh et al. *(12)* rated knowledge and practice on separate scales, similar to the scores calculated in this study. They observed that farmers in Lebanon with higher knowledge ratings also had higher practice ratings ($p<0.001$). Sam et al. *(13)* found that practice scores improved over time after farmers in India participated in a pesticide training program, but knowledge scores did not consistently increase with practice scores. Issa et al. *(49)* observed an overall decrease in the number (47 compounds in 1998 to 16 in 2006) and hazard classification

(25 WHO Class II or higher active ingredients in 1998 to 9 in 2006) of pesticides used in the West Bank between 1998 and 2006. Government and university pesticide training and educational interventions were common during this period in the West Bank, providing circumstantial evidence that increased knowledge may have led to safer pesticide use. Farmers in Brazil *(17)* and Greece *(50)* were found to have high knowledge of the dangers of pesticide use, but took few precautions to prevent exposure; however no formal test of association was performed in either of these studies.

Much of the evidence regarding the relationship between pesticide knowledge and practices is related to the use of PPE. Farmers in the West Bank were found to use individual PPE items only if they had knowledge of the item *(14)*. In contrast, only 6.7% of Ethiopian farmers reported using PPE for protection against pesticide exposure although 99.2% thought PPE should be used *(51)*. Similarly, Sivayoganathan et al. *(15)* observed that many farmers in Sri Lanka knew about many PPE items, but comparatively few farmers used every item of which they knew. In Ghana, the relationship between PPE knowledge and use was unclear because farmers could identify almost all PPE items when prompted, but identified very few spontaneously; the number of PPE items in use more closely reflected spontaneous responses *(16)*. Because of the hot climate in these study locations, the discomfort associated with wearing extra clothing and devices in the heat led many farmers not to use PPE despite their knowledge of it *(15, 49-51)*. In this study, farmers most frequently reported that PPE items were inappropriate while applying pesticides, which may indicated that a lack of knowledge in addition to hot climate may influence the decision to use PPE in these farmers.

With regard to the appropriate application of pesticides, however, the evidence suggests a more consistent relationship. In South Africa, women who had training in pesticide application were more likely to correctly interpret pictograms on labels *(46)*. Correspondingly, farmers in Costa Rica could not distinguish pest insects from beneficial or harmless insects and therefore applied inappropriate pesticides at inappropriate times *(52)*.

To the author's knowledge, none of the previous studies of the relationship between pesticide knowledge and practice have reported effect modifiers or confounders of this relationship. Salameh et al. *(12)* used a bivariate analysis to adjust for potential confounders of this association, such as education, but did not report which confounders, if any, were included in the final model. Sam et al. *(13)* stratified knowledge, attitude, and practice scores by gender, but did not utilize multivariate methods to explore other covariates. In the model reported here, the pesticide applicator variable was retained as a confounder, although the coefficient of the variable was not significantly different from zero. The influence of the pesticide applicator as a confounder of this relationship is not surprising. One would expect that the respondent's knowledge about pesticides would be related to the amount of experience they had applying pesticides, although the direction of this relationship is not well established; some evidence suggests that farmers with more application experience have greater knowledge *(13)*, while other evidence suggests the opposite *(12)*. Practices would also be expected to differ between applicators.

The location of the respondent's farm was determined to be an effect modifier in this study, with respondents from farms located in towns having a stronger association between pesticide knowledge and practices. Practice and knowledge were lowest among farmers in towns, but their practice scores were relatively more similar than their knowledge scores to those of farmers in villages, municipalities, and slums. All farms located in towns, municipalities, and slums were located in the central districts in close proximity to the city of Dhaka. In 1998, the population density in urban areas of Dhaka was 14,000 people per square kilometer, with the entire megacity covering a total of 1530 square kilometers *(53)*. Because the entire megacity area is not urbanized, farms are scattered throughout the city, with some near dense housing developments. As evidenced by the focus group discussions, farmers are aware that pesticides can harm human health, and take precautions that they think will reduce such harms. Farms located in towns were larger, on average, than farms in municipalities or slums, and would be expected to be more accessible to people nearby than farms in villages. It is possible that farmers in towns, having relatively large farms in densely populated areas, had a heightened awareness of how their pesticide application and storage practices could affect those near their farm. Consequently, farmers in towns may have been more likely to act on the knowledge they had about safe pesticide application even though their pesticide-related knowledge was generally lower than farmers in villages, municipalities, or slums. It is also possible that farmers in towns imitated the practices of their more knowledgeable colleagues in villages, municipalities, or slums such that their practices improved without gains in knowledge. From the available information, it is not clear why farmers in towns appeared to have a stronger relationship between pesticide knowledge and practices in this study.

Growing beans was also determined to be an effect modifier in this study, with bean growers exhibiting a weaker association between pesticide knowledge and practice than non-bean growers. This is consistent with previous findings that suggested bean and eggplant growers were more likely to overapply pesticides regardless of pesticide application knowledge *(11)*. Farmers have also been found to use higher proportions of WHO class Ia and Ib pesticides on beans in Dhaka, eggplant in Jessore, and cabbage in Jessore and Khulna *(4)*. Such practices were also mentioned in the focus group discussion in Dhaka district where farmers applied pesticides earlier, more often, and/or in greater quantities to beans, eggplants, and tomatoes. Notably, growing eggplant or tomatoes did not arise as effect modifiers. This may have been observed because there were fewer bean growers who also grew eggplant and/or tomato (15%) than eggplant growers who grew beans and/or tomatoes (33%) or tomato growers who also grew eggplant and/or beans (57%). The influence of bean growers among eggplant and tomato non-growers may have cancelled out the impact of poor pesticide practice by eggplant and tomato growers. Eggplant growers in particular have been targeted for IPM training, including grafting of eggplant on wild eggplant root stock that is resistant to bacterial wilt. Without such grafting, as much as 30% of production costs for eggplant are used for pesticide application *(54)*.

Finally, the number of information sources reported by respondents was another effect modifier in this study, with farmers who reported more information sources having a stronger association between pesticide knowledge and practices. Likewise in the bivariate analysis, practice scores, but not knowledge scores differed according to the quality of information sources, with NGOs and Ministry of Agriculture officials considered higher quality sources. Consistent with this finding, Salameh et al. *(12)* found that the quantity and quality of information sources led to better risk perception, even among those with little education. Furthermore, those farmers who only received pesticide information orally had significantly lower practice ratings.

The relationship between knowledge and practice scores seemed to hold geographically, which suggests that it may be independent of regional differences within Bangladesh. Differences in the strength of association according to farm location or regional variation in crops could not be distinguished based on the mapping analysis here. While farmers in upazilas that reported using more information sources appeared to have higher knowledge and practice scores, a concomitant increase in the strength of the association with the number of information sources was not apparent. This relationship may have been more pronounced with greater spatial resolution, but pooling farmers by administrative units smaller than the upazila would have been misleading due to the uneven distribution of farmers in smaller units.

ii. Notable minor findings

There were no significant differences in knowledge or practice scores by sex, which was surprising given the vast differences in gender roles in Bangladesh. Although the Bangladeshi constitution provides for sex equality, in practice this is rarely the case, as gender discrimination is often justified by religious beliefs. Bangladeshi women are expected to stay at home and do housework, while men are responsible for economically productive work outside the home. Women generally may not leave the home without permission, and their mobility is limited without male supervision. Men often control women's access to educational, economic, social, and legal institutions, necessitating women's life-long dependence on a male relative *(55)*. Because access to education differs greatly between men and women, it is especially surprising that knowledge scores did not differ by sex. Sons are often given access to education over daughters when families cannot afford to send all of their children to school *(55)*. However, education also showed no correlation with knowledge of safe pesticide application and storage among these farmers. It is possible that female respondents received pesticide information from and were supervised by men during pesticide application such that their knowledge and practices were similar. However attitude scores did differ between the sexes, with men demonstrating a greater sense of responsibility for the safe use of pesticides than women. The difference in attitudes may stem from traditional gender roles as well. Because men are responsible for matters outside the home *(55)*, they would be more likely to buy pesticides, and settle disputes with neighbors over harm to livestock from pesticides, for example.

Pesticide use was observed to be highest during the summer monsoon season (May-October) in this study. Vegetable production is 60-70% higher during the winter months (November-April) in Bangladesh *(56)*, but as farmers noted in the Narail focus group, more pest attacks occur during the summer months. The increased pest attacks during the summer may contribute to crop loss and lower productivity during this time, as well as increased pesticide use.

iii. Limitations

Because a small convenience sample of farmers was selected for this study, the results may not be generalizable to the entire study area. However, this study was primarily carried out for the purpose of surveying farmers within EPRC project areas to gather baseline data about their pesticide use. Therefore the sampling scheme should be sufficient to capture the practices, knowledge, and attitudes of the target population. The small sample size may also have been insufficient to detect a significant association between pesticide knowledge and practice, given that the relationship was only marginally significant. The results are suggestive of a true association, but should be confirmed, perhaps by a pesticide education intervention among EPRC project participants to investigate the effect of changes in knowledge on safe pesticide practices.

Limited and variable knowledge of pesticides among the farmers in this sample may also have limited the validity of the questionnaire responses. During the interviews, interviewers had to define different terms for different farmers, which may have altered their responses. Similarly, farmers did not know the names of the pesticides they used, or gave inaccurate names in many cases, so not all pesticides could be identified. Pesticide labels could not be used to confirm names in many cases because pesticides were not kept in the original container. These problems in themselves indicate a need for better pesticide-related education among these farmers. With limited familiarity with common pesticide-related concepts and little knowledge of the specific hazards associated with different pesticides, it is highly unlikely that these farmers could use pesticides safely with their current understanding. This was also evident in that farmers, on average, only practiced about 50% of the safe practices measured by the questionnaire. Measuring doses was also an uncommon practice, and many farmers gave estimated doses. Some doses were reported in terms of spoonfuls or capfuls, and measurements from a typical spoon or cap were used in these cases. However it is unclear whether all farmers filled the spoons or caps to the same level, or used the same sized spoon or cap every time they applied pesticides. Regardless, many of these conservative estimates of dosage indicate that farmers overapplied pesticides frequently, indicating a pressing need for education on pesticide dosing, and the health, environmental, and economic risks associated with overapplication.

Finally, farmers were asked to give information about pesticides used over the course of an entire year at the time of the interview. This may have generated significant recall bias in the survey data and contributed to the problems with incorrectly naming pesticides. It seems more likely that farmers would have omitted pesticides rather than recalling additional pesticides that they did not spray, so these estimates of the number and doses of pesticides used are probably underestimates. Records of pesticide application were not kept by any of the farmers, so it is unlikely that this recall bias would differ between farmers of different types, or between those with higher or lower practice scores. Income also may have been subject to recall bias because farmers reported a much higher annual income than their counterparts in the general population. Because a lower proportion of farmers in the study owned their farms compared to the general population, this result seems counterintuitive, especially considering that economic growth in the agricultural sector averaged only 2% between 2001 and 2005 *(57)*. Average income may be skewed by the three farmers who reported extremely high annual incomes, but it is not clear whether these are true incomes or overestimates due to recall bias.

V. CONCLUSIONS AND RECOMMENDATIONS

Based on the results of this study, knowledge of safe pesticide application and storage has some association with safe practices, and the best way to disseminate such knowledge is at the grassroots level. Farmer field schools and IPM clubs, such as those initiated through the ASPS *(30)*, appear to be a successful model for improving pesticide-related knowledge and reducing pesticide use in Bangladesh. Since its initiation by the FAO in Southeast Asia in the late 1980s, the FFS model has been successfully implemented in many regions, including several West African countries. A typical FFS consists of a small group of farmers who meet weekly in the field. The field is divided into a conventionally treated plot, and a plot treated according to current best practices. Farmers work in small groups to observe and report basic agronomic and ecologic elements of each plot and collectively manage both plots. Such community-based learning approaches give farmers the opportunity to learn through practice about the ecosystem processes that create healthy soil structure and increase crop yield, and can also help farmers learn to market the additional produce. Implementing FFS can build partnerships and social capital at every level from the farming community to the Ministry of Agriculture, stimulate demand for literacy, and encourage women's participation in agriculture, in addition to introducing IPM practices, improving yields, and reducing health and environmental impacts of agriculture *(58)*.

Even when IPM techniques are successfully applied, pesticides may still be necessary to control some pests *(58)*. The results from both the focus groups and interviews indicate that farmers do not or cannot read pesticide labels, so improved labeling cannot be expected to increase safe pesticide application and storage practices. Pictorial labels have been suggested to overcome illiteracy among pesticide users in low-resource settings, but in light of the evidence such pictograms seem ill-advised: many South African farmers were unable to correctly interpret warning pictograms in two separate studies unless they had previous pesticide training *(46, 59)*. Therefore, verbally providing heuristics, or mental shortcuts, for safe pesticide use that apply to broad categories of pesticides may prove more effective. For example, the ILO recommends allowing seven days between pesticide application and returning to the sprayed field as a rule of thumb for any pesticide *(37)*. Such heuristics could be provided through a FFS program.

Ironically, the distribution of ASPS activities is not commensurate with the distribution of farms in Bangladesh. ASPS activities occur in all administrative divisions except Khulna division in the southwest *(48)*, despite the fact that Khulna division has more farm holdings than either Barisal or Sylhet division *(60)*. Additionally, within the study area, there were more farm holdings in the southwest districts than the central districts (293,706 farm holdings in central districts, 553,975 farm holdings in the southwest districts), although this does not reflect the total number of farm holdings in the divisions these districts represent (3,163,191 farm holdings in central Dhaka division, 1,504,256 farm holdings in southwest Khulna divison) *(60)*. In future agricultural programs, EPRC may consider replicating and expanding this model in areas where it has not yet been implemented. Comprehensive guidance on the implementation of FFS is beyond the scope of this paper, however facilitator manuals and reviews of basic FFS concepts are available from several sources *(58, 61-63)*. Establishing community support and investment and selecting appropriate FFS locations are fundamental to the sustainable implementation and dissemination of IPM and pesticide knowledge. Farmers must want to learn more about IPM techniques and safe pesticide use, and FFS sites must be located close enough that FFS graduates from different communities can support each other, but not so scattered or isolated that they cannot share their new knowledge to non-participant farmers *(47)*. Currently, community support for pesticide-related education appears to exist among farmers in EPRC project areas based on the focus group discussions. These farmers recognize that their knowledge of the health and environmental hazards associated with pesticide use is limited, and have expressed a strong desire to learn more. Based on the finding that bean growers were less likely to act on their knowledge of safe pesticide use, it may be useful to target bean growers over other farmers for IPM training. Demonstrating less pesticide-intensive methods of pest control for bean farmers may make them more willing to use fewer pesticides or use pesticides more safely. Reliable donor, rather than community, support will likely prove more difficult to obtain given the need to reinforce training messages over time and the lack of impact evaluation methodologies currently available for demonstrating results *(47)*.

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VII. TABLES AND FIGURES

Figure 1. Conceptual framework of knowledge transmission and pesticide practices

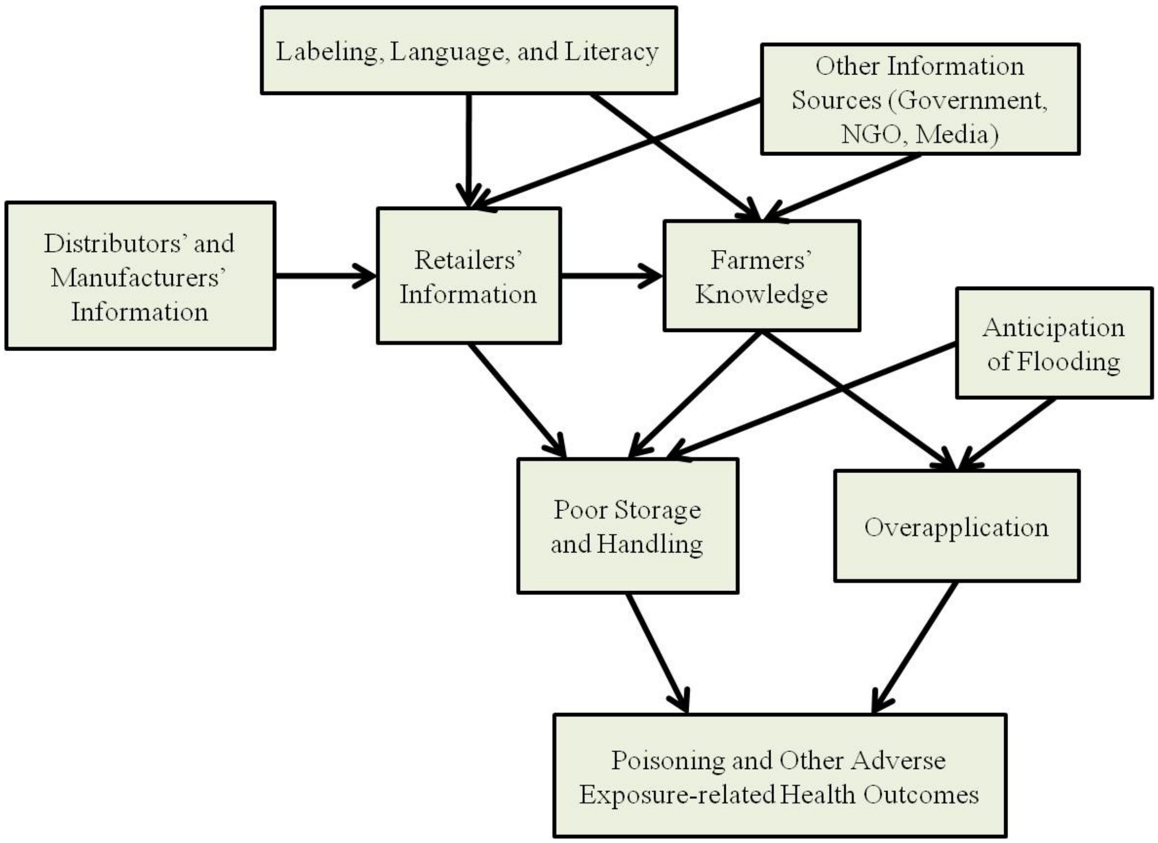


Figure 2. Map of study area

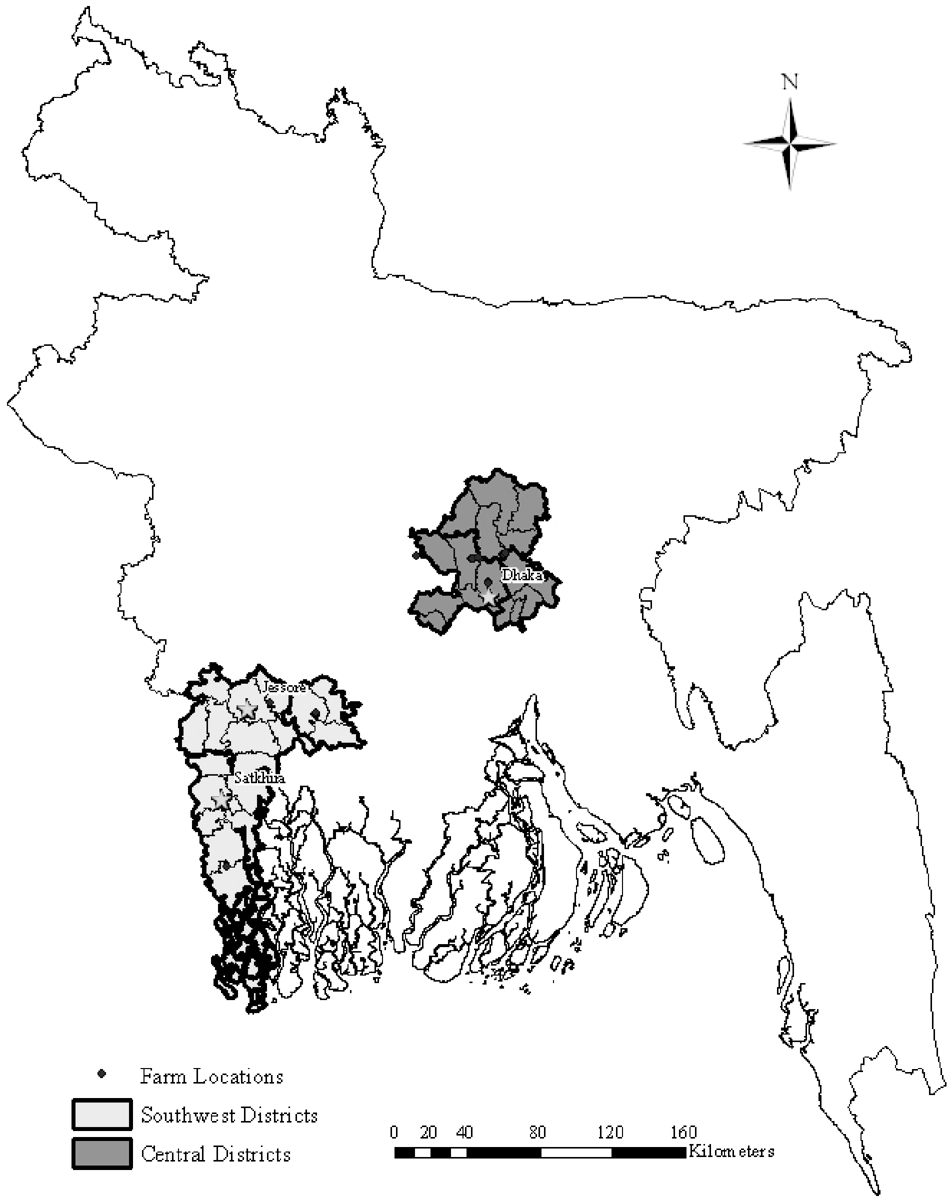


Table 1. Demographic characteristics of respondents and general population of Bangladesh

	Respondents	**General Population**[a]	**p-value**[b]
Median Age	43.50 years	20.69 years	-
Male	79.19%	51.89%	p<0.0001
Education			p=0.0726
No Schooling	50%	42.11%	
Class I-V	19.45%	31.72%	
Class VI-VIII	11.11%	12.10%	
Class IX or equivalent	8.34%	4.69%	
SSC or equivalent	6.94%	5.55%	
HSC or equivalent	4.17%	2.16%	
Degree or equivalent	0%	1.22%	
Master's and above	0%	0.44%	
Annual Income	160,261 BDT ($2268.42 USD)	23,820 BDT ($337.16 USD)[c]	-
Primary Occupation[d]			-
Business	27.78%	5.29%	
Agriculture	56.94%	19.69%	
Service	6.94%	0.67%	
Carpenter	1.39%	0.91%	
Work in foreign country	2.78%	7.75%[e]	
Day Labor	4.17%	7.93%[f]	
Secondary Occupation			-
Business	25.53%	-	
Agriculture	64.83%	-	
Service	6.38%	-	
Day Labor	4.26%	-	
Do you think that your earning is sufficient for the basic needs of your family?[g]			p=0.0003
Sufficient	24.24%	12.2%	
Moderately Sufficient	66.67%	60.4%	
Not Sufficient	9.09%	27.4%	
Own Agricultural Land	55.56%	85.97%[h]	p<0.0001
Area of Farm	1.33 acres	1.25 acres[h]	p=0.7547
Area of Farm Owned by Respondent	0.92 acres	0.84 acres[h]	p=0.7641
Years working on farm	15.16 years	-	-

[a]Bangladesh Census 2001 *(64)* unless otherwise noted. [b]Standard errors were not available for general population statistics, therefore significant p-values may not reliably indicate differences between groups. [c]Daily wages of human labor by crop season, Bangladesh Bureau of Statistics average, 2001-2002, without food *(65)*. [d] "Field of Main

Economic Activity" section of census *(64)*. [e]"Others" category. [f]"Working Status" section of census *(64)*. [g]Bangladesh Demographic and Health Survey 2007 *(66)*. [h]Agricultural Sample Census 2005 *(67)*.

Table 2. Pesticide training and access to pesticide training

	Number of farmers (percent)
Had training	0 (0.00)
Had access to training	9 (12.50)
Had access to training and planned to get training	7 (9.72)

Table 3. Crops grown by participating farmers

Crop	Number of farmers who grew crop (percent)
Boro Rice	7 (9.72)
Aman Rice	16 (22.22)
Tomato	14 (19.44)
Brinjal (Eggplant)	27 (37.50)
Okra	18 (25.00)
Pumpkin	17 (23.61)
Bitter Gourd	26 (36.11)
Potato	0 (0.00)
Sweet Gourd	30 (41.67)
Bean	20 (27.78)
Spinach	3 (4.17)
Pui Shaak	23 (31.95)
Cauliflower	6 (8.33)
Cabbage	1 (1.39)

Figure 3. Number of pesticide formulations applied June 2009 through May 2010

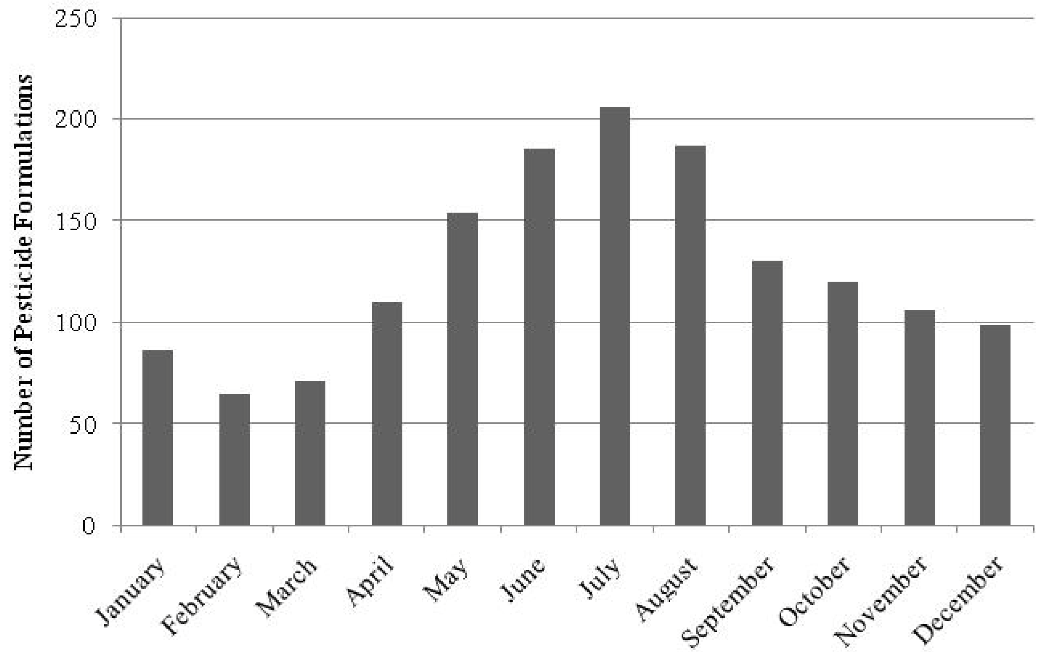


Figure 4. Distribution of proportion of WHO Class II and higher active ingredients used by individual farmers

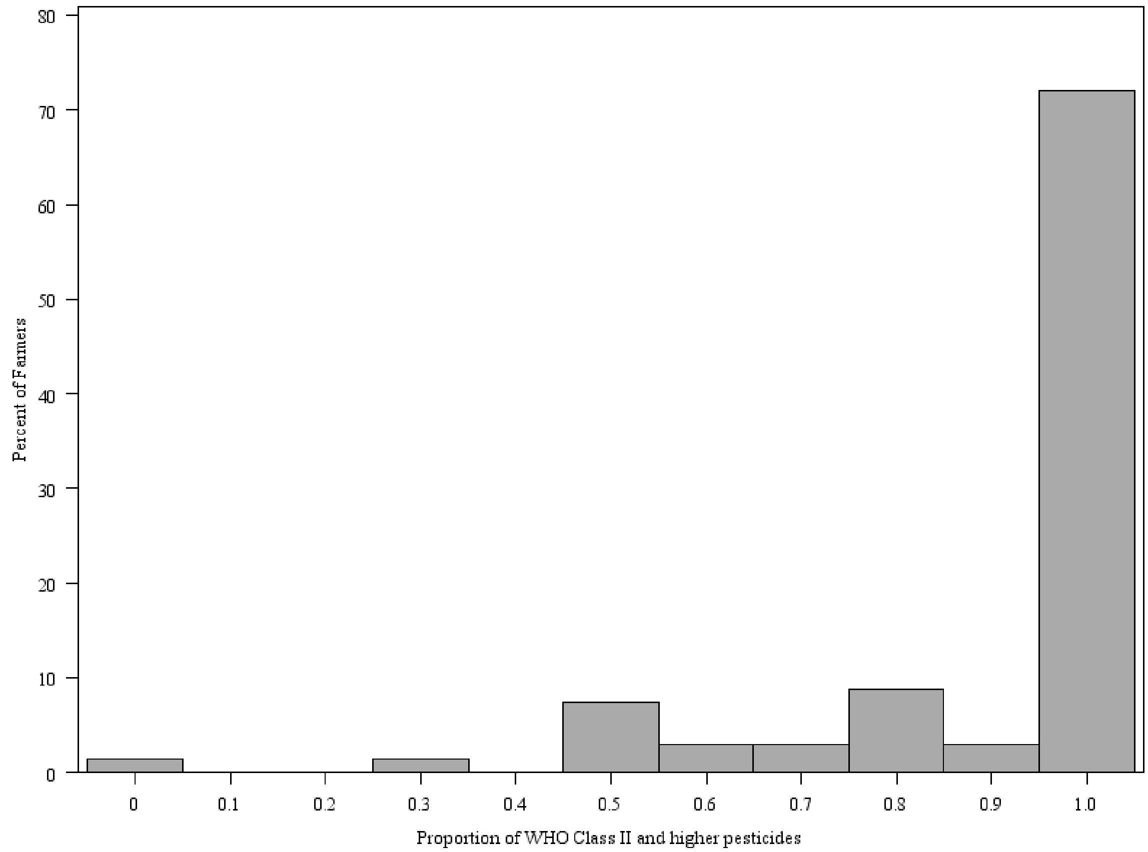


Figure 5. Distribution of the number of items of personal protective equipment used

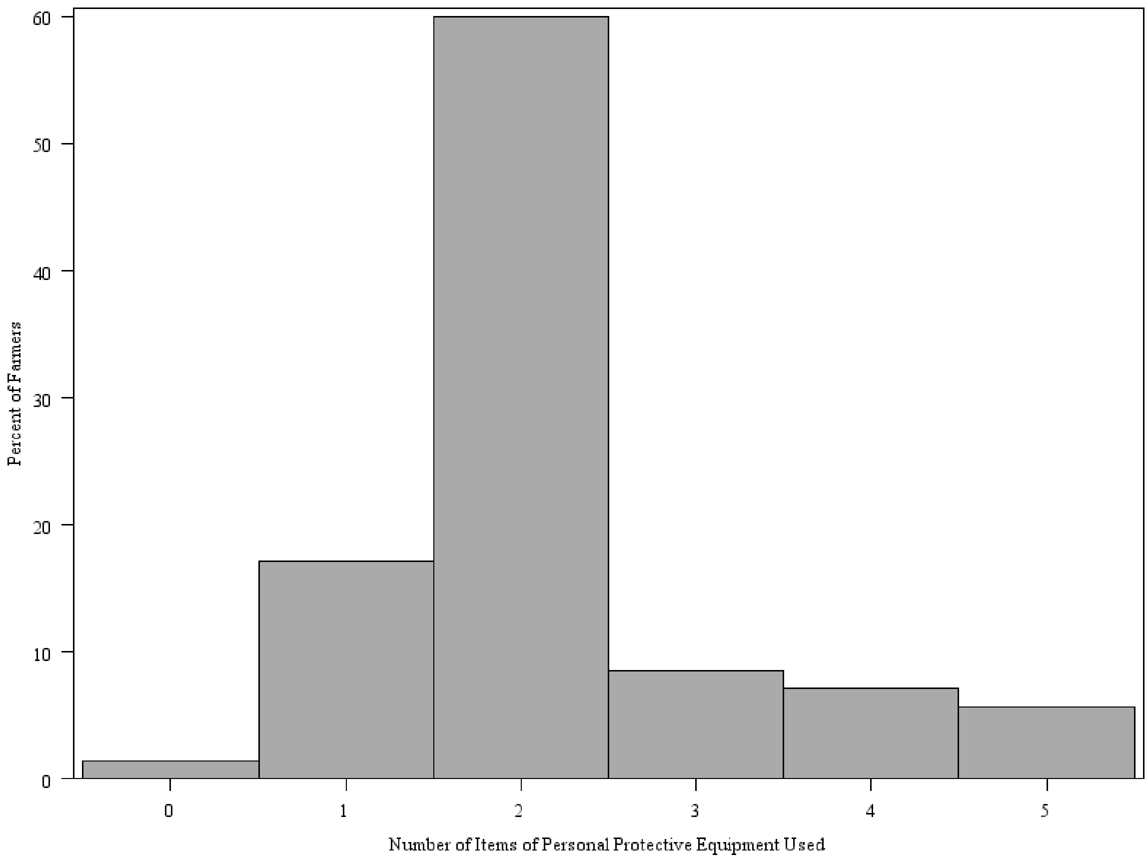


Table 4. Summary statistics for scores calculated for overapplication, inappropriate crop, and re-entry period

Score[a]	**N**	**N Missing**	**Mean**	**SD**	**Median**	**Min**	**Max**
Overapplication	63	9	0.95	0.17	1.00	0.00	1.00
Crop specified on label	72	0	0.01	0.02	0.00	0.00	0.09
Sufficient re-entry period	70	2	0.04	0.17	0.00	0.00	1.00

[a]Possible scores range from 0 to 1.

Table 5. Storage practices

Storage Practice	**N responding**	**N practicing (percent)**
Has sanitary services (bathroom/showers/etc) near storage location	69	11 (15.94)
Uses well ventilated area	69	42 (60.87)
Has cement floor (impermeable to liquids)	68	6 (8.82)
Has complete walls	69	15 (21.74)
Has a first –aid kit	69	2 (2.90)
Has absorbent material in case of a pesticide spill (sawdust, dirt, sand)	69	7 (10.14)
Stores pesticides on shelves or pallets	69	41 (59.42)
Uses metal shelves	61	8 (13.11)
Does not store fertilizers, seeds, animal feed and veterinary products next to pesticide products	69	56 (81.16)
Separates products according to their level of flammability and action (insecticides, herbicides, fungicides)	69	8 (11.59)
Stores the most toxic pesticide on the bottom and the liquids below the powders/dusts if not separated according to action	65	6 (9.23)
Has a fire extinguisher	69	0 (0.00)
Does not have a pesticide odor	69	11 (15.94)
Has warning symbols or signs: no smoking, no lighting of matches etc.	69	20 (28.99)
Has means of communication (phone, radio etc,)	69	61 (88.41)
Is not located in an urban area	69	59 (85.51)
Does not store food, drinks or medicine next to pesticides	69	68 (98.55)
Locks the place where the pesticides are stored	69	12 (17.39)

Table 6. Practices to prevent children's exposure to pesticides

Preventive Measure	**N Responding**	**N Practicing (percent)**
Prevents children from accessing stored pesticides	69	56 (81.16)
Keeps children away during and after spraying pesticides	70	40 (57.14)
Prevents children from accessing empty pesticide packages	71	67 (94.37)

Table 7. Reported information sources

Source	**Number of farmers (percent[a])**
Media	35 (53.03)
NGO	5 (7.58)
Ministry of Agriculture	2 (3.03)
Pesticide Company	21 (31.82)
Word-of-mouth	59 (89.39)
Never Heard	30 (45.45)

[a]N=66

Figure 6. Number of information sources by upazila

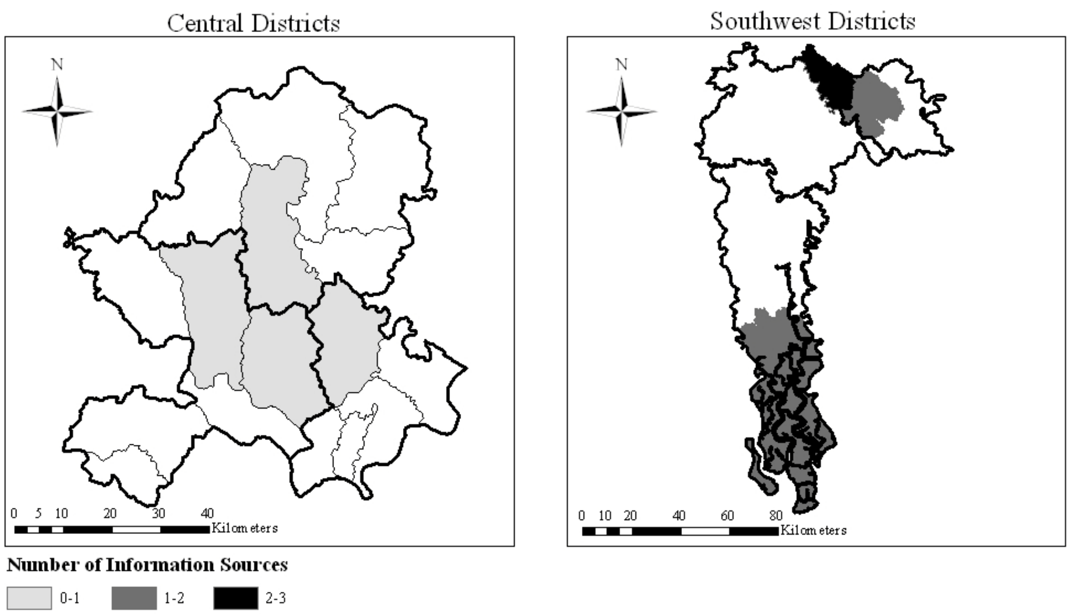


Table 8. Reported attitudes

Attitude	**N Responding**	**N who agree (percent)**
If a pesticide is sold in the market, it means it is safe no matter how or by whom it is used.	72	30 (41.67)
A pesticide is only effective if its effect can be seen immediately after spraying.	72	50 (69.44)
A pesticide is more effective if it is sprayed according to personal experience and not necessarily according to the recommended amount.	71	42 (59.15)
Every person who is using pesticides is responsible for their safe use.	72	51 (70.83)

Figure 7. Distribution of practice scores

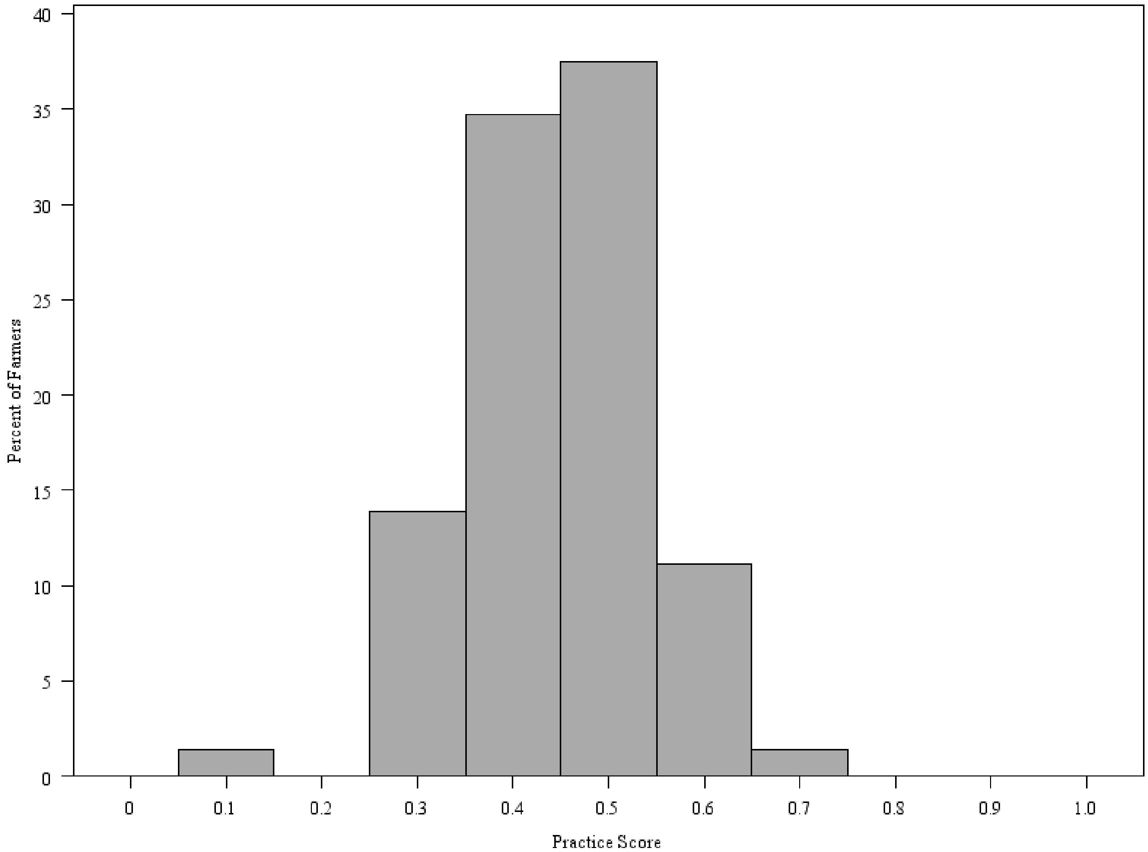


Figure 8. Distribution of knowledge scores

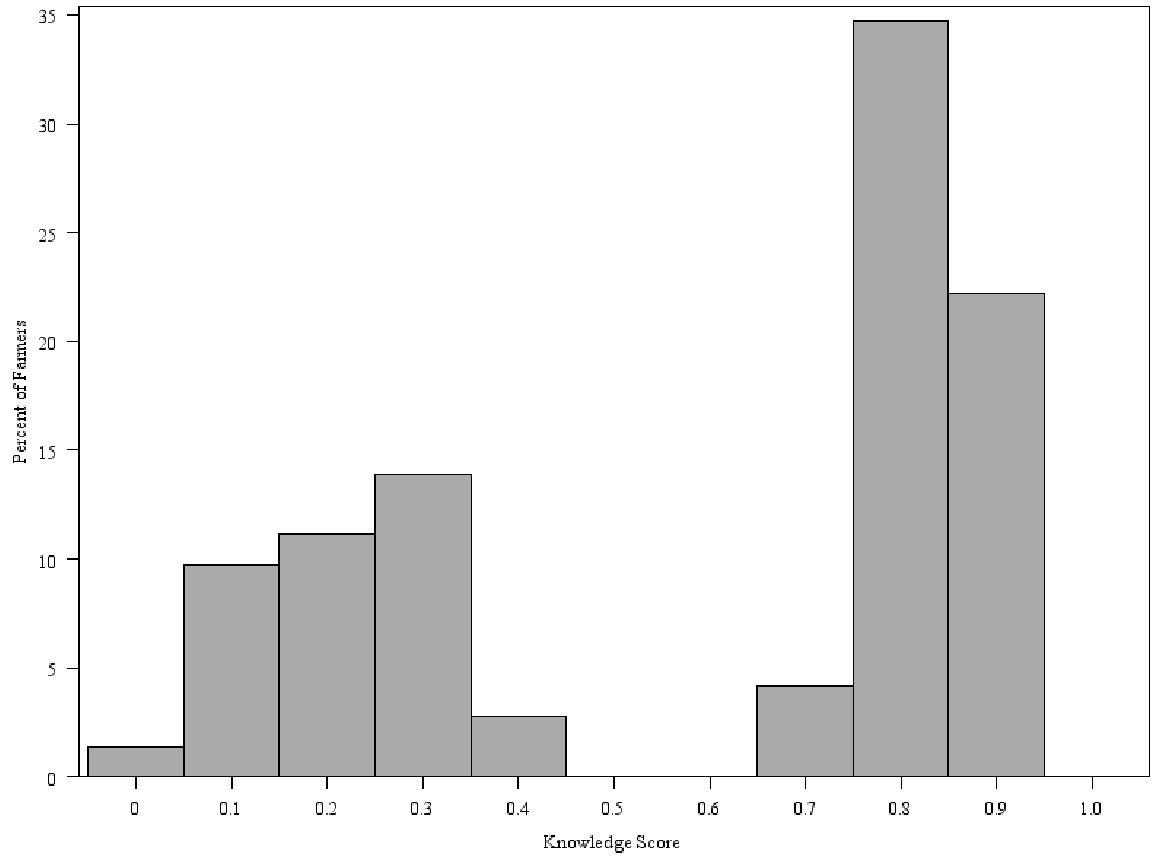


Figure 9. Distribution of attitude scores

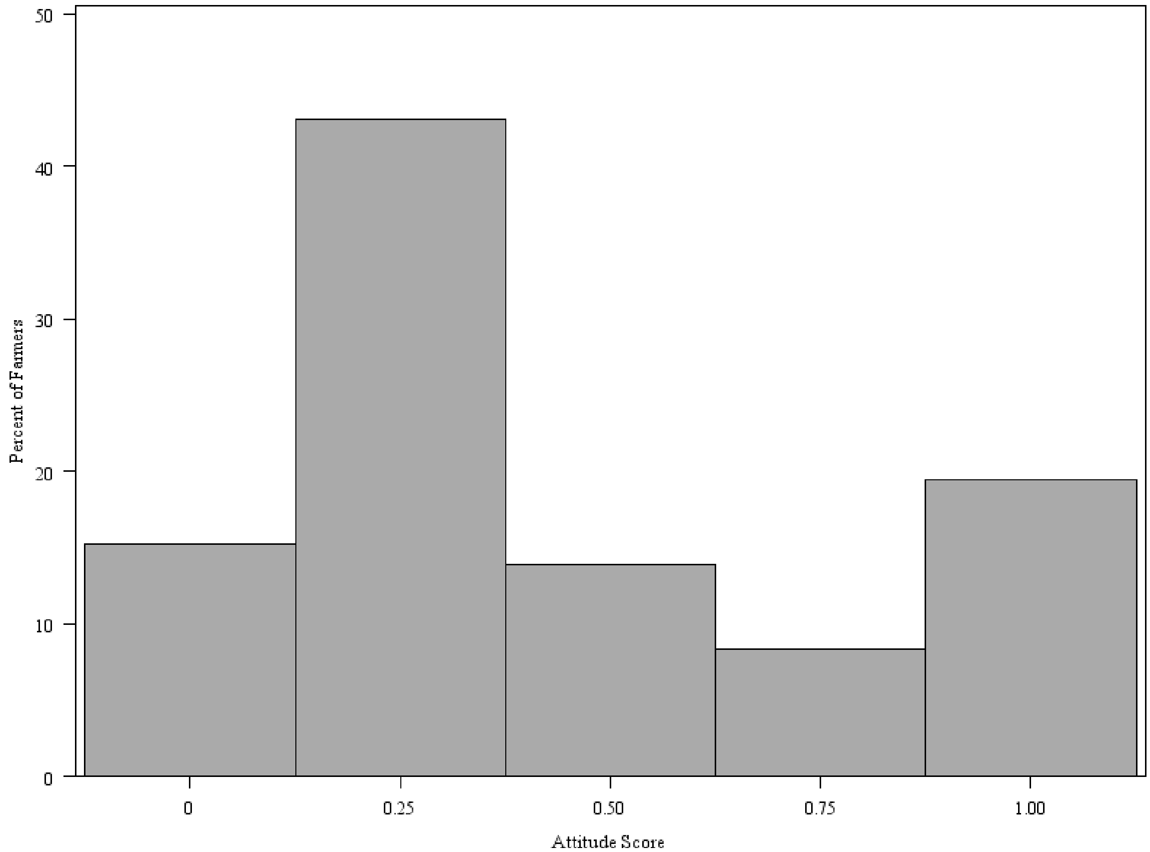
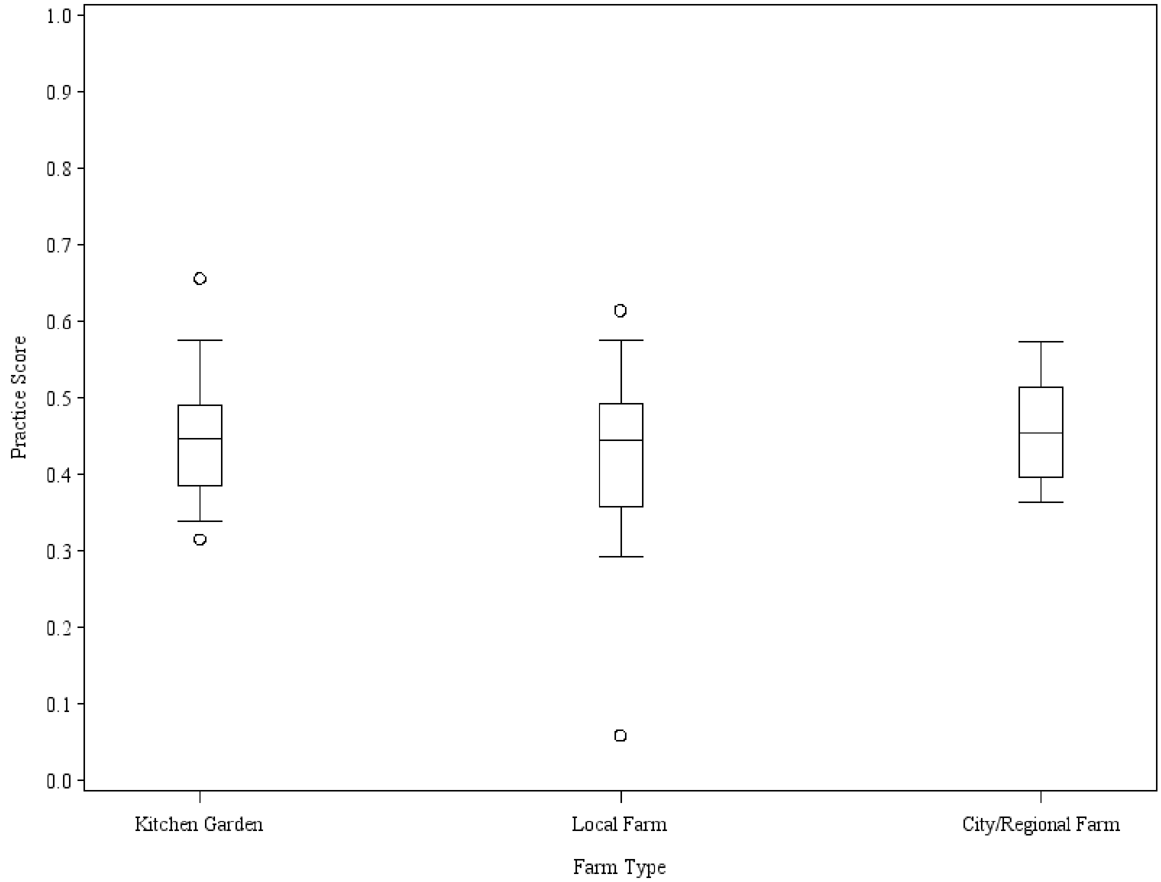
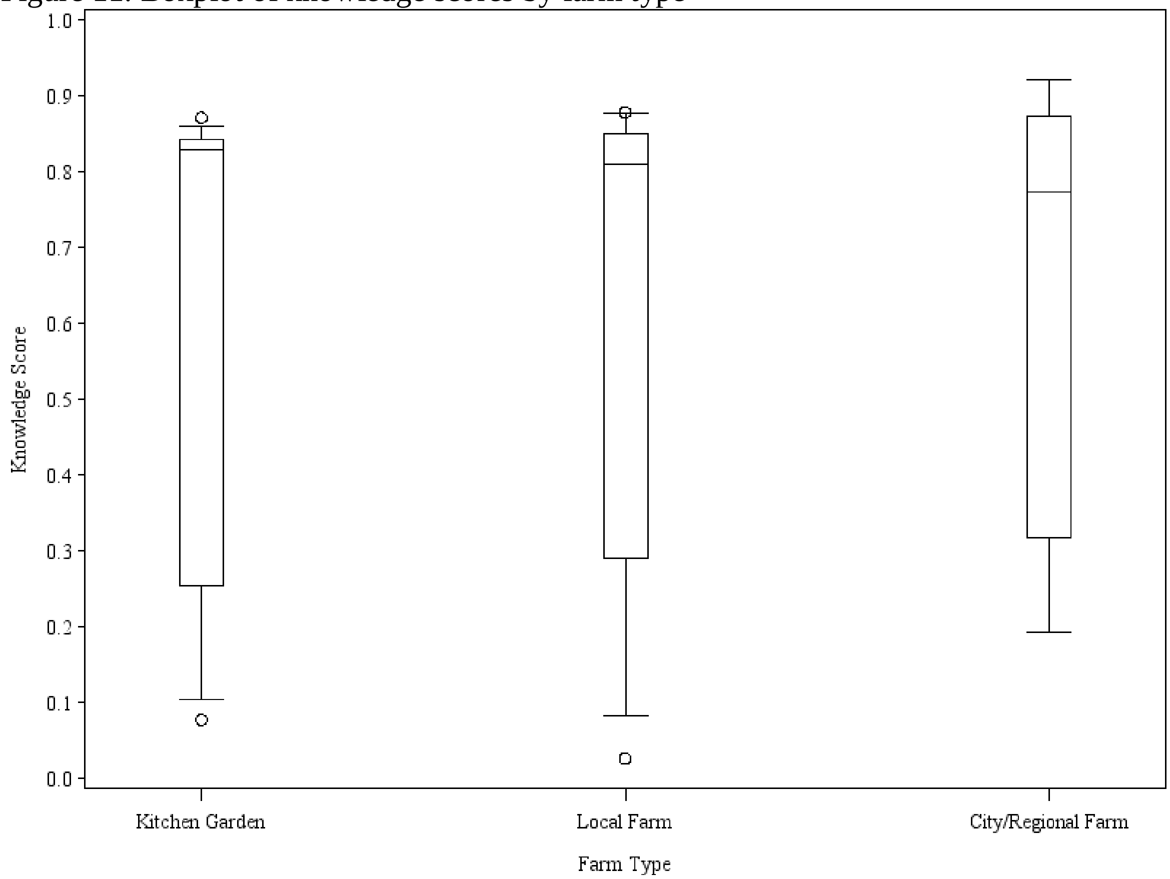


Figure 10. Boxplot of practice scores by farm type[a]



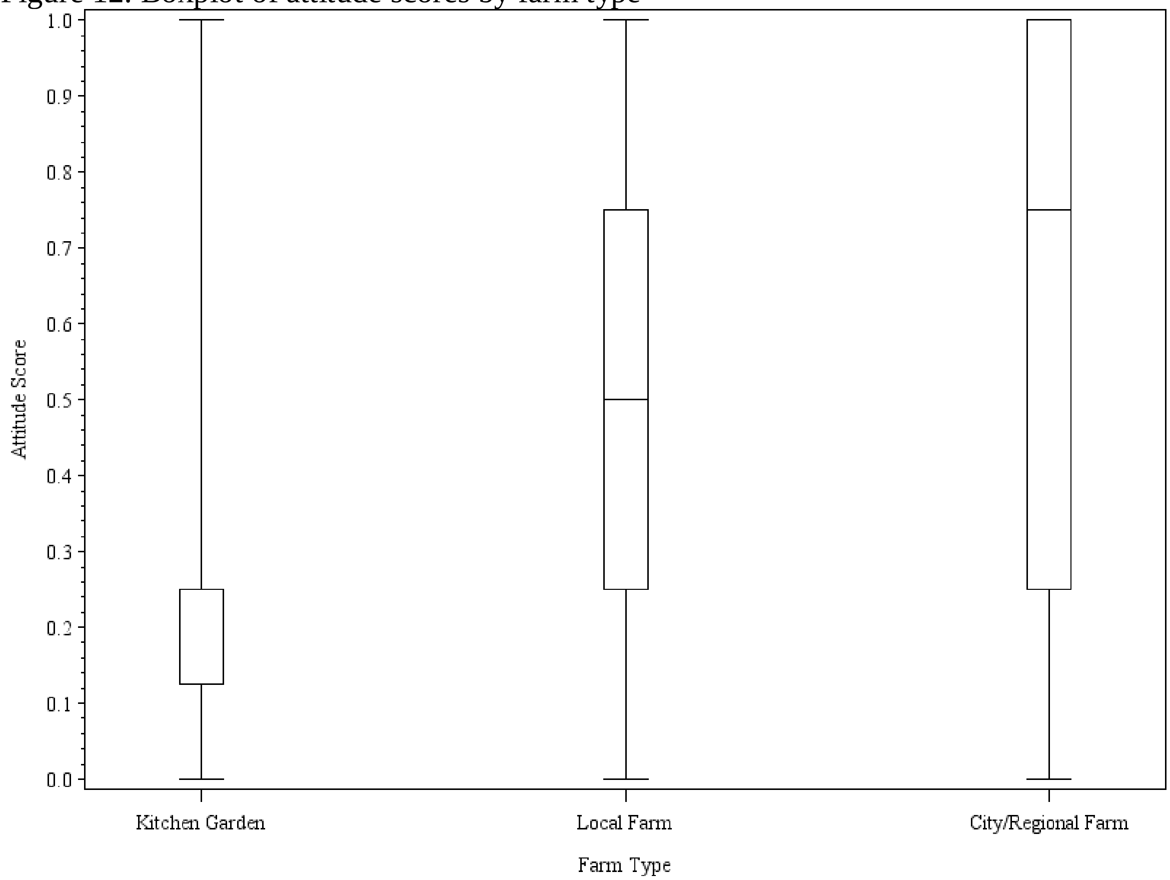
[a]Center line in box denotes median. Edges of box denote 25th and 75th percentiles. Whiskers denote 5th and 95th percentiles. Circles denote potential outliers outside the range of the 5th and 95th percentiles.

Figure 11. Boxplot of knowledge scores by farm type[a]



[a]Center line in box denotes median. Edges of box denote 25th and 75th percentiles. Whiskers denote 5th and 95th percentiles. Circles denote potential outliers outside the range of the 5th and 95th percentiles.

Figure 12. Boxplot of attitude scores by farm type[a]

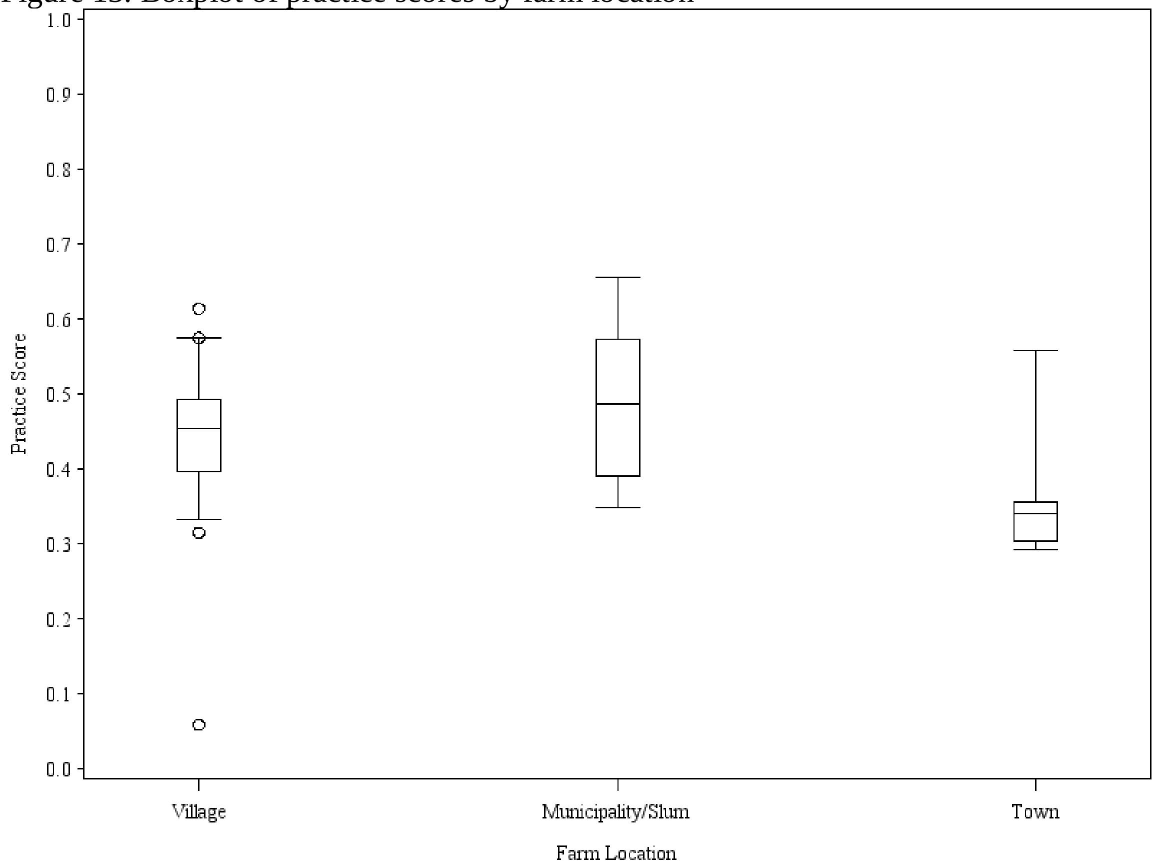


[a]Center line in box denotes median. Edges of box denote 25th and 75th percentiles. Whiskers denote 5th and 95th percentiles. Circles denote potential outliers outside the range of the 5th and 95th percentiles.

Table 9. Average practice, knowledge and attitude scores by district

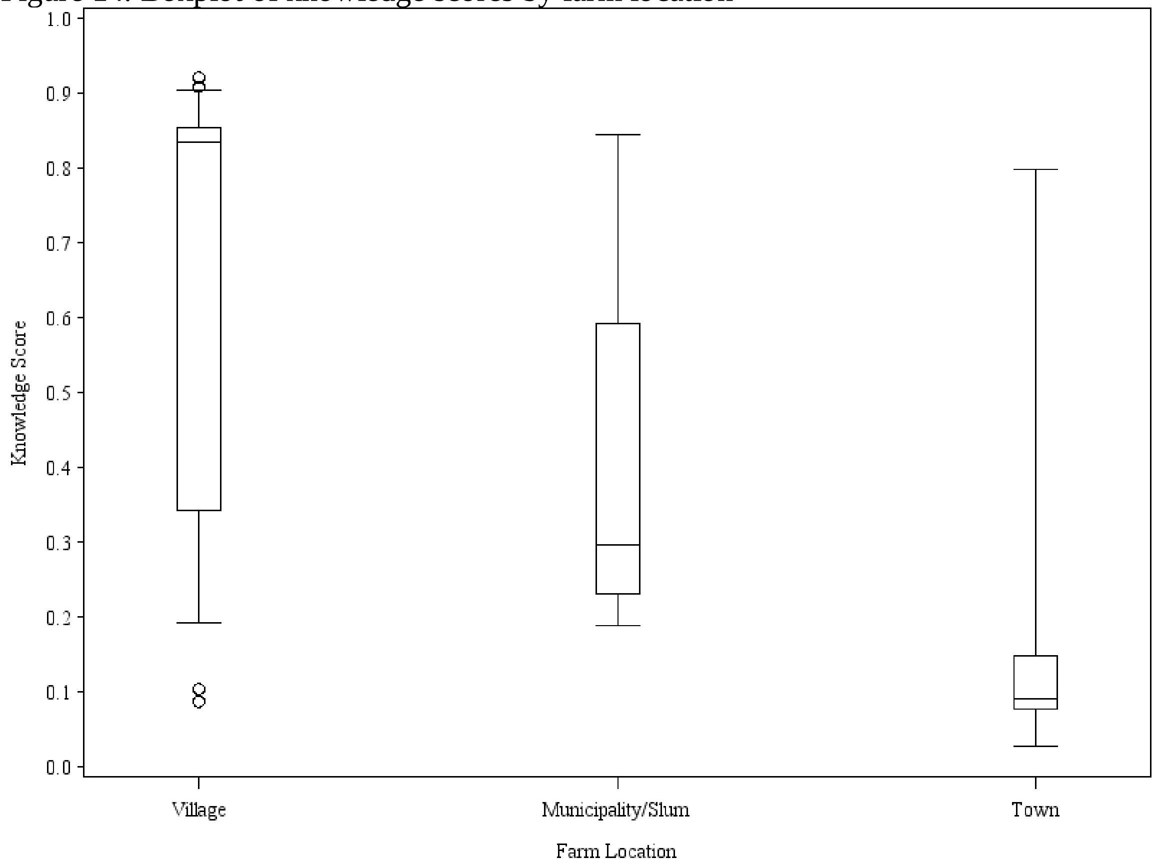
District	**Score**	**Mean**	**SD**
Dhaka	*Practice*	0.44	0.10
(n=21)	*Knowledge*	0.55	0.32
	Attitude	0.25	0.18
Gazipur	*Practice*	0.45	0.06
(n=21)	*Knowledge*	0.56	0.29
	Attitude	0.30	0.27
Narayanganj	*Practice*	0.41	0.12
(n=10)	*Knowledge*	0.35	0.36
	Attitude	0.27	0.20
Jessore	*Practice*	0.51	0.07
(n=5)	*Knowledge*	0.86	0.01
	Attitude	1.00	0.00
Narail	*Practice*	0.41	0.14
(n=9)	*Knowledge*	0.74	0.19
	Attitude	0.69	0.24
Satkhira	*Practice*	0.45	0.04
(n=6)	*Knowledge*	0.87	0.04
	Attitude	0.96	0.10

Figure 13. Boxplot of practice scores by farm location[a]



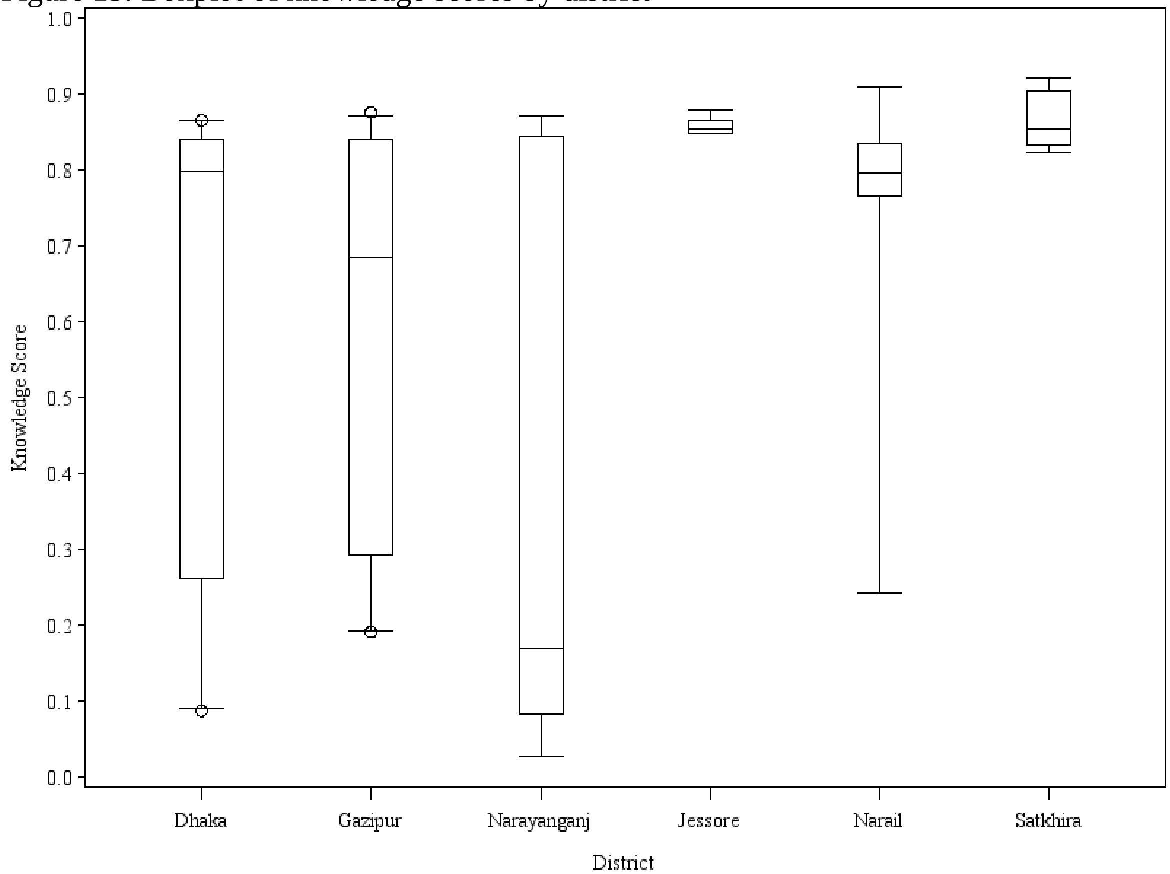
[a]Central districts: Dhaka, Gazipur, Narayanganj. Southwest districts: Jessore, Narail, Satkhira. Center line in box denotes median. Edges of box denote 25th and 75th percentiles. Whiskers denote 5th and 95th percentiles. Circles denote potential outliers outside the range of the 5th and 95th percentiles.

Figure 14. Boxplot of knowledge scores by farm location[a]



[a]Central districts: Dhaka, Gazipur, Narayanganj. Southwest districts: Jessore, Narail, Satkhira. Center line in box denotes median. Edges of box denote 25th and 75th percentiles. Whiskers denote 5th and 95th percentiles. Circles denote potential outliers outside the range of the 5th and 95th percentiles.

Figure 15. Boxplot of knowledge scores by district[a]



[a]Central districts: Dhaka, Gazipur, Narayanganj. Southwest districts: Jessore, Narail, Satkhira. Center line in box denotes median. Edges of box denote 25th and 75th percentiles. Whiskers denote 5th and 95th percentiles. Circles denote potential outliers outside the range of the 5th and 95th percentiles.

Figure 16. Practice and knowledge scores by upazila

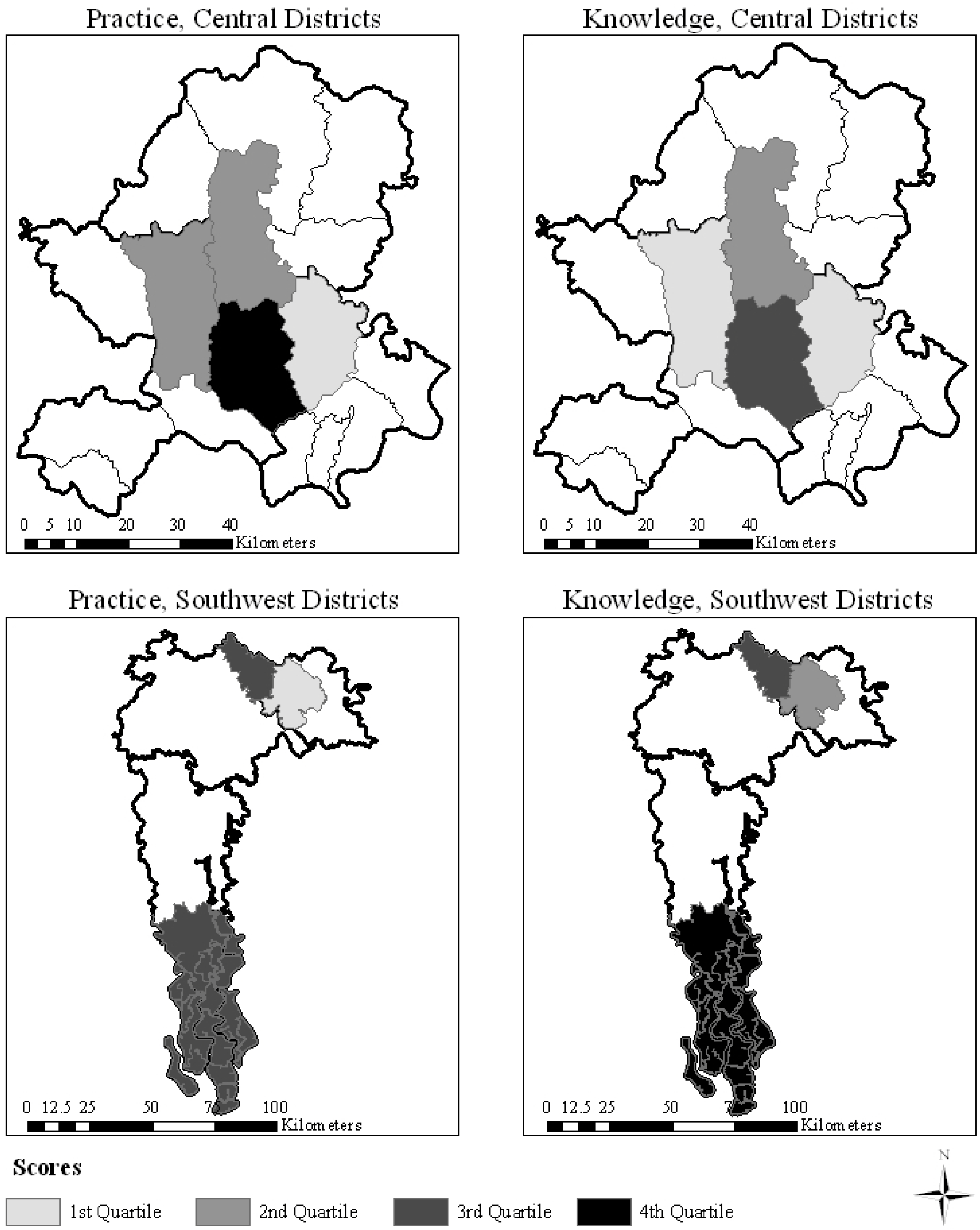
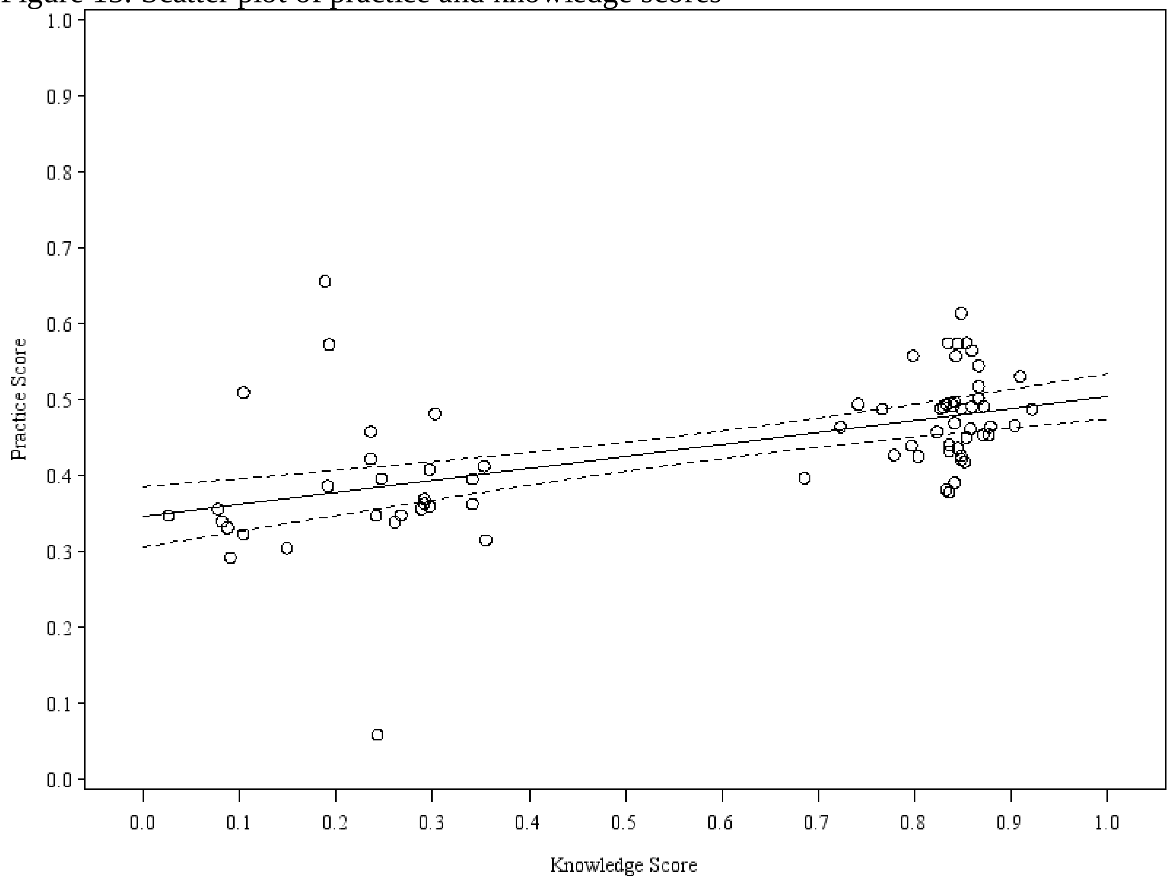


Figure 15. Scatter plot of practice and knowledge scores[a]



[a]Circles denote individual data points. Solid line denotes linear fit line. Dashed lines denote 95% confidence limits.

Table 10. Final multiple linear regression model

Variable	**β**	**SE**	**p**
Intercept	0.38813	0.03465	<0.0001
Knowledge	0.10183	0.05836	0.0863
Number of information sources	-0.07756	0.03261	0.0207
Farm grows beans	0.12656	0.04141	0.0034
Farm located in a municipality or slum	0.07636	0.04721	0.1112
Farm located in a town	-0.16035	0.04748	0.0013
Respondent is not the pesticide applicator	0.00532	0.01643	0.7471
Knowledge x Number of information sources	0.09699	0.04110	0.0217
Knowledge x Farm grows beans	-0.22263	0.06119	0.0006
Knowledge x Farm located in a municipality or slum	-0.04688	0.09104	0.6085
Knowledge x Farm located in a town	0.31245	0.09973	0.0027

Table 11. Effect of interaction terms on knowledge coefficient

Interaction with knowledge	$\boldsymbol{\beta_{Knowledge}}$
No Interaction	0.1018
Knowledge x Farmer reported one information source	0.1988
Knowledge x Farmer reported two information sources	0.2958
Knowledge x Farmer reported three information sources	0.3928
Knowledge x Farm grows beans	-0.1208
Knowledge x Farm located in a municipality or slum	0.0550
Knowledge x Farm located in a town	0.4143

VIII. APPENDIX 1: Government Recommendations for Pesticide Application

Table 1: Government Pesticide Recommendations *(7)*

Crop	**Common Diseases/ Pests**	**Common Name/ Active Ingredient (WHO Class *(8)*[a])**	**Trade Name**	**Dose (all liquids mixed with water unless otherwise noted)**	**Method of Application**	**Timing of Application**	**Maximum Number of Applications**
Rice, Amon & Boro	Rice Tungro Virus spread by Green Leaf Hopper	Isoprocarb (II) Phenthoate (II) - - Fenobucarb (II) Carbosulfan (II) Fenitrothion (II)	Mipcin Kap Ektara Sopsin Bassa Marshal Sumithion	2 mL/L 1.7 L/ha 60g/ha or 0.12 g/L 2 mL/L - 2 mL/L 5 mL/L	Spray	As and when required	
	Kholpora disease spread by *Rhizoctonia solani*	Phenthoate (II) Potash (fertilizer) Fudi (like urea)	Kap - -	1.7 L/ha - -	Spray	As and when required	
	Blast disease spread by *Pyricularia oryzae*	- - Thiophanate Methyl (U) Carbendazim (U) Dicopper dichloride trihydroxide (NA)	Edifen Homai Topsin M Knowin, Bavistin Cupravit	- - 2 g/L - - -		As and when required	
	Ufra disease spread by hookworm *Ditylenchus angustus*	Carbofuran (Ib)	Furadan	10 kg/ha	Granules	Early stage of the disease	
	Pata pora disease spread by bacteria *Xanthomonas oryzae* var. *oryzae*	Fertilizers esp. urea and potash	-	5 kg potash per ¼ acre		As and when required	

Crop	Common Diseases/ Pests	Common Name/ Active Ingredient (WHO Class *(8)*[a])	Trade Name	Dose (all liquids mixed with water unless otherwise noted)	Method of Application	Timing of Application	Maximum Number of Applications
	Rice short horned grasshopper	Carbosulfan (II) Quinalphos (II) Cypermethrin (II)	Marshal Karlux, Ekalux, Korolux Ripcord	2 mL/L 3 mL/L 1 mL /L	Spray	As and when required	
	Rice bug	Malathion (III) Chlorpyrifos (II) Dimethoate (II) Carbaryl (II)	Malathion Dusban/Lorsban Tatgor Sevin	2 mL/L 2 mL/L 2 mL/L 2 g/L	Spray	As and when required	
	Rice thrips	Fenitrothion (II) Dimethoate (II) Carbaryl (II)	Sumithion Tatgor Sevin	2 mL/L 2 mL/L 2 g/L	Spray	As and when required	
Tomato	Tomato fruit borer	Deltamethrin (II) Cypermethrin (II)	Decis Ripcord	1 mL/L 2 mL/L	Spray	As and when required	
	Tomato aphids	- -	Admayar Acetaph	0.5 mL/L 1 g/L	Spray	As and when required	
Bean	Bean aphids	Pirimicarb (II)	Pyrimor DP	1-2 g/L	Spray	As and when required	
	Bean fruit borer	Cypermethrin (II) Deltamethrin (II) Fenvalerate (II)	Ripcord Decis Sumicidin	1 mL/L 1 mL/L 0.5 mL/L	Spray	As and when required	
	Bean mite	Bromopropylate (U) - Sulfur (III)	Neoron Calthen Thiovit	2 mL/L 1.5 mL/L 2 g/L	Spray	As and when required	
	Bean stem fly	Carbofuran (Ib) Diazinon 60 EC (II)	Furadan Basudin	10 kg/ha 1.12 L/ha	Granules Spray	As and when required	
Eggplant (Brinjal)	Brinjal shoot and fruit borer	Cypermethrin (II) Fenitrothion (II) Diazinon (II)	Ripcord Sumithion Basudin	1 mL/L 1.5-2 mL/L 1 mL/L	Spray	As and when required	Once per year
Mostly attacked by insects	Jassid of Brinjal Leaf	Oxydemeton Methyl (Ib) - -	Metasystox Subicorn Esatac	1 mL/L 1 mL/L 1.5 g/L	Spray	As and when required	

Crop	Common Diseases/ Pests	Common Name/ Active Ingredient (WHO Class *(8)*[a])	Trade Name	Dose (all liquids mixed with water unless otherwise noted)	Method of Application	Timing of Application	Maximum Number of Applications
	Brinjal leaf roller	Fenitrothion (II) Fenitrothion (II)	Sumithion Folithion	1.5-2 mL/L 2 mL/L	Spray	As and when required	
	Brinjal mealy bug	Fenitrothion (II) Malathion (III)	Sumithion Malathion	1.5-2 mL/L 2 mL/L	Spray	As and when required	
	Red mite of brinjal	Sulfur (U) Sulfur (U)	Thiovit Kumulus	2.5 g/L 2.5 g/L	Spray	As and when required	
	Epilachna beetle	- Fenitrothion (II)	Denitol Sumithion	2 mL/L 1.5-2 mL/L	Spray	As and when required	
Okra (Lady Finger)	Okra shoot and fruit borer	Cypermethrin (II) Deltamethrin (II) Cypermethrin (II) - Fenitrothion (II) Diazinon (II)	Ripcord Decis Fastac Subicorn Sumithion Basudin	1 mL/L 0.5 mL/L 0.5 mL/L 2 mL/L 2 mL/L 2 mL/L	Spray	As and when required	
	Okra leaf roller	Fenitrothion (II) Fenitrothion (II) -	Sumithion Folithion Nixion	2 mL/L 2 mL/L 2 mL/L	Spray	As and when required	
	Okra Jassid/ White fly	Dimethoate (II) - - - Oxydemeton Methyl (Ib)	Perfecthion/Rogor /Tygor/Sangor Estaf Admayar Ektara Metasystox	2 mL/L 0.5 mL/L 0.5 mL/L 0.25 g/L 1.5 mL/L	Spray	As and when required	
Pumpkin	Red pumpkin beetle of Cucurbits	Cypermethrin (II) Isoprocarb (II) - - Carbaryl (II)	Ripcord Mipcin Sopsin Ektara Sevin	1 mL/L 2 mL/L 2 mL/L 1 mL/L 2 g/L	Spray	As and when required	
	Cucurbit Fruit Fly	Trichlorfon (II) -	Dipterex 50 EC Subicorn	1mL/L 2mL/L	Spray	As and when required	

Crop	Common Diseases/ Pests	Common Name/ Active Ingredient (WHO Class *(8)*[a])	Trade Name	Dose (all liquids mixed with water unless otherwise noted)	Method of Application	Timing of Application	Maximum Number of Applications
	Epilachna Beetle	- Fenitrothion (II) Carbaryl (II)	Denitol/Tribon Sumithion Sevin	1 mL/L 2 mL/L 2 g/L	Spray	As and when required	
	Red mite of cucurbits	- Sulfur (III) Sulfur (III)	Ranvit Thiovit Kumulus	2 g/L 2 g/L 2 g/L	Spray	As and when required	
	Bottle gourd aphids	Dimethoate (II) Diazinon (II)	Sangor Basudin	2 mL/L of each, mixed together	Spray	As and when required	
	Bottle gourd fruit fly	Trichlorfon (II) -	Dipterex 50 EC Subicorn	1 mL/L 2 mL/L	Spray	As and when required	
Leafy Vegetable	Leaf spot of Indian spinach (*Cercospora* spp.)	Carbendazim (U) - Thiophanate Methyl (U) Propiconazole (II)[b]	Bavistin Noween Topsin M Tilt 250 EC	1 g/L 1 g/L 2 g/L 0.5 mg/L	Spray	As and when required	
Potato	Potato Cut Worm	Diazinon (II) Diazinon (II) Carbofuran (Ib) Chlorpyrifos (II)	Basudin Diazinon Furadan Dursban/Lorsban	16.8 kg/ha 13.5 kg/ha 10 kg/ha 2.52-5 mL/L	Granules Granules Granules Spray	As and when required	
	Potato green aphids	Chlorpyrifos (II)	Dursban/Lorsban	2.52-5 mL/L	Spray	As and when required	
	Potato tuber worm	Carbaryl (II)	Sevin	Mix 1 ton sand, 1 kg carbaryl, and 1.5 ton potato to prevent rot in cold storage	-	As and when required	
Cauliflower & Cabbage	Leaf spot disease (*Cercospora* sp.)	- Mancozeb (U)	Rovurol Dithane M 45	2.5 g/L 2.5 g/L	Spray Spray	After an attack, 10-12 days apart	2 or 3 times
Bitter Gourd	Powdery mildew of bitter gourd (*Odium* sp.)	Propiconazole (II)[b] Sulfur 80% (III)	Tilt 250 EC -	0.5 mL/L 2 g/L	Spray Spray	-	

Crop	Common Diseases/ Pests	Common Name/ Active Ingredient (WHO Class *(8)*[a])	Trade Name	Dose (all liquids mixed with water unless otherwise noted)	Method of Application	Timing of Application	Maximum Number of Applications
	Downey mildew of bitter gourd (*Pseudoperenospora cubensis*)	- Mancozeb (U) Metalaxyl +Mancozeb (II + U)	Sikior Mancozeb Redumal Gourd	1-2 g/L 2 g/L 2 g/L	Spray Spray Spray	As soon as the leaves turn yellow	
	Leaf bunches of bitter gourd (*Mycoplasma*)	Tetracycline (NA) Leddermycin (NA)	- -	500 ppm 500 ppm	Spray Spray	-	
Sweet Gourd	Powdery mildew of bottle and sweet gourd (*Oidium* spp.)	Sulfur (U) Propiconazole (II) -	- Tilt 250 EC & Ranvit	15 kg 0.5 mL & 2 g /L	Powder Spray Spray	-	Affected leaves should be collected and disposed
	Downey mildew of bottle and sweet gourd (*Pseudoperenospora cubensis*)	- Mancozeb (U) Metalaxyl +Mancozeb (II + U)	Sikior Mancozeb Redumal Gourd	1-2 g/L 2 g/L 2 g/L	Spray Spray Spray	-	
	Leaf spot of cucurbits (*Cercospora* sp.)	Carbendazim (U) Mancozeb (U) Metalaxyl +Mancozeb (II + U)	Bavistin Mancozeb Redulmal Gourd	1 g/L 2.5 g/L 2 g/L	Spray Spray Spray	-	
Spinach	Leaf spot of Indian spinach (*Cercospora* sp.)	Carbendazim (U) Carbendazim (U)	Bavistin Knowin	1 g/L 1 g/L	Spray Spray	-	

[a]WHO Classification of Hazard: (Ia) Extremely Hazardous; (Ib) Highly Hazardous; (II) Moderately Hazardous; (III) Slightly Hazardous; (U) Unlikely to present acute hazard in normal use; (O) Believed to be obsolete or discontinued for use as pesticides *(8)*
[b]WHO Classification of Hazard not included in the 2009 guidelines, classification from 2004 guidelines *(68)*
NA = WHO Classification of Hazard not found in 2004 or 2009 guidelines
EC = Emulsifiable Concentrate

Table 2: Government Recommended Re-entry Periods *(7)*

Name of Pest	**Pesticide Brand Name (Common Name, WHO Class[a])**	**Re-entry Period[b]**
Brinjal Lady's finger Jassid/White Fly Bitter Gourd Fruit Fly Tomato Fruit Borer Yardlong Bean Hairy Caterpillar	Sumithion 50 EC (fenitrothion, II)	3-21 days
	Agrothion (malathion, III)	3-21 days
	Basuthrin 10 EC (cypermethrin, II)	3 days
	Sumialpha 5 EC (esfenvalerate, II)	7 days
	Diazinon 60 EC (diazinon, II)	7 days
	Malathion 57 EC (malathion, III)	7 days
	Siphonon 57 EC (NA)	7 days
	Zithiol 57 EC (malathion, III)	7 days
	Perfecthion 40 EC (dimethoate, II)	7-14 days
	Pyrifos 20 EC (chlorpyrifos, II)	7 days
Fungus of potato, tomato, and other vegetables	Dithane M 45 EC (mancozeb, U)	5-7 days
	Redumal M Z 72 (metalaxyl +mancozeb, II + U)	7 days

[a]WHO Classification of Hazard: (Ia) Extremely Hazardous; (Ib) Highly Hazardous; (II) Moderately Hazardous; (III) Slightly Hazardous; (U) Unlikely to present acute hazard in normal use; (O) Believed to be obsolete or discontinued for use as pesticides *(8)*
[b]Re-entry period is the time between pesticide application and the time the first human enters the treated field after application.

IX. APPENDIX 2: Scoring Assignment Procedure

Table 1: Practice Scoring

Question	Correct (1)	Incorrect (0)	Partially Correct (0.5)	Source
12a: Where do you buy your pesticides?	National dealer, local dealer, directly delivered	Informal dealer/smuggler, IDK	Other OR (Informal dealer/smuggler AND national dealer, local dealer OR directly delivered)	*(36, 37)*
13: Dose, area, and quantity of each pesticide applied in the past year.	(# application rates less than or equal to label/government recommendation)/(# crop-pesticide combinations)			*(7, 38)*
13: Pesticide name and crop to which the pesticide was applied in the past year.	(# crop-pesticide combinations same as label/government recommendation)/(# crop-pesticide combinations)			*(7, 38)*
14a,b: Do you mix different brands of pesticides before application?	If 14a =No OR (14a=Yes AND all mixtures recommended by label/government)	If 14a=yes AND any mixture is not recommended by label/government	-	*(7, 38, 39)*
16: When purchasing pesticides, are you usually supplied with information on the pesticides, such as pamphlets or instructions, describing safety issues or procedures?	Yes	No	-	*(36)*
16a: If yes, do you read and understand the instructions in the pamphlets? *and* 16b: If you cannot read, do you get help from others who can read?	16a=Yes OR (16a=No AND 16b=Yes)	16a=No AND 16b=No	-	*(40)*
17a: Do you follow the instructions given on the label?	Yes	No	-	*(40)*

Question	Correct (1)	Incorrect (0)	Partially Correct (0.5)	Source
17b: Do you mix pesticides: with bare hands; with hands and wearing gloves; with a stick, but bear hands; with a stick and wearing gloves?	Stick AND Gloves	Bare hands	(Stick OR Gloves) OR (Bare hands AND any other)	*(40)*
17c: How do you clean the sprayer's nozzle: by blowing air through it with your mouth; by using a thin wire?	Thin wire	Blowing air	Yes to both	*(37, 40)*
17d: Do you determine the wind direction first and then spray with the direction of the wind?	Yes	No	-	*(40)*
17e: Do you spray when it is windy?	No	Yes	-	*(39)*
17f: Do you eat or drink or smoke while spraying pesticides?	No	Yes	-	*(36, 37, 40)*
17g: Do you wash the pesticide bottle or pesticide sprayer: in the pond/canal/dighi/bill/haor/river; in a distant place far from the pond/canal/dighi/bill/haor/river?	Far from water source	In water source	Both	*(37, 39)*
17h: After spraying do you: wash your hands immediately; Wash your hands before eating, smoking or urinating?	Immediately	No to both	Before eating/drinking/smoking OR Yes to both	*(36, 37, 40)*
17h: After spraying do you: change your clothes immediately; change your clothes immediately after arriving at home?	Immediately	No to both	After arriving home OR Yes to both	*(36, 37, 40)*

Question	**Correct (1)**	**Incorrect (0)**	**Partially Correct (0.5)**	**Source**
17i: Do you display a sign board or red flag or an empty pesticide bottle in the sprayed area after an application in order to warn others?	Yes	No	-	*(37, 39)*
17j: Do you keep medicine or food items in pesticide bottles after washing them out?	No	Yes	-	*(36, 39)*
[17k: Do you break up the empty bottles of the pesticides? *and* 17l: Do you bury the empty bottles under the ground? *and* 17m: Do you display a sign indicating that pesticide bottles/packages are buried here?], 17n: Do you return or recycle empty pesticide bottles?, 17o: Do you burn empty pesticide bottles?	Yes to at least one	No to all	If only answered 17k-m, 1/3 for each yes	*(36, 37, 39)*
17p: Can children access empty pesticide packages?	No	Yes	-	*(36)*
18: When you mix/use the pesticide solution, does the liquid come into contact with any part of your body?	No	Yes	-	*(40)*
19: Where do you keep the children during and after spraying pesticides?	Isolated from field	Not isolated from field	-	*(37)*

Question	Correct (1)	Incorrect (0)	Partially Correct (0.5)	Source
20: For each crop you grow and pesticide you use how long after application does the first worker re-enter the field? (What is the re-entry period?)	(# crop-pesticide combinations that meet label/government recommendations)/(# crop-pesticide combinations); If crop-pesticide-specific recommendation not given in Appendix 1 Table 2, 7 days was used as a default recommendation.			*(7, 37, 38)*
21: Do you use the common dress or take some other step at the time of spraying pesticides? If yes, do you wear any of the following and is it in good condition: boots/shoes, hat/head cover, glasses, full-sleeve shirt/kurta, gloves, mask, full-length lungi/trousers?	[(use=Yes AND good condition=Yes) + 0.5(use=Yes AND good condition=No)]/8			*(36, 39, 40)*
22a[a]: Has sanitary services (bathroom/showers/etc)	Yes	No	-	*(37, 41)*
22b[a]: Well ventilated area	Yes	No	-	*(37, 41)*
22c[a]: Has cement floor (impermeable to liquids)	Yes	No	-	*(37, 41)*
22d[a]: Has complete walls	Yes	No	-	*(37, 41)*
22e[a]: Has a first –aid kit	Yes	No	-	*(36, 37, 39, 41)*
22f[a]: Has absorbent material in case of a pesticide spill (sawdust, dirt, sand)	Yes	No	-	*(39, 41)*
22g[a]: Pesticides are stored on shelves or pallets	Yes	No	-	*(37)*
22h[a]: The shelves are metal	Yes	No	-	*(37)*

Question	Correct (1)	Incorrect (0)	Partially Correct (0.5)	Source
22i[a]: The fertilizers, seeds, animal feed and veterinary products are stored next to the pesticide products	No	Yes	-	*(39)*
22j[a]: The products are separated according to their level of flammability and action (insecticides, herbicides, fungicides)	Yes	No	-	*(37)*
22k[a]: If the products are not separated the most toxic should be on the bottom and the liquids below the powders/dusts	Yes	No	-	*(37)*
22l[a]: Has a fire extinguisher	Yes	No	-	*(37, 41)*
22m[a]: Has a pesticide odor	No	Yes	-	*(37, 39)*
22n[a]: Has warning symbols or signs: no smoking, no lighting of matches etc.	Yes	No	-	*(37, 42)*
22o[a]: Has means of communication (phone, radio etc,)	Yes	No	-	*(39)*
22p[a]: Located in an urban area	No	Yes	-	*(37, 41)*
22q[a]: Food, drinks or medicine are stored next to pesticides	No	Yes	-	*(39)*
22r[a]: Can the children enter into or reach the place where pesticides are stored?	No	Yes	-	*(36)*

Question	Correct (1)	Incorrect (0)	Partially Correct (0.5)	Source
22s[a]: Is it under lock and key the place where the pesticides are preserved?	Yes	No	-	*(39, 41, 42)*

[a]Question 22 was answered by the interviewer based on their observations of the pesticide storage place identified by the farmer.

Table 2: Knowledge Scoring

Question	**Correct (1)**	**Incorrect (0)**	**Partially Correct (0.5)**	**Source**
23: Pesticides may enter the human body through the following routes: inhalation (by breathing in); skin; mouth; eyes; none of the above; I don't know. (Check all that apply)	0.25 each for inhalation, eyes, skin, mouth	None of the above	-	*(37, 39, 43)*
24: According to your knowledge, the toxicity symptoms of pesticides can be which of the following: headache; skin; rash/skin irritating/itching; watery eyes/sore eyes; abdominal pain/diarrhea; burning sensation in the eyes/face; muscle weakness/fatigue/body pain; nausea/vomiting; excessive salivation; cough/cold/chest pain/breathlessness; not sure; none of above? (Check all that apply)	$1/9^{th}$ each for each symptom group	None of the above, Not sure	-	*(37)*

Question	**Correct (1)**	**Incorrect (0)**	**Partially Correct (0.5)**	**Source**
25: Pesticide residue may exist in the following: air; soil; groundwater; fruits, seeds, and leaves of crops; none of the above; I don't know. (Check all that apply)	0.25 each for air, crops, soil, groundwater	None of the above, IDK	-	*(43)*
26: Do you think pesticides cause harm to the environment?	Yes	No, IDK	-	*(9, 25, 27, 37, 69, 70)*
29: you heard of any integrated Pest Management (IPM) techniques to reduce the need of using pesticides?	Yes	No	-	*(37, 39, 43)*
30: Please indicate the main source of the following instructions that you may have heard:	1 for each instruction heard/known	0 for each "Never heard this before"	-	See below
Read and follow the instructions on the package. Get help reading if needed.	See above	See above	-	*(40)*
Do not mix pesticides with bare hands.	See above	See above	-	*(40)*
While cleaning the sprayer's nozzle do not place your mouth on it or blow on it.	See above	See above	-	*(37, 40)*

Question	**Correct (1)**	**Incorrect (0)**	**Partially Correct (0.5)**	**Source**
Before spraying pesticides take all precautionary measures such as wearing protective clothing.	See above	See above	-	*(36, 39, 40)*
Do not spray pesticides against the wind.	See above	See above	-	*(40)*
Do not eat or drink or smoke while spraying pesticides.	See above	See above	-	*(36, 37, 40)*
Do not wash pesticide bottle or sprayer in the pond/canal/dighi/bill/haor/river.	See above	See above	-	*(37, 39)*
Wash and clean the sprayer and your clothes at a far distance from the pond/canal/dighi/bill/haor/river.	See above	See above	-	*(37, 39)*
After applying the pesticides on your field, display a sign, flag, or bottle so that everybody understands that you sprayed pesticides on that field.	See above	See above	-	*(37, 39)*
Do not let any children or domestic cattle or poultry birds enter the field within 7 days of pesticides application.	See above	See above	-	*(37, 39)*

Question	**Correct (1)**	**Incorrect (0)**	**Partially Correct (0.5)**	**Source**
Do not keep other things in the pesticide bottle or package.	See above	See above	-	*(36, 37, 39)*
Tear up the pesticides package or break the bottle into pieces and then bury them under the ground. Then flag the area as containing buried pesticides.	See above	See above	-	*(36, 37, 39)*
Keep the pesticides under lock and key so that they are out of the reach of children, domestic cattle, and poultry birds.	See above	See above	-	*(39, 41, 42)*
Do not keep food or medicine where you keep pesticides.	See above	See above	-	*(39)*
In the event of an accident, provide first aid to the patient, following the instructions on the label. Take the patient and the pesticide package to the doctor as soon as possible.	See above	See above	-	*(37, 39)*

Table 3: Attitude Scoring

Question[a]	Correct/Accepts Responsibility for safe application (1)	Incorrect/Doesn't accept responsibility (0)
31: If a pesticide is sold in the market, it means it is safe no matter how or by whom it is used.	No	Yes, I Don't Know
32: A pesticide is only effective if its effect can be seen immediately after spraying.	No	Yes, I Don't Know
33: A pesticide is more effective if it is sprayed according to personal experience and not necessarily according to the recommended amount.	No	Yes, I Don't Know
34: Every person who is using pesticides is responsible for their safe use.	Yes	No, I Don't Know

[a]This section asked respondents whether they agreed or disagreed with each statement.

X. APPENDIX 3: Supplemental tables and figures

Table 1. Summary statistics of proportion of WHO Class II and higher pesticides used

	N	N Missing	Mean	SD	Median	Min	Max
Proportion WHO Class II and higher	68	4	0.89	0.20	1.00	0.00	1.00

Table 2. Application practices

Application practice	N responding	N practicing (percent)
Buys pesticides from legal source	71	58 (81.69)
Does not mix several pesticides before application (excluding GOB recommended mixtures)	55	54 (98.18)
Is supplied with information on the pesticides	69	11 (15.94)
Reads and understands instructions	13	8 (61.54)
Gets help reading if unable to read instructions	3	3 (100.00)
Follows instructions given on the label	71	38 (53.52)
Mixes pesticides with a stick and wearing gloves	70	3 (4.29)
Cleans the sprayer's nozzle by using a thin wire	54	34 (62.96)
Determines the wind direction first and then sprays with the direction of the wind	69	51 (73.91)
Does not spray when it is windy	70	44 (62.86)
Does not eat, drink, or smoke while spraying pesticides	71	70 (98.59)
Washes the pesticide bottle or pesticide sprayer in a distant place far from the pond/canal/dighi/bill/haor/river	53	33 (62.26)
Washes hands immediately after spraying	71	56 (78.87)
Changes clothes immediately after spraying	70	39 (55.71)
Displays a sign board, red flag or empty pesticide bottle in the sprayed area after an application in order to warn others	71	23 (32.39)
Does not keep medicine or food items in pesticide bottles after washing them out	71	65 (91.55)
Breaks up empty pesticide bottles	71	8 (11.27)
Buries empty pesticide bottles	71	31 (43.66)
Displays a sign indicating that pesticide bottles/packages are buried here	70	8 (11.43)

Returns or recycles empty pesticide bottles	71	2 (2.82)
Burns empty pesticide bottles?	71	1 (1.41)
Prevents pesticide liquid from coming into contact with any part of body	70	53 (75.71)

Table 3. Number of recommended personal protective equipment items used

Number of recommended PPE items used	**N**
0	1 (1.43)
1	12 (17.14)
2	42 (60.00)
3	6 (8.57)
4	5 (7.14)
5	4 (5.71)
Total	70 (100.00)

Table 4. Number of farmers using each item of personal protective equipment

PPE item	**Number of farmers (percent[a])**
Boots/Shoes	8 (11.43)
Hat	10 (14.29)
Glasses/Goggles	5 (7.14)
Long Sleeves	60 (85.71)
Gloves	3 (4.29)
Mask	5 (7.14)
Long Pants/Lungi	63 (90.00)
Other[b]	19 (28.36)
Cloth Mask	17 (24.29)
Sandals	1 (1.43)

[a]Percent of 70 farmers who responded to this question.
[b]Not included in number of PPE items used b/c not considered to offer adequate protection. See table below.

Table 5. Reasons for not using personal protective equipment

PPE Item	**Reason for Non-use**	**Number of Responses**
Boots/Shoes	Inappropriate	60
Hat	Inappropriate	59
Glasses/Goggles	Inappropriate	65
Long Sleeves	Inappropriate	13
Gloves	Inappropriate	64
	Unavailable	2
Mask	Inappropriate	54
	Unavailable	3
Long Pants/Lungi	Inappropriate	11

Figure 1. Distribution of overapplication

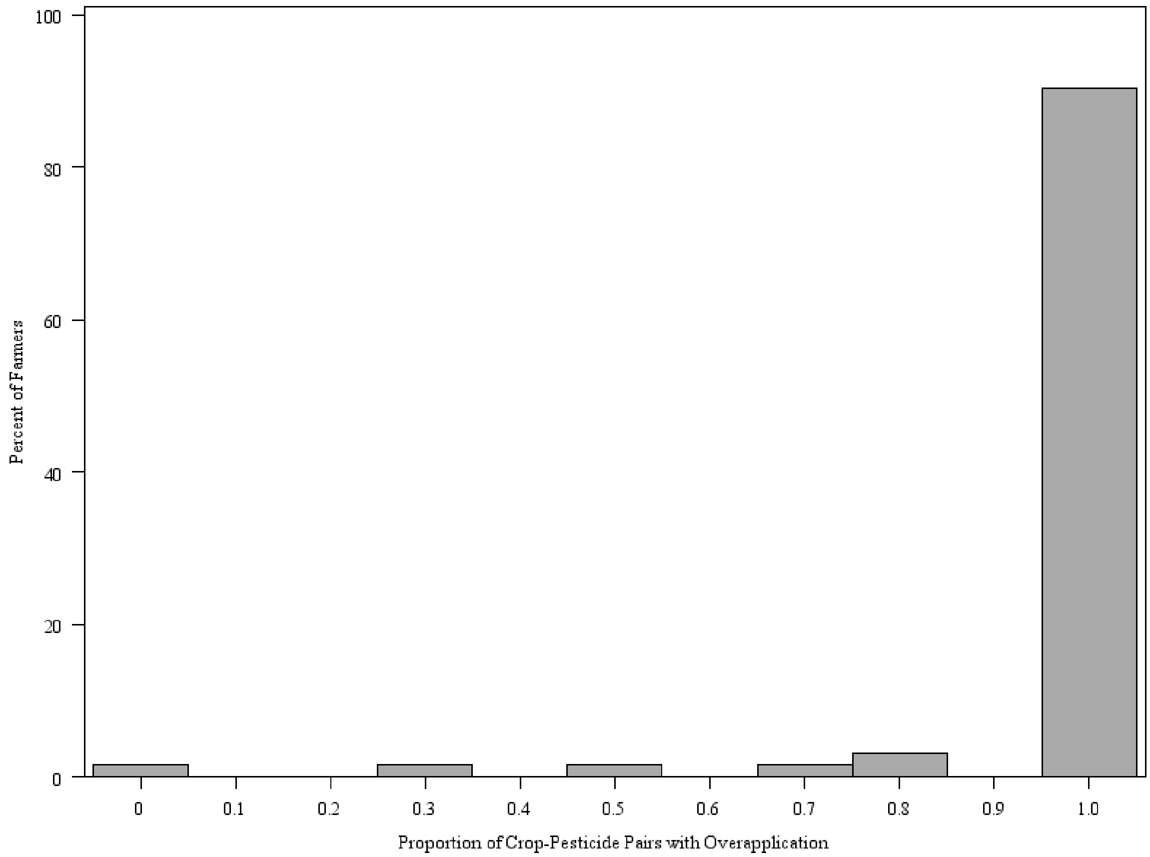


Figure 2. Distribution of crop-pesticide pairs with crop specified on the label

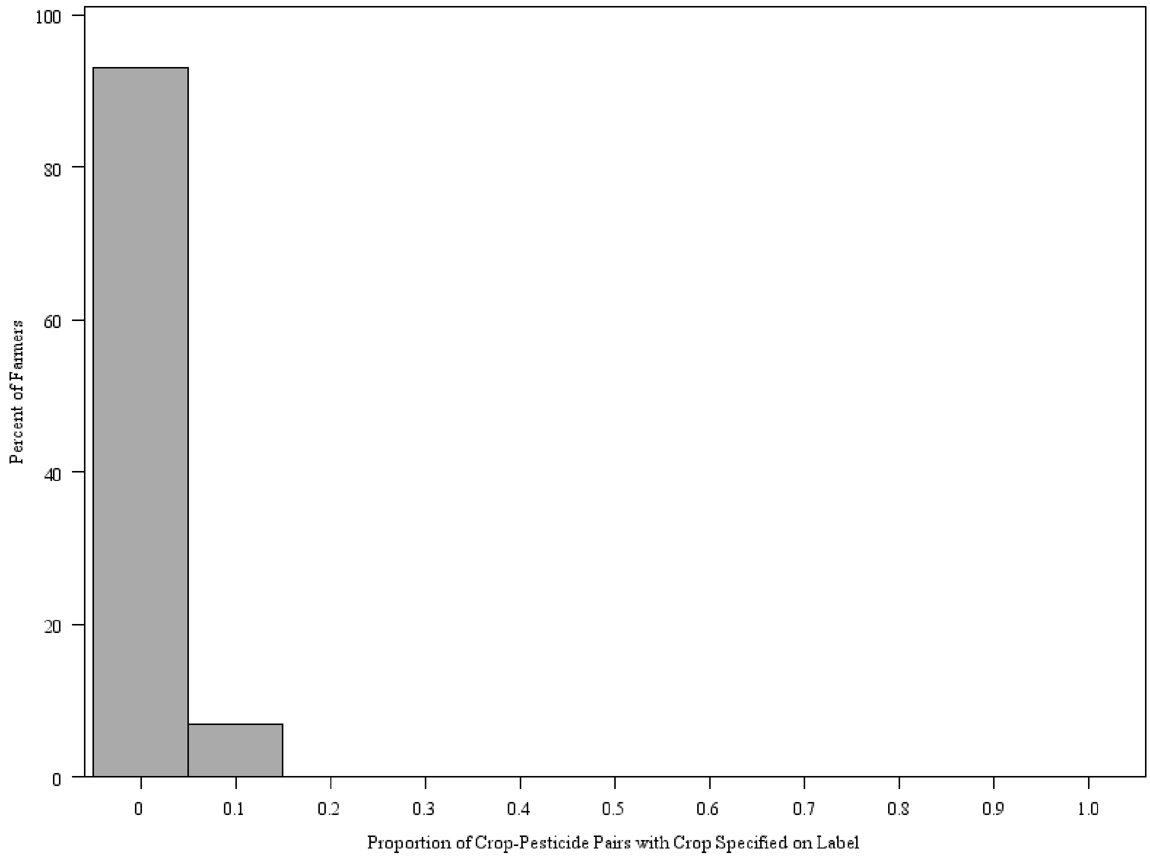


Figure 3. Distribution of crop-pesticide pairs with sufficient re-entry periods

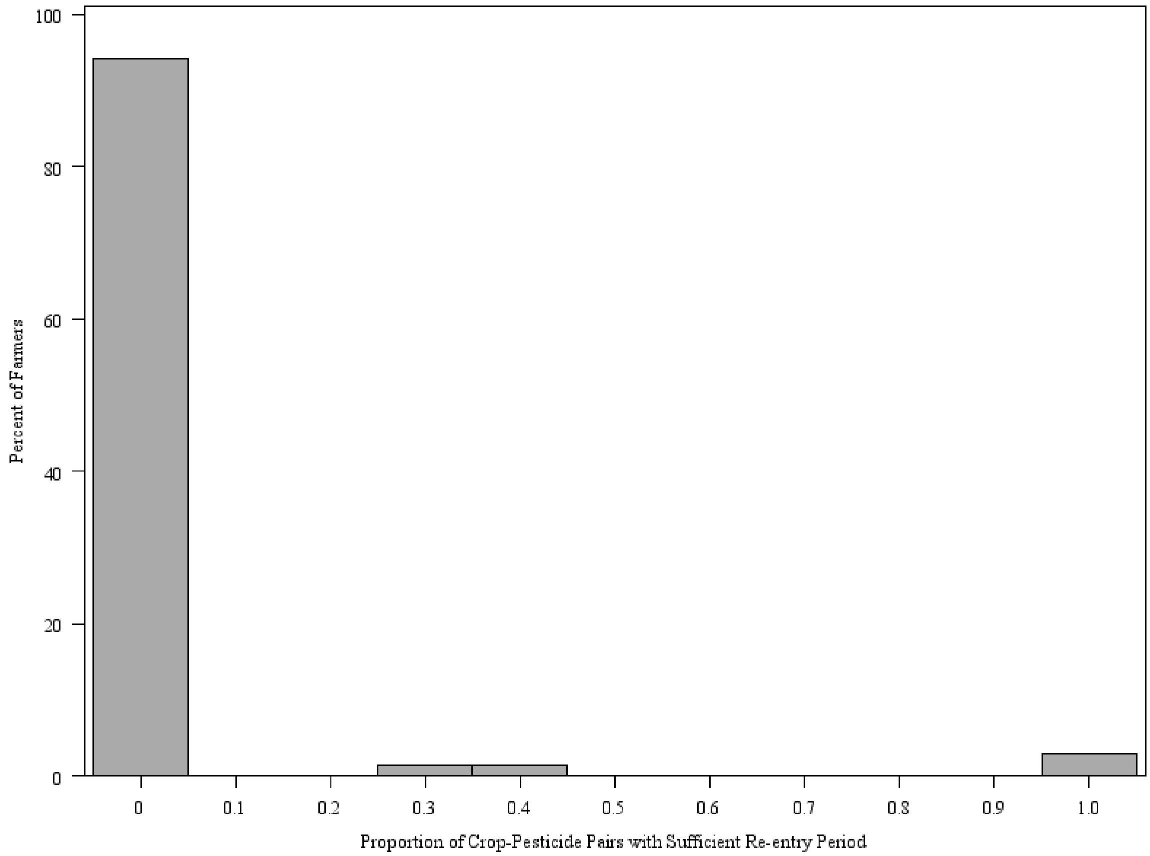


Table 6. Reported knowledge

Knowledge	**N Responding**	**N with this knowledge (percent)**
Pesticides may enter the human body through the following routes:	72	
Inhalation		56 (77.78)
Skin		39 (54.17)
Mouth		14 (19.44)
Eyes		28 (38.89)
None of the above		2 (2.78)
I don’t know		0 (0.00)
According to your knowledge, the toxicity symptoms of pesticides can be which of the following:	72	
Headache		38 (52.78)
Skin rash/skin irritating/itching		46 (63.89)
Watery eyes/sore eyes		30 (41.67)
Abdominal pain/diarrhea		16 (22.22)
Burning sensation in the eyes/face		26 (36.11)
Muscle weakness/fatigue/body pain		9 (12.50)
Nausea/vomiting		19 (26.39)
Excessive salivation		17 (23.61)
Cough/cold/chest pain/breathlessness		12 (16.67)
None of above		1 (1.39)
Not sure		0 (0.00)
Pesticide residue may exist in the following:	72	
Air		34 (47.22)
Soil		10 (13.89)
Groundwater		4 (5.56)
Fruits, seeds, and leaves of crops		19 (26.39)
None of the above		0 (0.00)
I don’t know		0 (0.00)

Knowledge	N Responding	N with this knowledge (percent)
Do you think pesticides cause harm to the environment?	54	52 (96.30)
Have you heard of any integrated Pest Management (IPM) techniques to reduce the need of using pesticides?	72	4 (5.56)
Please indicate the main source of the following instructions that you may have heard:		
Read and follow the instructions on the package. Get help reading if needed.	69	47 (68.12)
Do not mix pesticides with bare hands.	71	58 (81.69)
While cleaning the sprayer’s nozzle do not place your mouth on it or blow on it.	71	47 (66.20)
Before spraying pesticides take all precautionary measures such as wearing protective clothing.	70	46 (65.71)
Do not spray pesticides against the wind.	69	58 (84.06)
Do not eat or drink or smoke while spraying pesticides.	70	48 (68.57)
Do not wash pesticide bottle or sprayer in the pond/canal/dighi/bill/haor/river.	70	45 (64.29)
Wash and clean the sprayer and your clothes at a far distance from the pond/canal/dighi/bill/haor/river.	71	44 (61.97)
After applying the pesticides on your field, display a sign, flag, or bottle so that everybody understands that you sprayed pesticides on that field.	71	52 (73.24)
Do not let any children or domestic cattle or poultry birds enter the field within 7 days of pesticides application.	71	41 (57.75)
Do not keep other things in the pesticide bottle or package.	70	45 (64.29)
Tear up the pesticides package or break the bottle into pieces and then bury them under the ground. Then flag the area as containing buried pesticides.	71	43 (60.56)
Keep the pesticides under lock and key so that they are out of the reach of children, domestic cattle, and poultry birds.	71	24 (66.20)
Do not keep food or medicine where you keep pesticides.	71	44(61.97)

Knowledge	**N Responding**	**N with this knowledge (percent)**
In the event of an accident, provide first aid to the patient, following the instructions on the label. Take the patient and the pesticide package to the doctor as soon as possible.	71	50 (70.42)

Table 7. Specific practices known among farmers who reported knowledge of IPM (n=4)

IPM Practice	**Number reporting knowledge of this practice**
Rotation of crops	2
Biological control	1
Manual clearing	1
Smoke	1
Other (sex pheromone)	1

Figure 4. Distribution of the number of routes of pesticide exposure identified

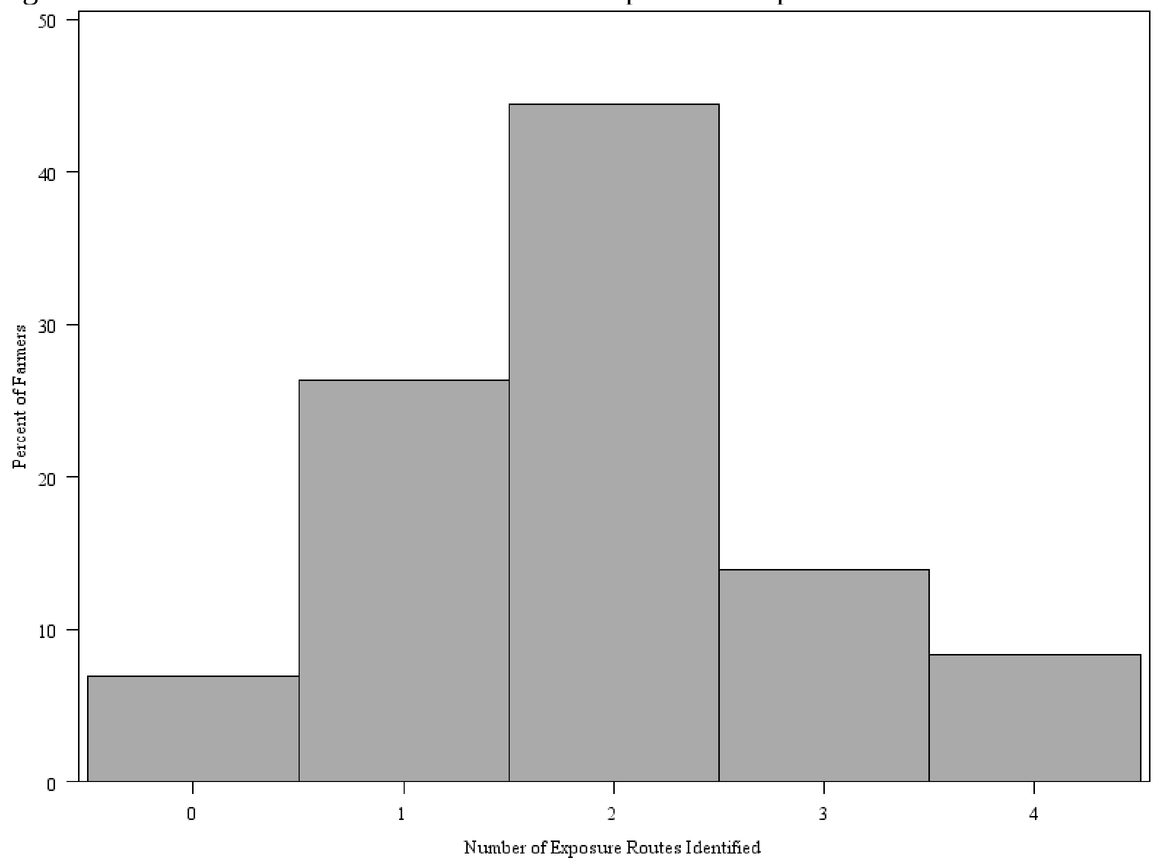


Figure 5. Distribution of the number of potential pathways of pesticide residue identified

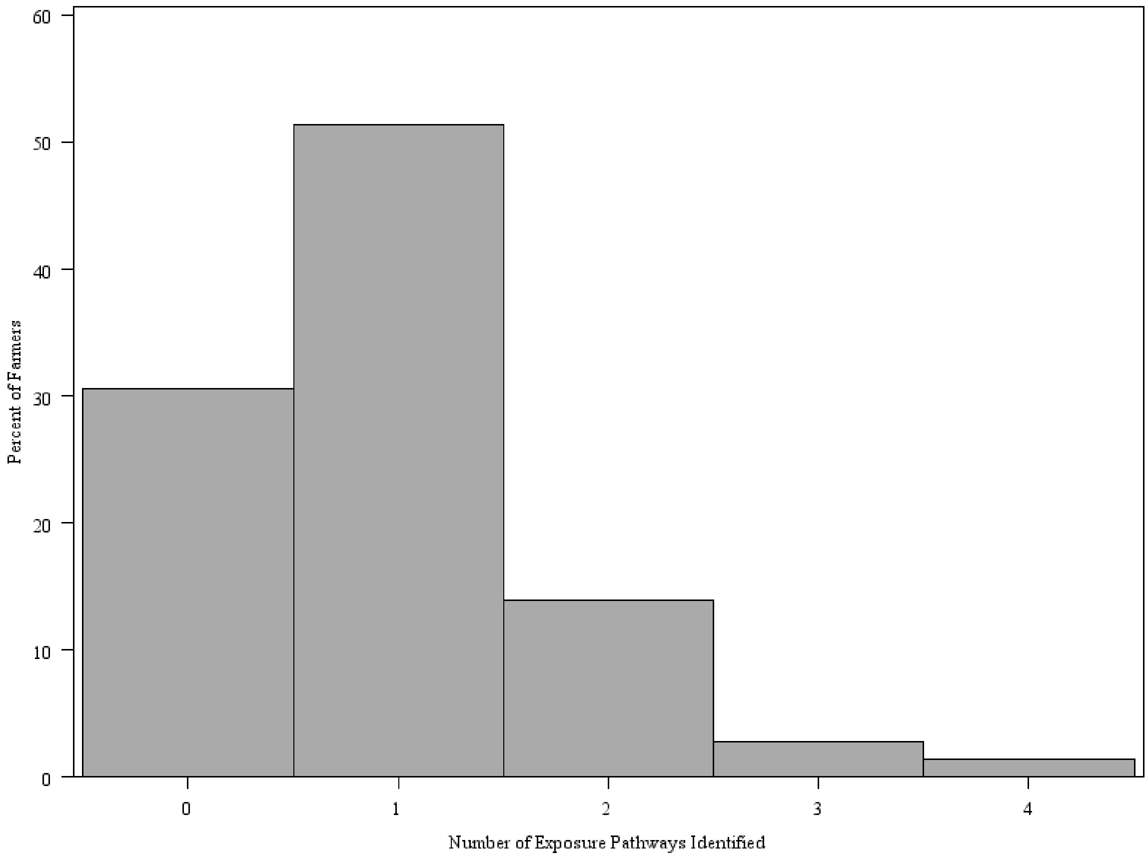


Figure 6. Distribution of the number of symptoms of acute pesticide poisoning identified

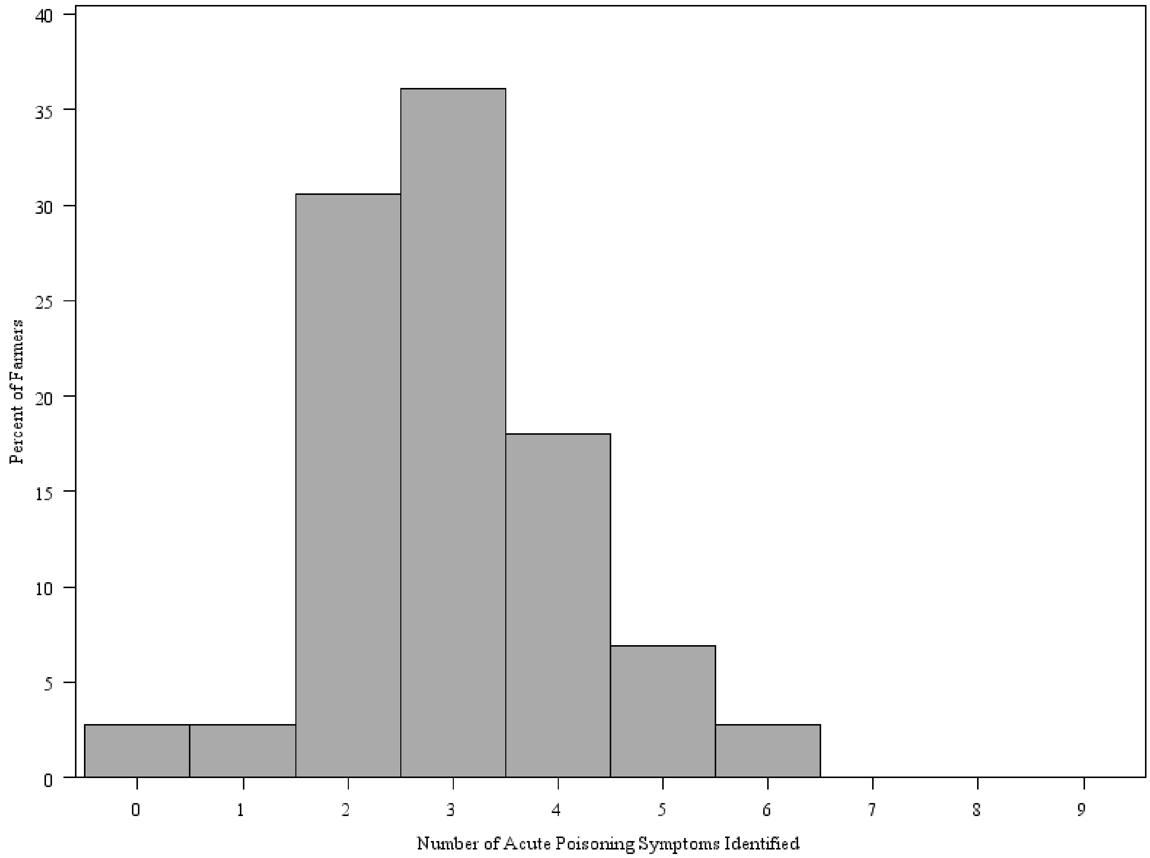


Figure 7. Distribution of the number of information sources reported

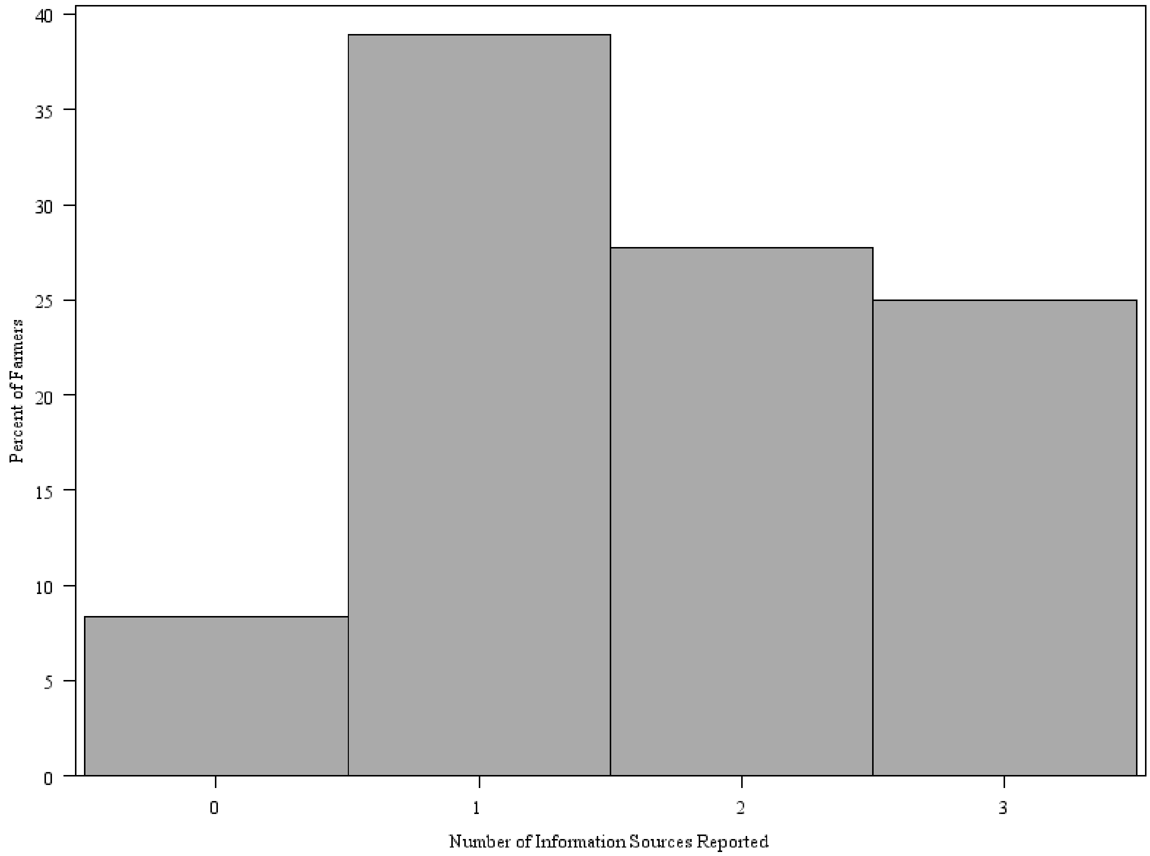


Figure 8. Information sources by upazila, central districts

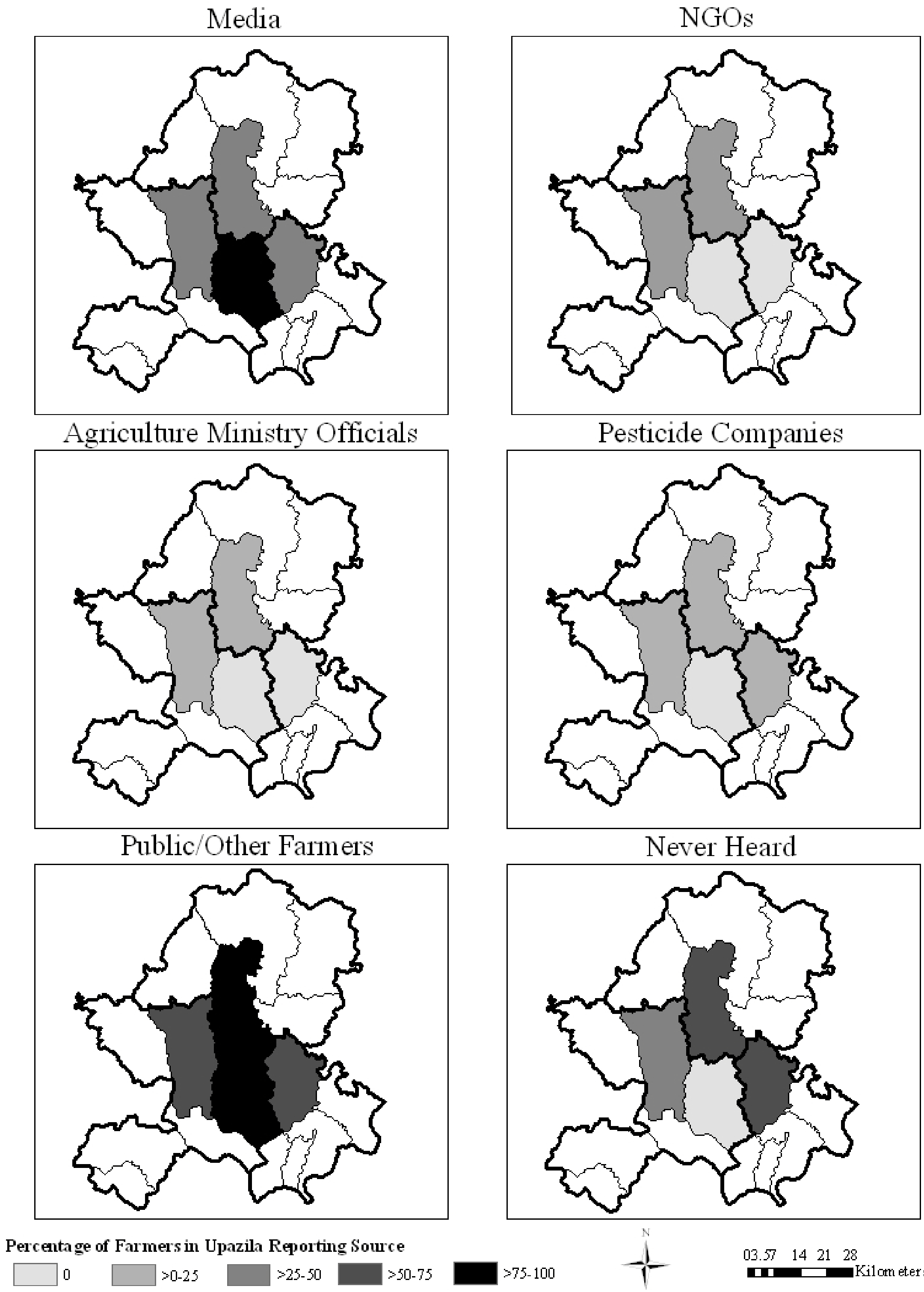


Figure 9. Information sources by upazila, southwest districts

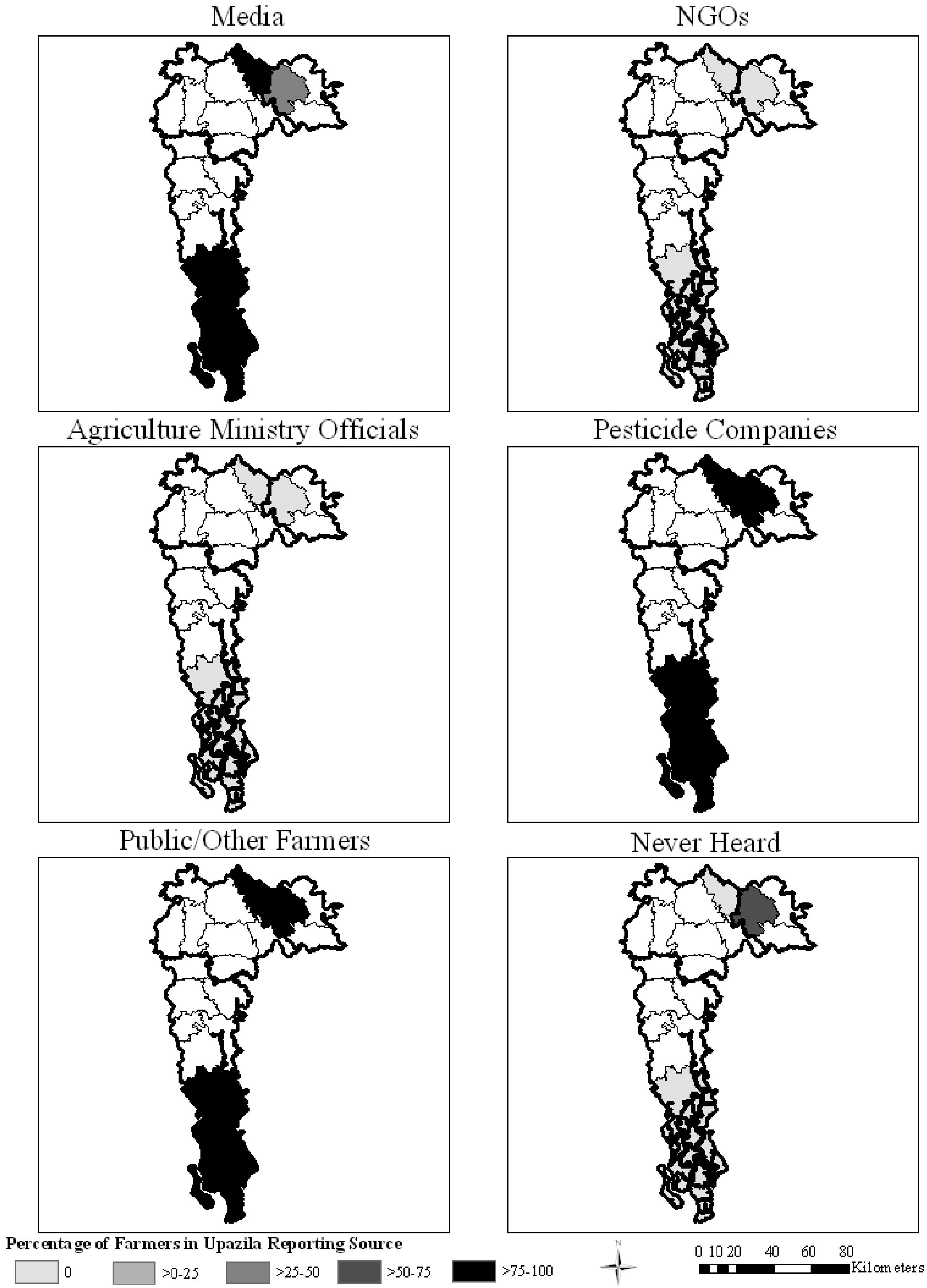


Table 8. Summary statistics for practice, knowledge, and attitude scores

Score	**N**	**Mean**	**SD**	**Median**	**Min**	**Max**
Practice	72	0.44	0.09	0.45	0.06	0.66
Knowledge	72	0.60	0.31	0.81	0.03	0.92
Attitude	72	0.43	0.34	0.25	0.00	1.00

Figure 10. Distribution of number of missing practice score components

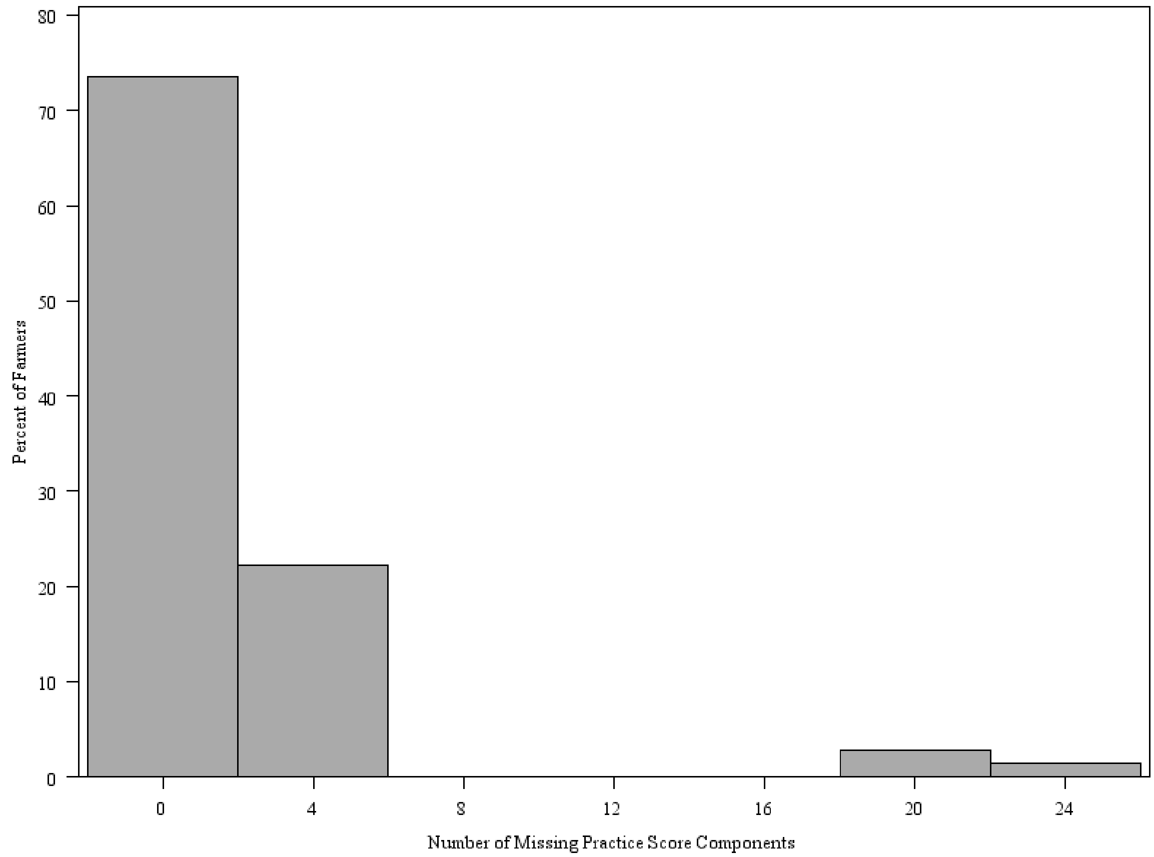


Figure 11. Distribution of number of missing knowledge score components

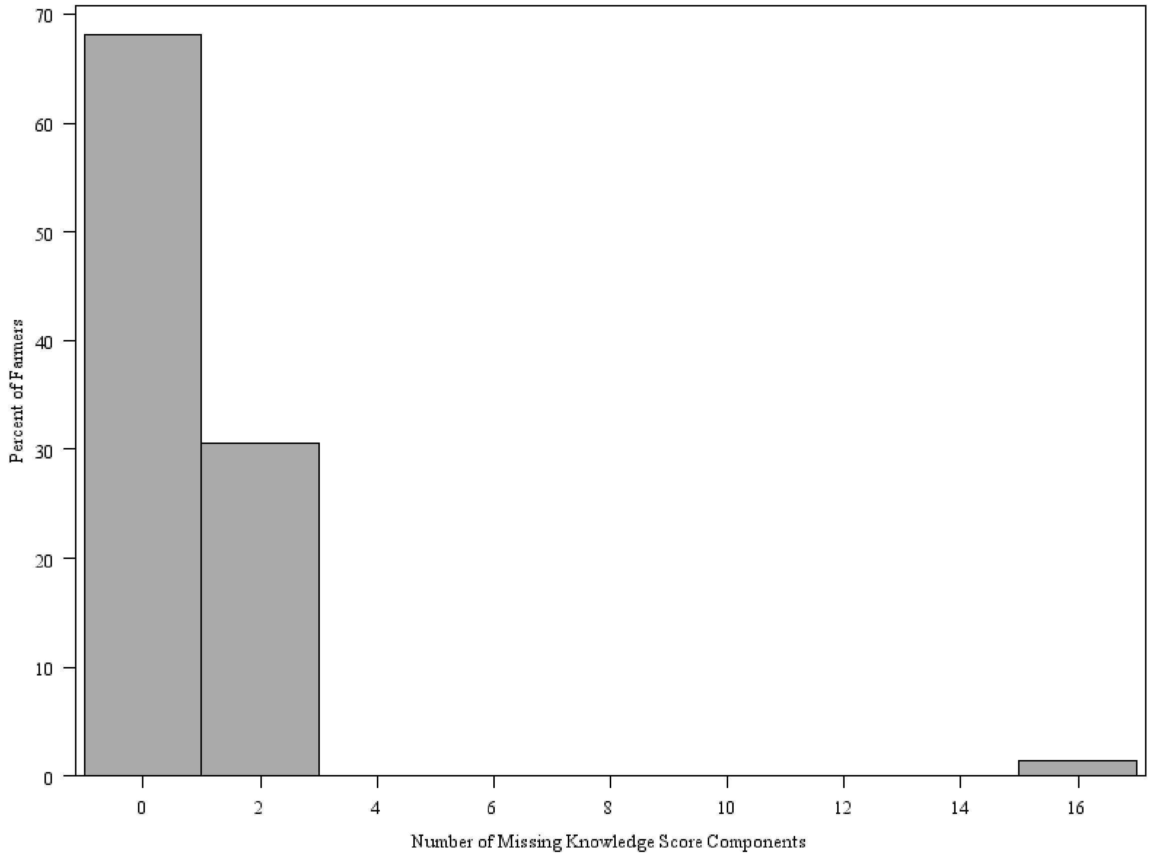


Figure 12. Distribution of components missing from attitude score

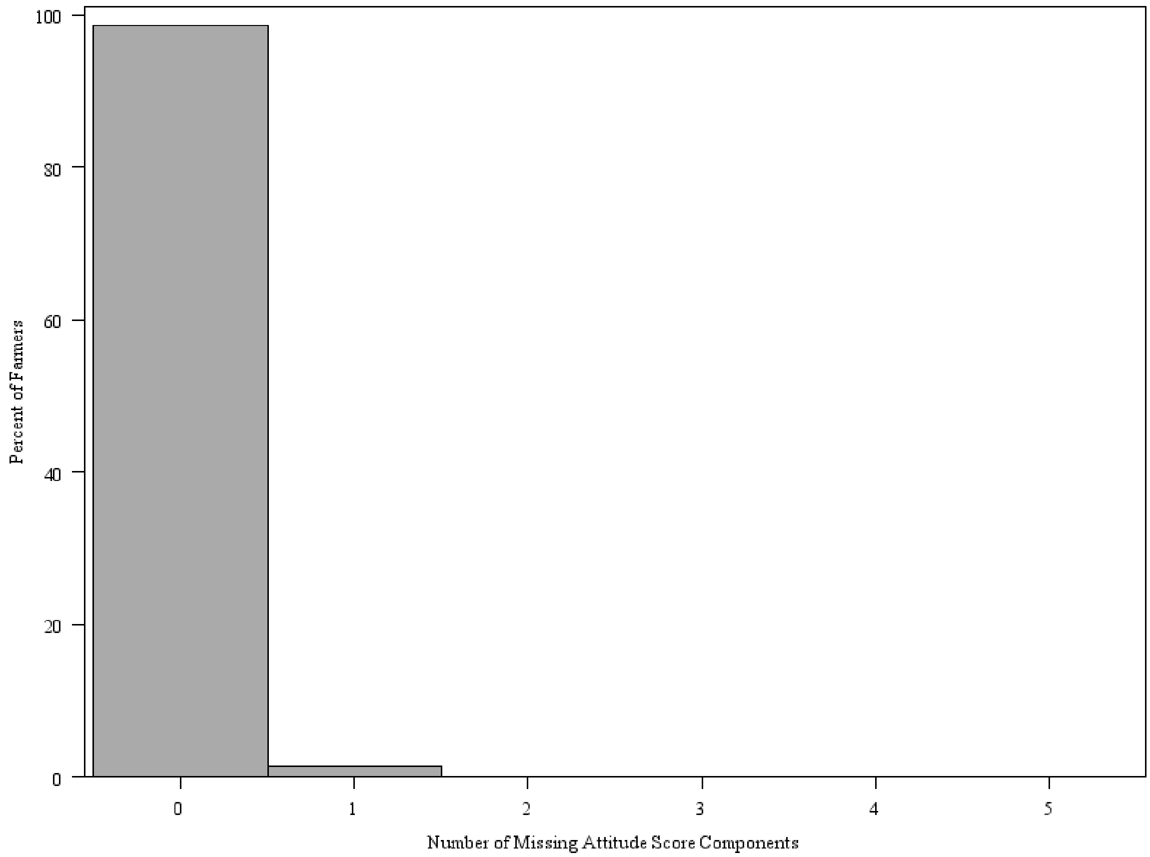


Table 9. Summary statistics for number of missing practice, knowledge and attitude score components

Missing Variable	**Number of possible components**	**N with no missing components**	**Mean**	**SD**	**Median**	**Min**	**Max**
Pmiss	42	25	1.85	4.36	1.00	0.00	25.00
Kmiss	20	49	0.57	1.93	0.00	0.00	16.00
Amiss	4	71	0.01	0.12	0.00	0.00	1.00

Table 10. Average practice, knowledge and attitude scores by farm type

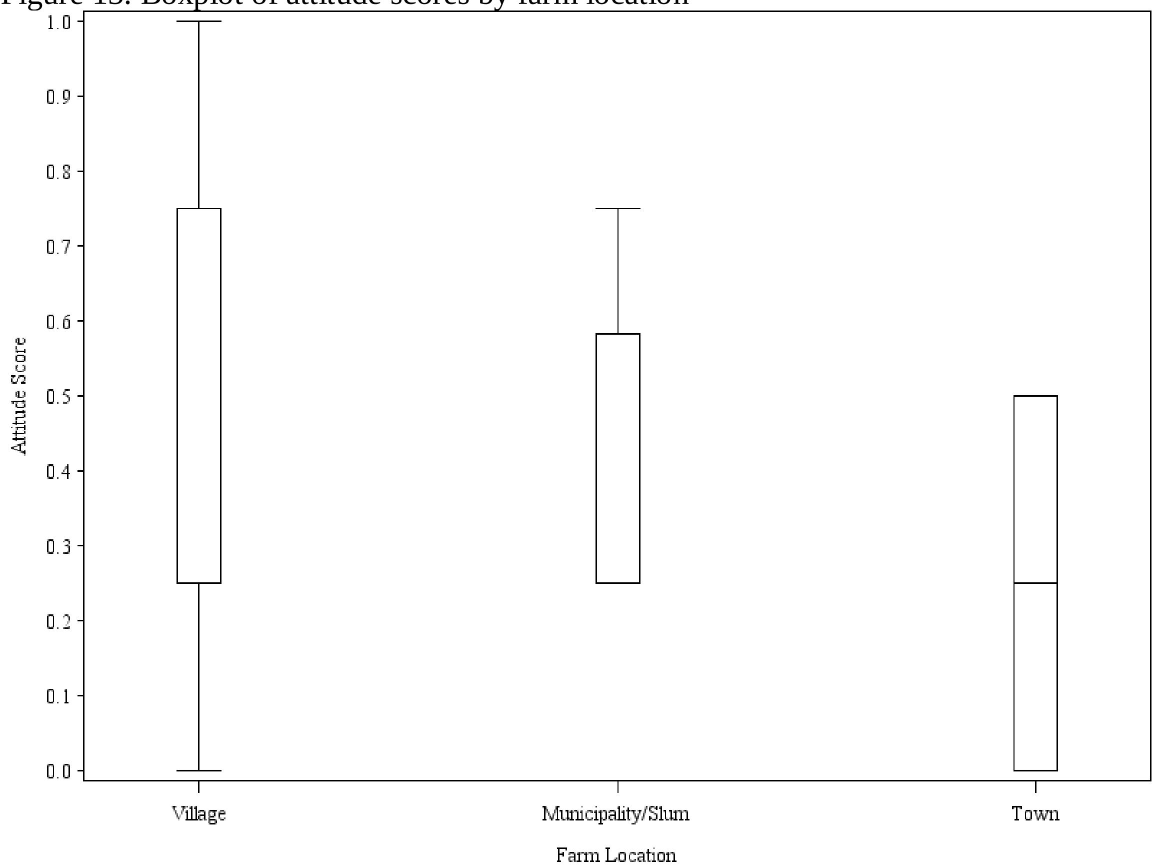
Farm Type	Score	Mean	SD
Kitchen Garden	*Practice*	0.45	0.08
(n=24)	*Knowledge*	0.57	0.31
	Attitude	0.27	0.27
Small/Medium	*Practice*	0.43	0.10
(n=36)	*Knowledge*	0.60	0.32
	Attitude	0.49	0.33
Large	*Practice*	0.46	0.07
(n=12)	*Knowledge*	0.64	0.29
	Attitude	0.60	0.39

Table 11. Tests for differences in means according to crops grown.

	p-value		
Crop	**Practice**	**Knowledge**	**Attitude**
Boro rice	0.4047[b]	0.6160[c]	0.0486[c]*
Aman rice[a]	0.4893[e]	0.0322[e]*	<0.0001[e]*
Tomato	0.0116[b]*	0.3191[c]	0.5494[b]
Eggplant	0.2352[b]	0.2855[c]	0.2661[b]
Okra	0.6199[b]	0.5777[c]	0.9737[b]
Pumpkin[a]	0.1709[b]	0.0314[c]*	0.7007[b]
Bitter Gourd[a]	0.6570[b]	0.9809[c]	0.2895[b]
Sweet Gourd	0.4410[b]	0.2994[c]	0.7644[b]
Bean	0.0844[b]	0.0052[c]*	0.8537[b]
Spinach	0.7163[b]	0.6433[c]	0.7794[c]
Pui shaak[a]	0.0135[d]*	0.1904[e]	0.2601[d]
Cauliflower	0.5021[b]	0.2179[c]	0.4577[b]
Cabbage[f]	-	-	-

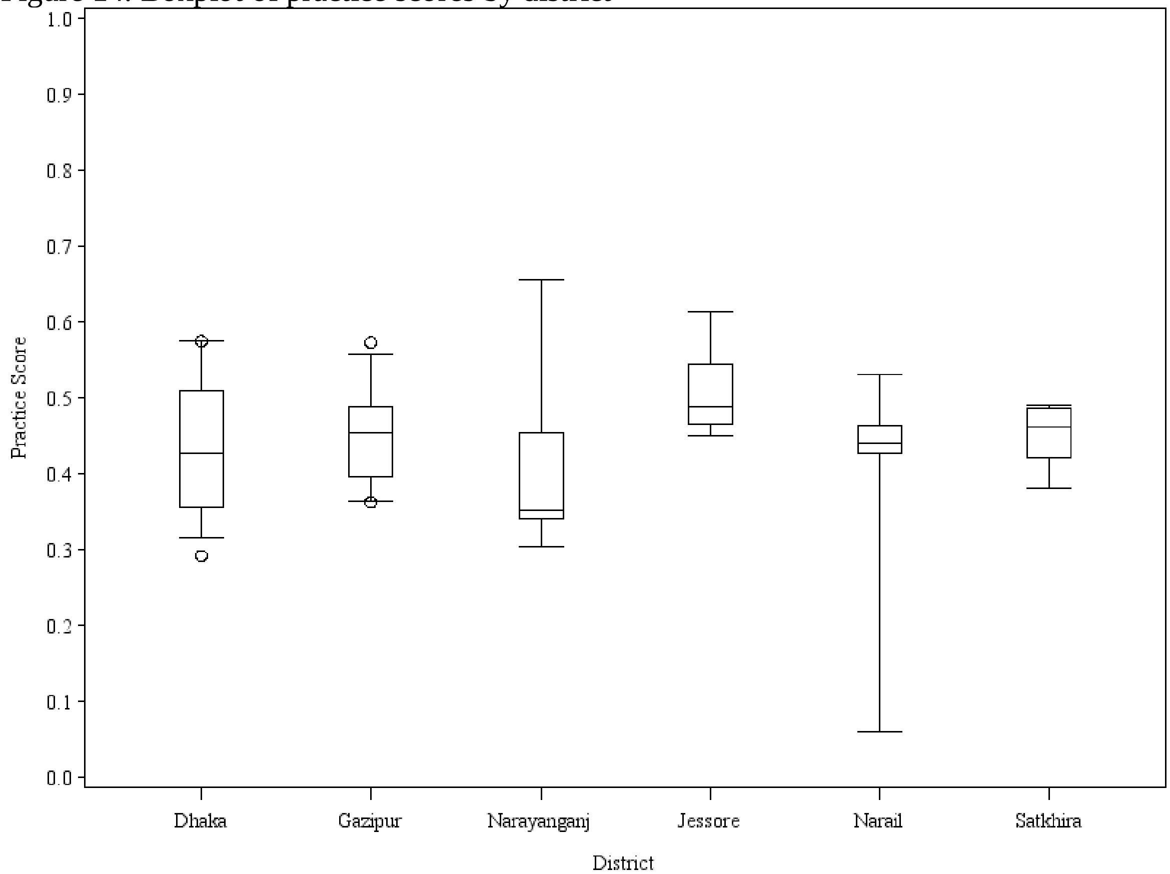
[a]Crop variable has three levels: 1) grows crop and uses pesticides on it, 2) grows crop and does not use pesticides on it, 3) does not grow crop; For pumpkin and bitter gourd, the one farmer that grew the crop but did not use pesticides on it was excluded. [b]Student's t-test. [c]Wilcoxon two-sample test (two-tailed). [d]One way ANOVA. [e]Kruskal-Wallis ANOVA. fOnly one farmer reported growing cabbage, so tests for differences in means could not be completed.
*p<0.05.

Figure 13. Boxplot of attitude scores by farm location[a]



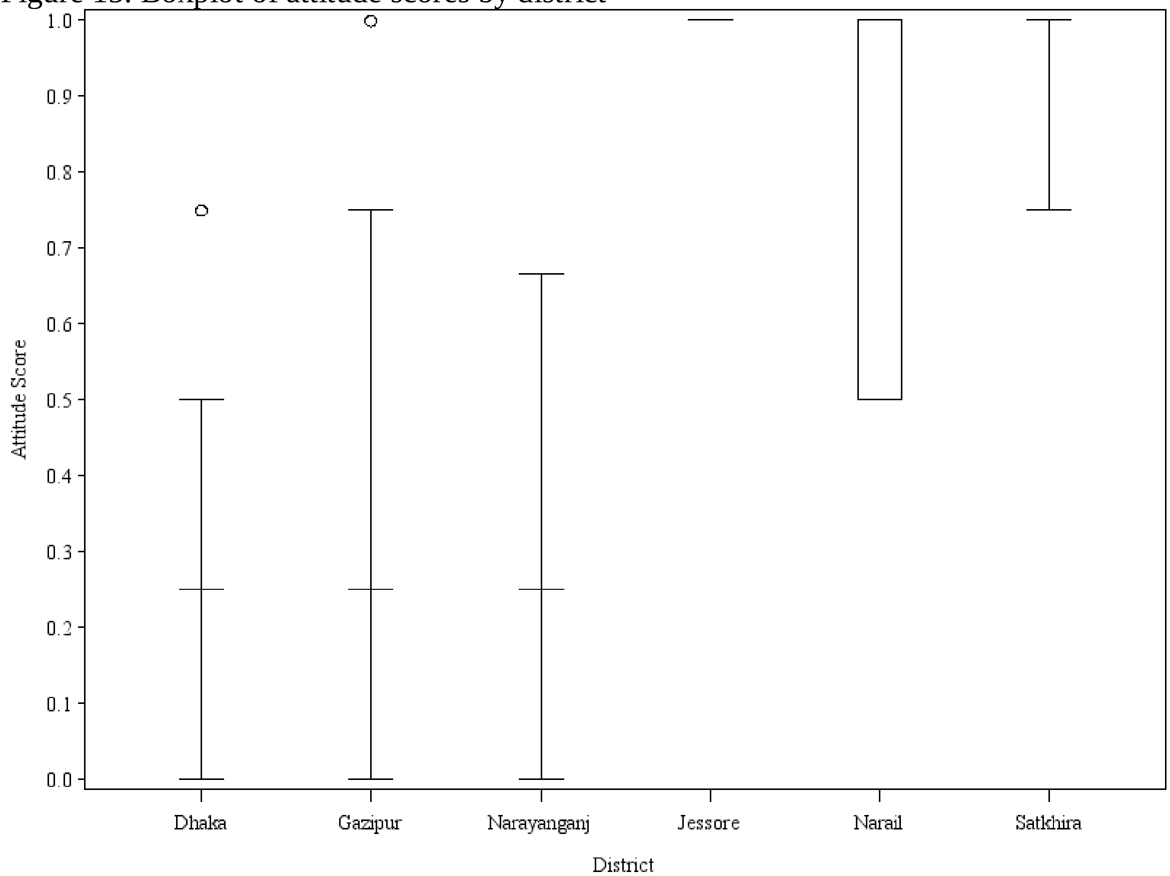
[a]Central districts: Dhaka, Gazipur, Narayanganj. Southwest districts: Jessore, Narail, Satkhira. Center line in box denotes median. Edges of box denote 25th and 75th percentiles. Whiskers denote 5th and 95th percentiles. Circles denote potential outliers outside the range of the 5th and 95th percentiles.

Figure 14. Boxplot of practice scores by district[a]



[a]Central districts: Dhaka, Gazipur, Narayanganj. Southwest districts: Jessore, Narail, Satkhira. Center line in box denotes median. Edges of box denote 25th and 75th percentiles. Whiskers denote 5th and 95th percentiles. Circles denote potential outliers outside the range of the 5th and 95th percentiles.

Figure 15. Boxplot of attitude scores by district[a]



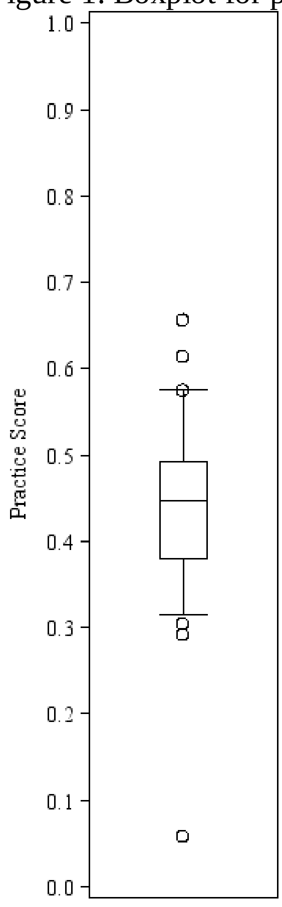
[a]Central districts: Dhaka, Gazipur, Narayanganj. Southwest districts: Jessore, Narail, Satkhira. Center line in box denotes median. Edges of box denote 25th and 75th percentiles. Whiskers denote 5th and 95th percentiles. Circles denote potential outliers outside the range of the 5th and 95th percentiles.

XI. APPENDIX 4: Model Building Process

Table 1. Indicators for normality of practice score

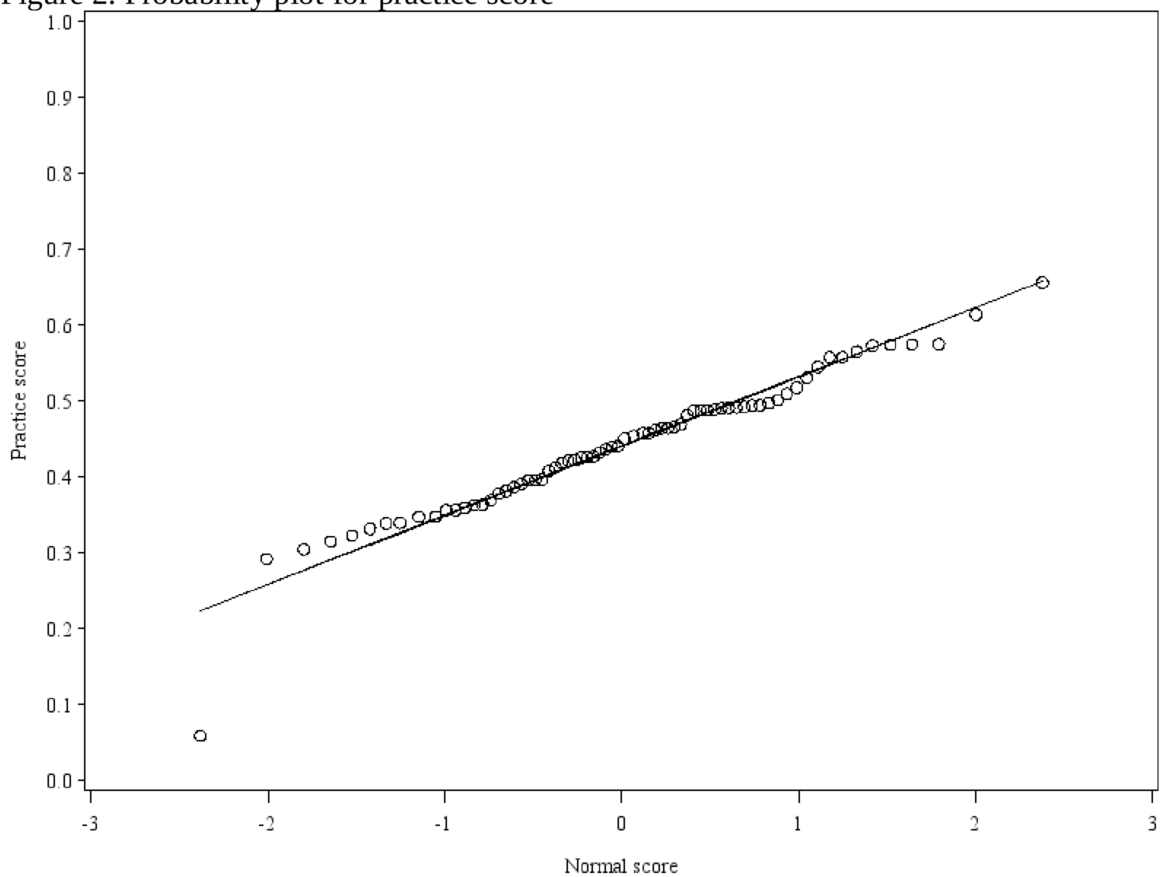
Indicator	**Value**
N	72
Skewness	-0.7518
Kurtosis	3.1472
Mean	0.4405
Median	0.4460
Shapiro-Wilk p-value	0.0064
Kolomogorov-Smirnov p-value	>0.1500
Histogram	See Figure 7 in text

Figure 1. Boxplot for practice score[a]



[a]Center line in box denotes median. Edges of box denote 25th and 75th percentiles. Whiskers denote 5th and 95th percentiles. Circles denote potential outliers outside the range of the 5th and 95th percentiles.

Figure 2. Probability plot for practice score[a]



[a]Solid line is a reference line denoting the expected distribution of scores in a perfectly normal population.

Table 2. Missingness and outliers in all variables

Variable	**Number Missing**	**Number of Potential Outliers**[a]
Practice	0	0
Knowledge	0	0
Attitude	0	0
Age	0	0
Income	0	3
Education	0	0
Total area of the farm	0	4
Years working on the farm	1	0
Proportion of WHO Class II and higher pesticides used	4	2
Number of information sources reported	0	0
Number of duties on the farm	0	0
Sex	0	-
Primary Occupation	0	-
District	0	-
Farm Type	0	-
Farm Location	1	-
Do you think that your earning is sufficient for the basic needs of your family?	6	-
Pesticide Applicator	2	-
Consumes crops at the house/compound where they are grown	0	-
Sells crops at local market	0	-
Sells crops at city/regional market	0	-
Farm grows *boro* rice	0	-
Farm grows *aman* rice	0	-
Farm grows tomatoes	0	-
Farm grows eggplant	0	-
Farm grows okra	0	-
Farm grows pumpkin	0	-
Farm grows bitter gourd	0	-
Farm grows sweet gourd	0	-
Farm grows beans	0	-
Farm grows spinach	0	-
Farm grows *pui shaak*	0	-
Farm grows cauliflower	0	-
Farm grows cabbage	0	-

[a]Any point more than 3 interquartile ranges below the 25th percentile or above the 75th percentile.

Table 3. Bivariate associations between continuous variables and practice, knowledge

Variable		**PCC**[a]	**p-value**
Knowledge	*Practice*	0.5391	<0.0001*
Attitude	*Practice*	0.1884	0.1129
	Knowledge	0.4329	<0.0001*
Age	*Practice*	-0.0727	0.5439
	Knowledge	-0.0965	0.4200
Income	*Practice*	-0.0204	0.8649
	Knowledge	-0.1303	0.2752
Education	*Practice*	0.2024	0.0883*
	Knowledge	0.18732	0.1151
Total area of the farm	*Practice*	0.0656	0.5841
	Knowledge	0.0942	0.4315
Years working on the farm	*Practice*	-0.1900	0.1126
	Knowledge	-0.2001	0.0943*
Proportion of WHO Class II and higher pesticides used	*Practice*	0.0982	0.4256
	Knowledge	-0.1517	0.2170
Number of information sources reported	*Practice*	0.4444	<0.0001*
	Knowledge	0.79601	<0.0001*
Number of duties on the farm	*Practice*	-0.08604	0.4724
	Knowledge	-0.0594	0.6202

[a]Pearson correlation coefficient.
*p<0.1.

Table 4. Bivariate associations between categorical variables and practice, knowledge

Variable		**p-value**
Sex	*Practice*	0.4120[a]
	Knowledge	0.1540[a]
Primary Occupation	*Practice*	0.1797[b]
	Knowledge	0.2772[b]
District	*Practice*	0.4157[b]
	Knowledge	0.0021[b]*
Farm Type	*Practice*	0.5457[b]
	Knowledge	0.7983[b]
Farm Location[c]	*Practice*	0.0207[b]*
	Knowledge	<0.0001[b]*
Do you think that your earning is sufficient for the basic needs of your family?	*Practice*	0.9172[b]
	Knowledge	0.2388[b]
Pesticide Applicator[c]	*Practice*	0.0240[b]*
	Knowledge	0.0017[b]*
Consumes crops at the house/compound where they are grown	*Practice*	0.6661[a]
	Knowledge	0.0254[a]*
Sells crops at local market	*Practice*	0.4053[a]
	Knowledge	0.0468[a]*
Sells crops at city/regional market	*Practice*	0.1463[a]
	Knowledge	0.0185[a]*
Farm grows *boro* rice	*Practice*	0.4047[a]
	Knowledge	0.9348[a]
Farm grows *aman* rice	*Practice*	0.7613[b]
	Knowledge	0.0099[b]*
Farm grows tomatoes	*Practice*	0.0116[a]*
	Knowledge	0.2896[a]
Farm grows eggplant	*Practice*	0.2352[a]
	Knowledge	0.0862[a]*
Farm grows okra	*Practice*	0.6199[a]
	Knowledge	0.7678[a]
Farm grows pumpkin	*Practice*	0.3512[b]
	Knowledge	0.0048[b]*
Farm grows bitter gourd	*Practice*	0.3139[b]
	Knowledge	0.3378[b]
Farm grows sweet gourd	*Practice*	0.4410[a]
	Knowledge	0.5098[a]
Farm grows beans	*Practice*	0.0844[a]*

Variable		**p-value**
	Knowledge	0.0026[a]*
Farm grows spinach	*Practice*	0.7163[a]
	Knowledge	0.9169[a]
Farm grows *pui shaak*	*Practice*	0.0135[b]*
	Knowledge	0.1485[b]
Farm grows cauliflower	*Practice*	0.5021[a]
	Knowledge	0.2609[a]
Farm grows cabbage[d]	*Practice*	0.1965[a]
	Knowledge	0.5187[a]

[a]Student's t-test. [b]One-way ANOVA. [c]After re-definition of variable. [d]Only one farm grew cabbage.
*p<0.1.

Table 5. Frequency distribution of variables in the model

Variable Level	**Frequency**
Number of information sources	
0	6
1	28
2	20
3	18
Farm Location	
Missing	1
Village	56
Municipality	7
Slum	1
Town	7
Farm grows beans	
Yes	52
No	20
Pesticide Applicator	
Missing	2
Respondent	40
Respondent's Husband	28
Respondent's Wife	0
Respondent's Son	1
Laborer	1

Table 6. Variance inflation factors

Variable	**Variance Inflaction Factor**
Knowledge	3.29
Number of information sources	2.80
Farm Location	
Municipality/Slum	1.13
Town	1.49
Farm grows beans	1.30
Respondent is not pesticide applicator	1.20

Table 7. Chunk test of all interaction terms simultaneously

Group	**Partial R-Square**	**Model R-Square**	**C_p**	**F (p-value)**
Single variables	0.4249	0.4249	25.9867	7.64 (<0.0001)
First order interaction terms	0.1703	0.4952	12.0000	4.80 (0.0010)

Table 8. Tests of interaction terms by manual backward elimination

Variable	**p-value, full model**	**p-value without Knowledge x Pesticide applicator**
Knowledge x Farm location[a]	0.0083	-
Knowledge x Municipality/slum	0.5548	0.6085
Knowledge x Town	0.0047	0.0027
Knowledge x Pesticide applicator	0.3409	-
Knowledge x Number of information sources	0.0300	0.0217
Knowledge x Farm grows beans	0.0007	0.0006

[a]p-value when Knowledge x Municipality/Slum and Knowledge x Town tested as a chunk.

Table 9. Assessment of confounding by pesticide applicator

Knowledge x Municipality/Slum	**Knowledge x Town**	**Knowledge x Number of Information Sources**	**Knowledge x Farm Grows Beans**	**$\beta_{knowledge}$, Full Model**	**$\beta_{knowledge}$, Reduced Model[a]**	**$\beta_{knowledge}$, Full : $\beta_{knowledge}$, Reduced[a]**
0	0	0	0	0.10183	0.10014	-1.66
0	1	0	0	0.41428	0.40923	-1.22
1	0	0	0	0.05495	0.0449	-18.29
1	1	0	0	0.3674	0.35399	-3.65
0	0	0	1	-0.1208	-0.12386	2.53
0	1	0	1	0.19165	0.18523	-3.35
1	0	0	1	-0.16768	-0.1791	6.81
1	1	0	1	0.14477	0.12999	-10.21
0	0	1	0	0.19882	0.20082	1.01
0	1	1	0	0.51127	0.50991	-0.27
1	0	1	0	0.15194	0.14558	-4.19
1	1	1	0	0.46439	0.45467	-2.09
0	0	1	1	-0.02381	-0.02318	-2.65
0	1	1	1	0.28864	0.28591	-0.95
1	0	1	1	-0.07069	-0.07842	10.94
1	1	1	1	0.24176	0.23067	-4.59
0	0	2	0	0.29581	0.3015	1.92
0	1	2	0	0.60826	0.61059	0.38
1	0	2	0	0.24893	0.24626	-1.07
1	1	2	0	0.56138	0.55535	-1.07
0	0	2	1	0.07318	0.0775	5.90
0	1	2	1	0.38563	0.38659	0.25
1	0	2	1	0.0263	0.02226	-15.36
1	1	2	1	0.33875	0.33135	-2.19
0	0	3	0	0.3928	0.40218	2.39
0	1	3	0	0.70525	0.71127	0.85
1	0	3	0	0.34592	0.34694	0.30
1	1	3	0	0.65837	0.65603	-0.36
0	0	3	1	0.17017	0.17818	4.71
0	1	3	1	0.48262	0.48727	0.96
1	0	3	1	0.12329	0.12294	-0.28
1	1	3	1	0.43574	0.43203	-0.85

[a]Reduced model does not include pesticide applicator variable.

Figure 3. Scatterplot of observed vs. predicted values of practice score[a]

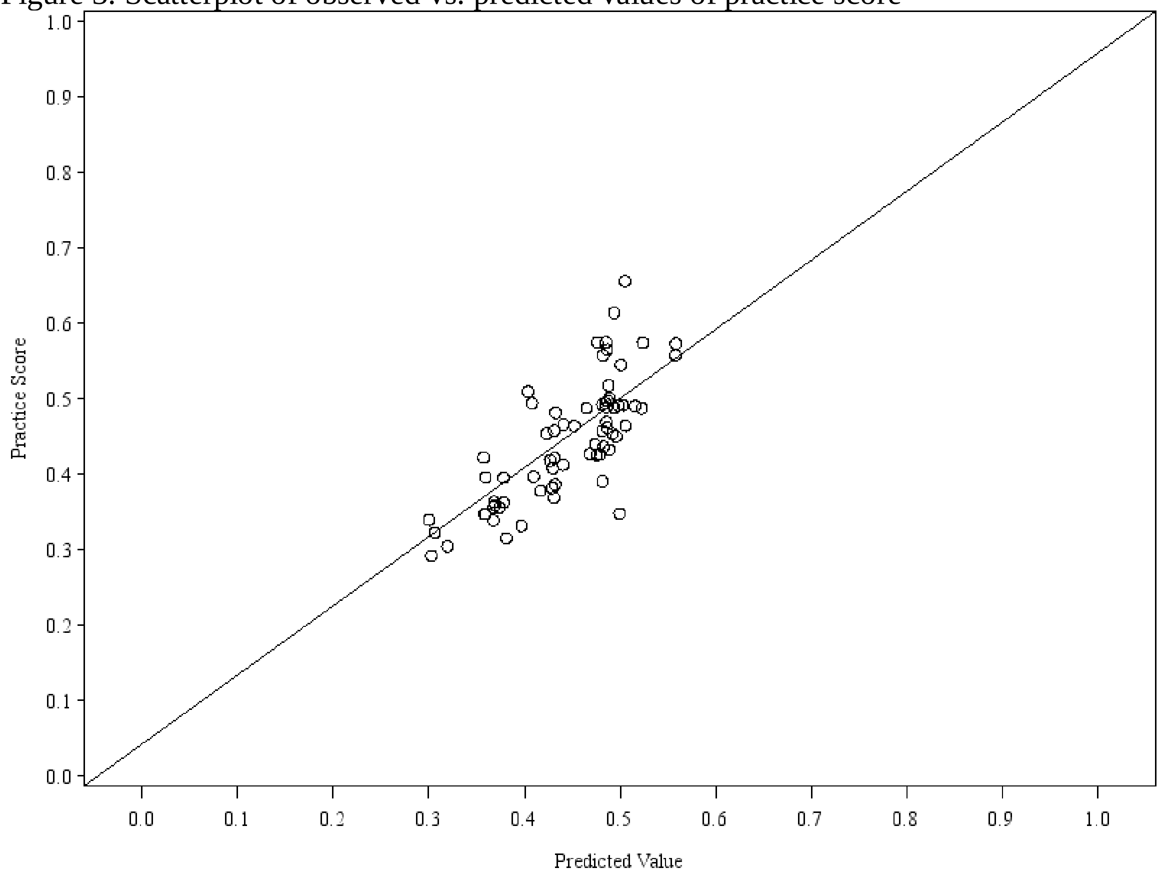


Table 10. Indicators for normality of residuals of practice score

Indicator	Value
N	69
Skewness	0.4615
Kurtosis	1.1797
Mean	0.0000
Median	-0.0099
Shapiro-Wilk p-value	0.0306
Kolomogorov-Smirnov p-value	0.0212

Figure 4. Histogram of residuals of practice score

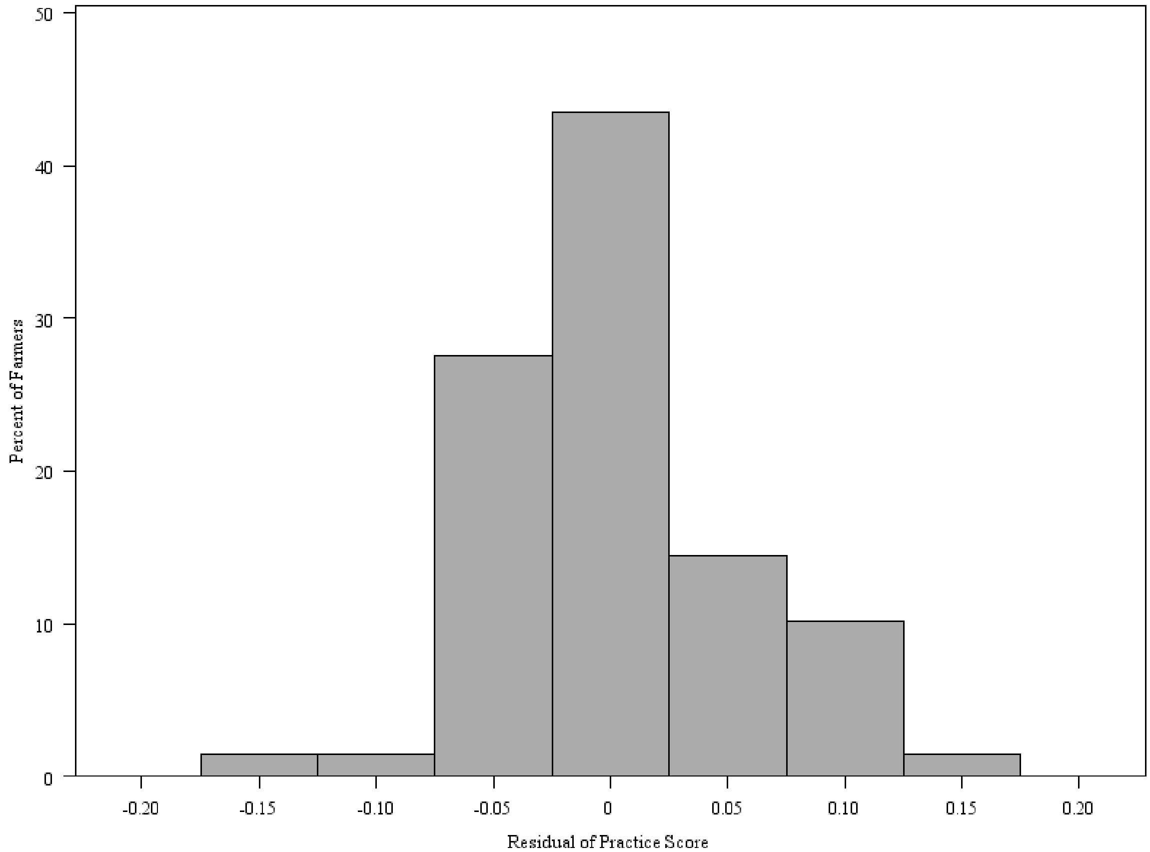
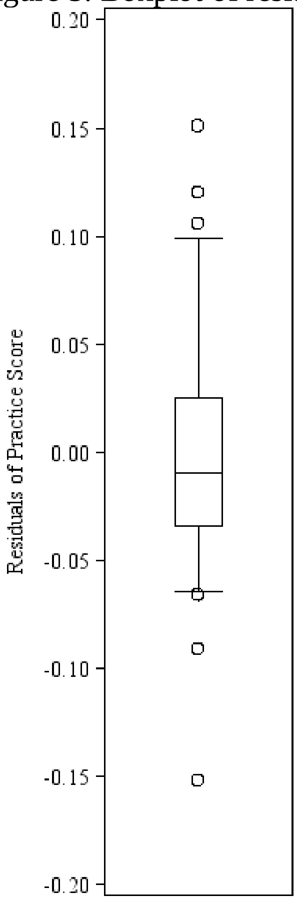
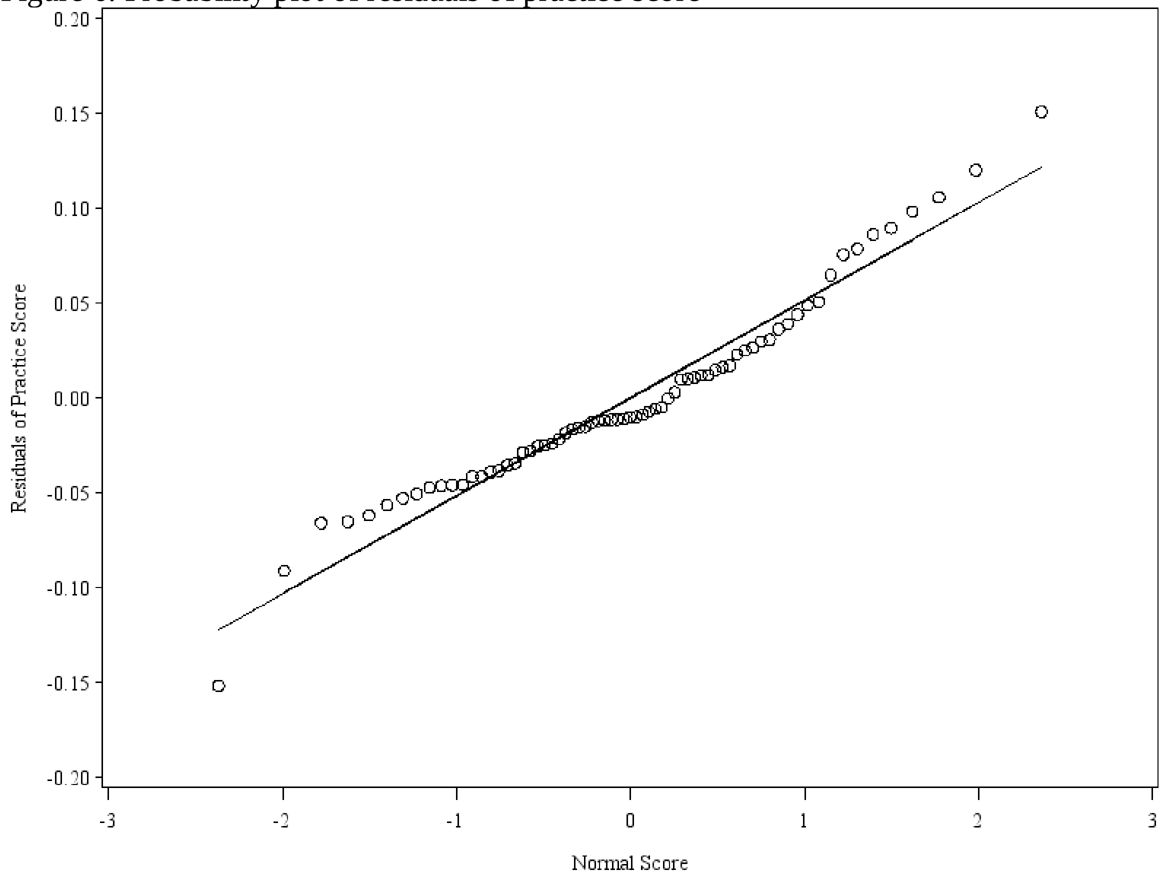


Figure 5. Boxplot of residuals of practice score



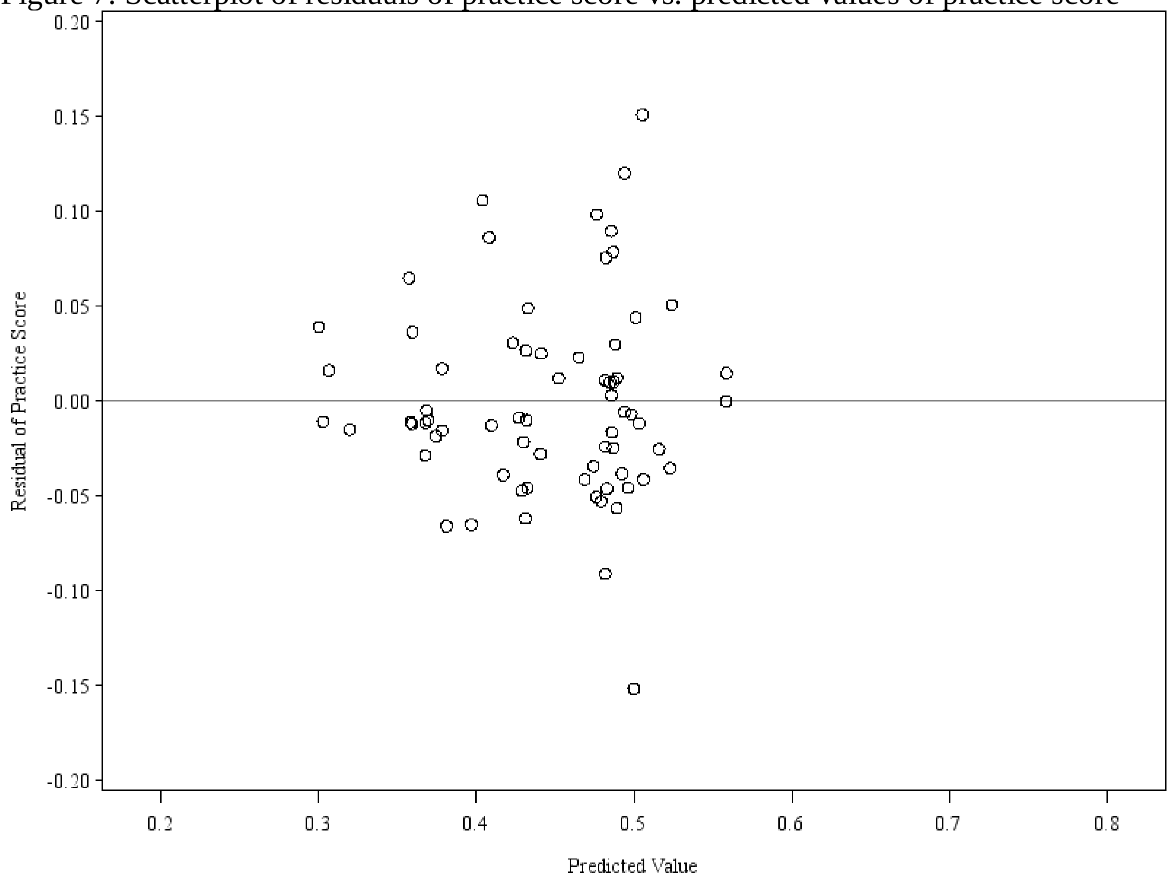
[a]Center line in box denotes median. Edges of box denote 25th and 75th percentiles. Whiskers denote 5th and 95th percentiles. Circles denote potential outliers outside the range of the 5th and 95th percentiles.

Figure 6. Probability plot of residuals of practice score[a]



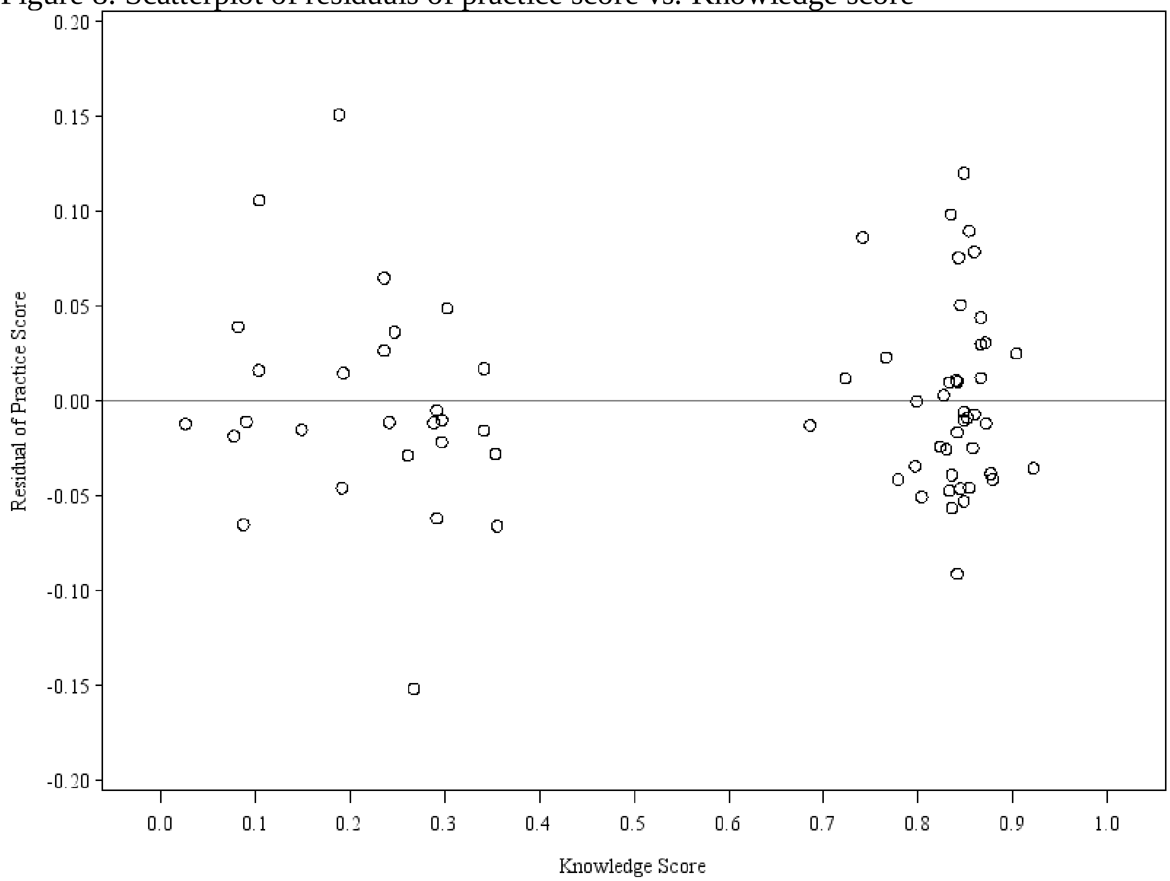
[a]Solid line is a reference line denoting the expected distribution of scores in a perfectly normal population.

Figure 7. Scatterplot of residuals of practice score vs. predicted values of practice score[a]



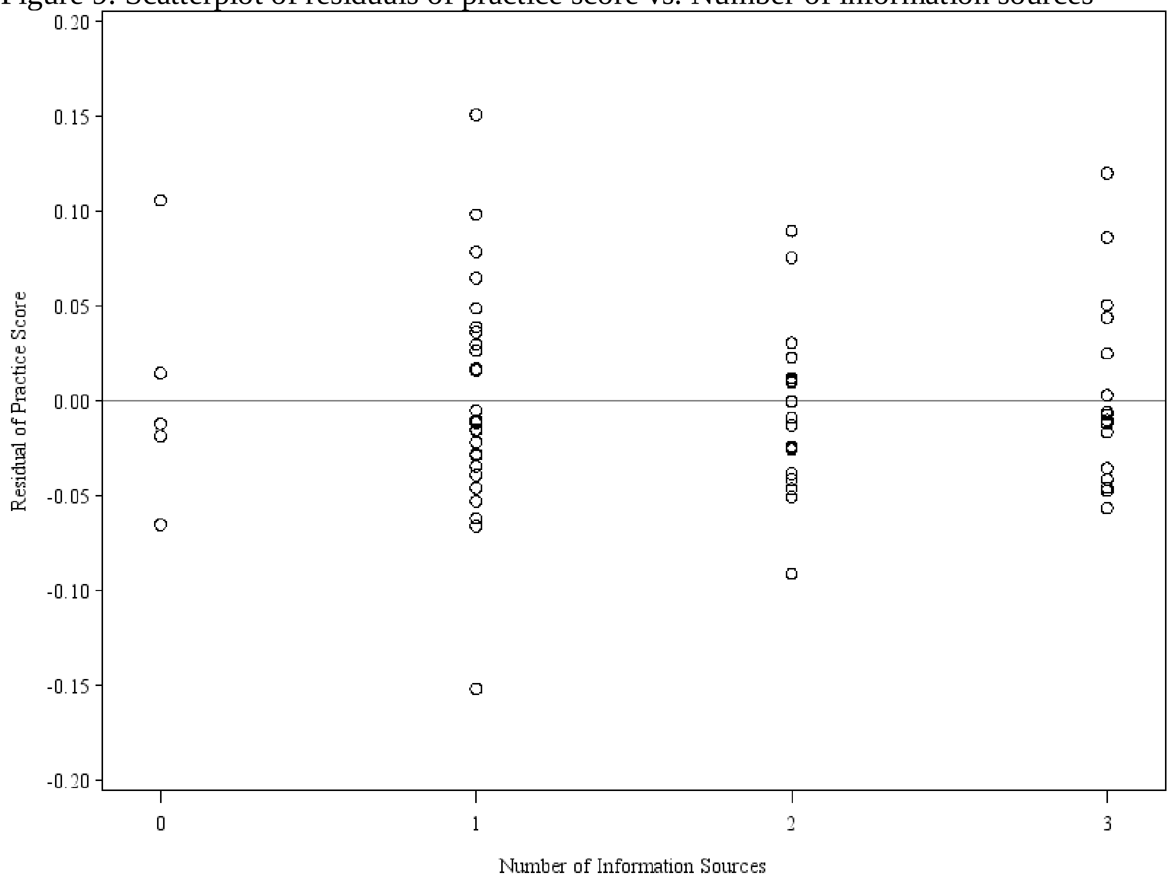
[a]Solid reference line denotes residual of zero.

Figure 8. Scatterplot of residuals of practice score vs. Knowledge score[a]



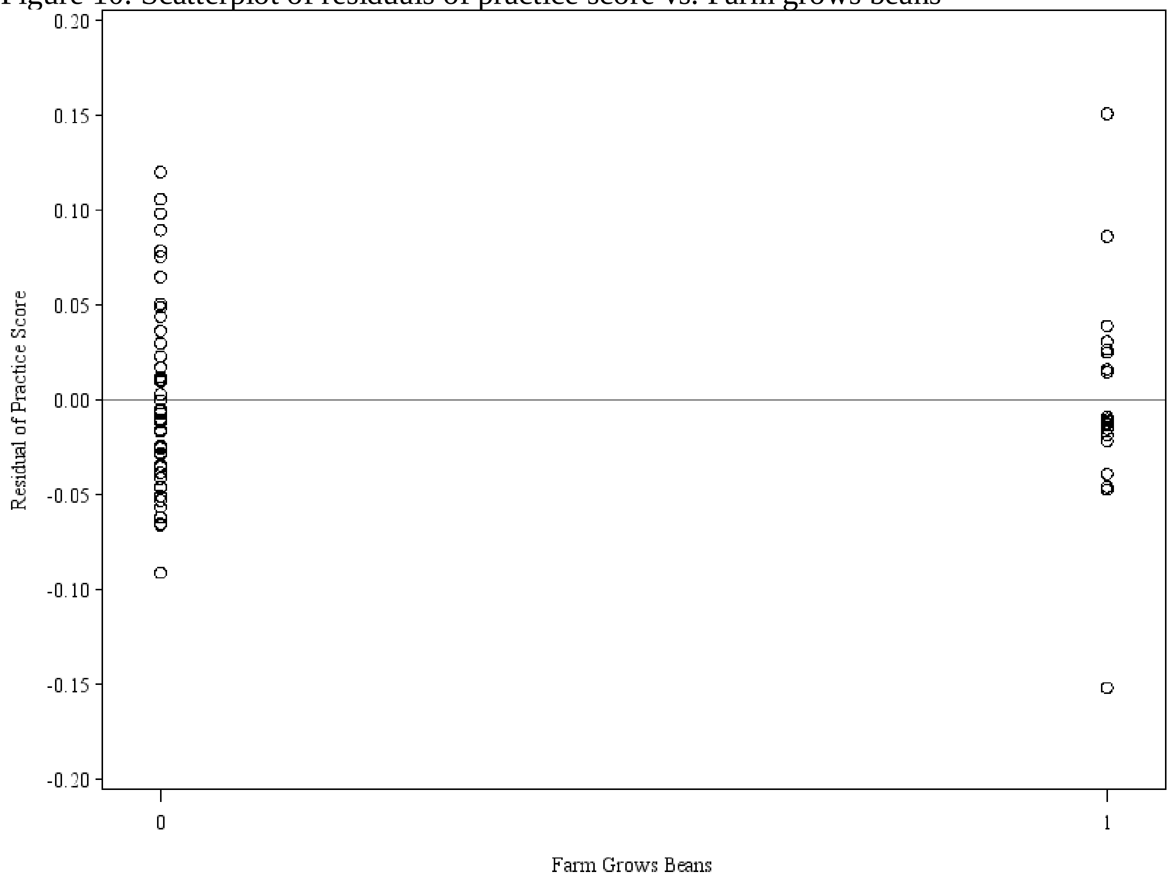
[a]Solid reference line denotes residual of zero.

Figure 9. Scatterplot of residuals of practice score vs. Number of information sources[a]



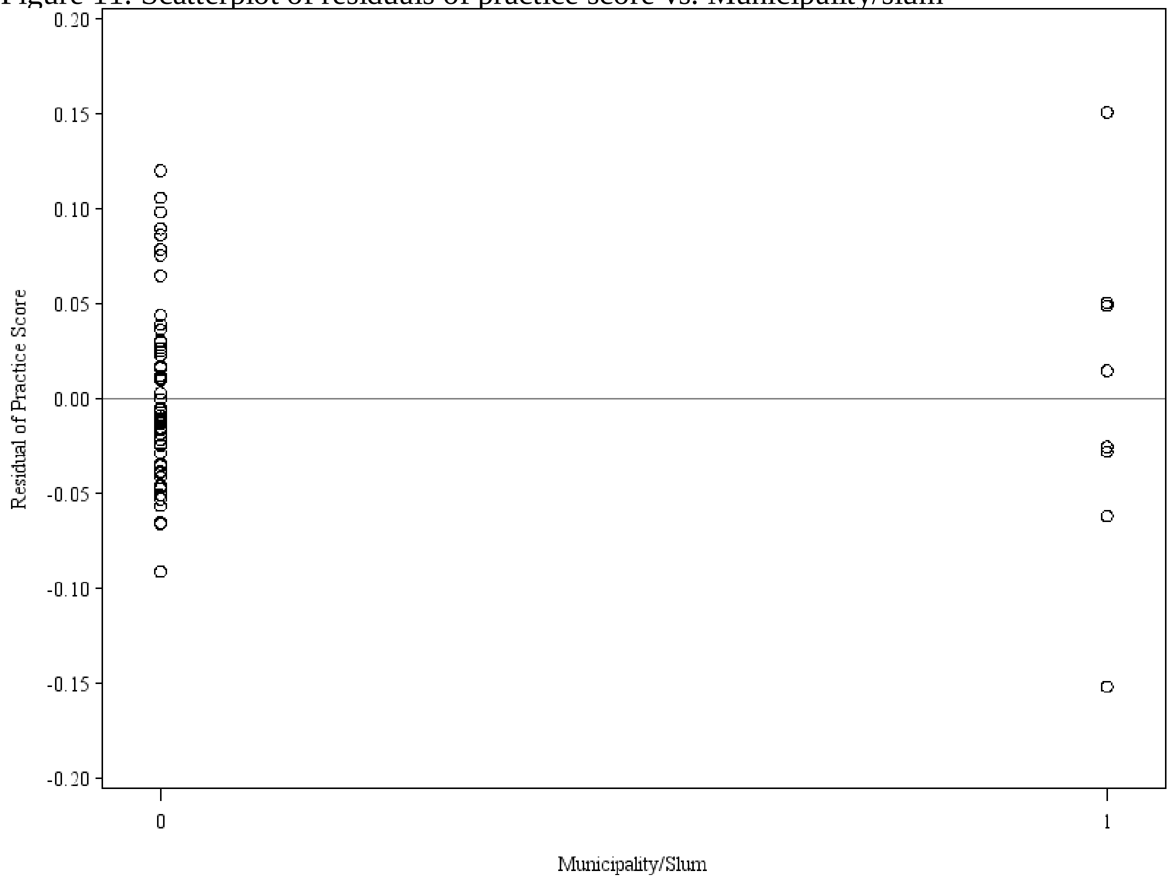
[a]Solid reference line denotes residual of zero.

Figure 10. Scatterplot of residuals of practice score vs. Farm grows beans[a]



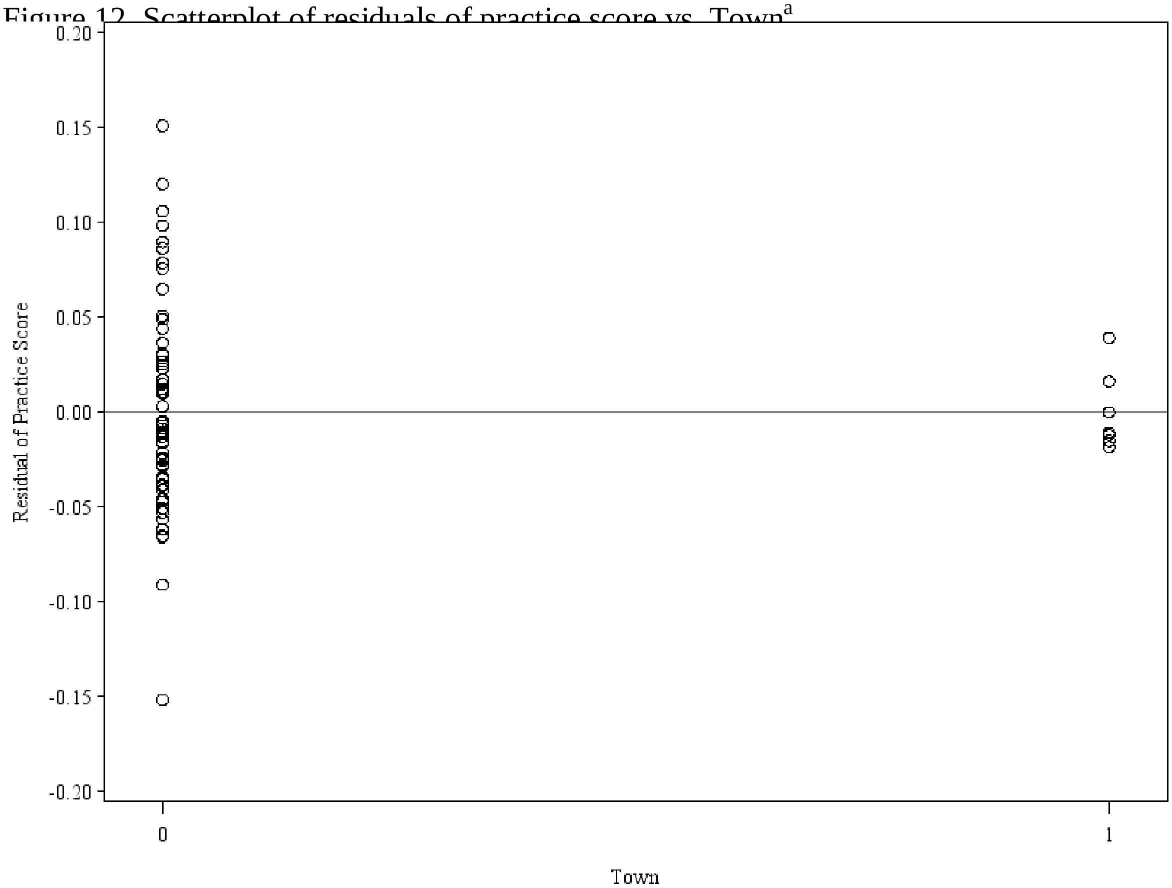
[a]Solid reference line denotes residual of zero.

Figure 11. Scatterplot of residuals of practice score vs. Municipality/slum[a]



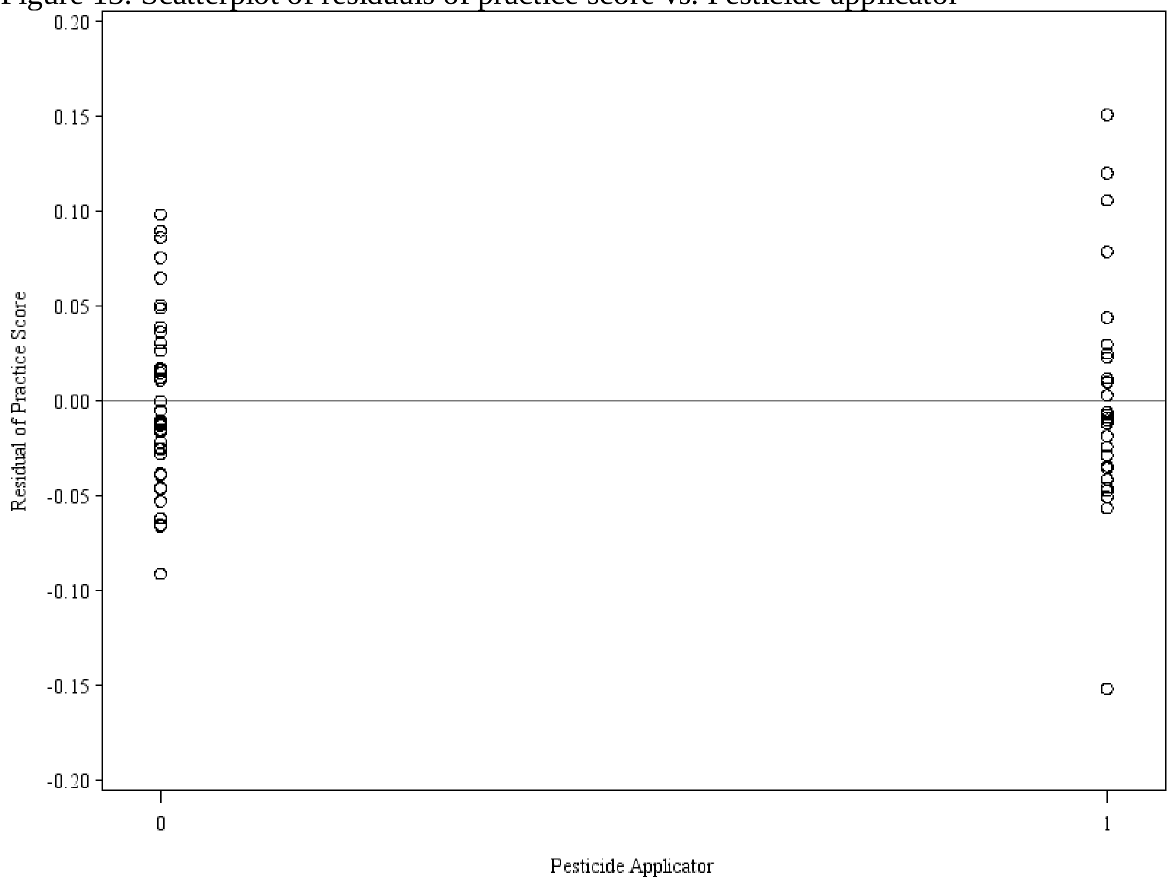
[a]Solid reference line denotes residual of zero.

Figure 12. Scatterplot of residuals of practice score vs. Town[a]



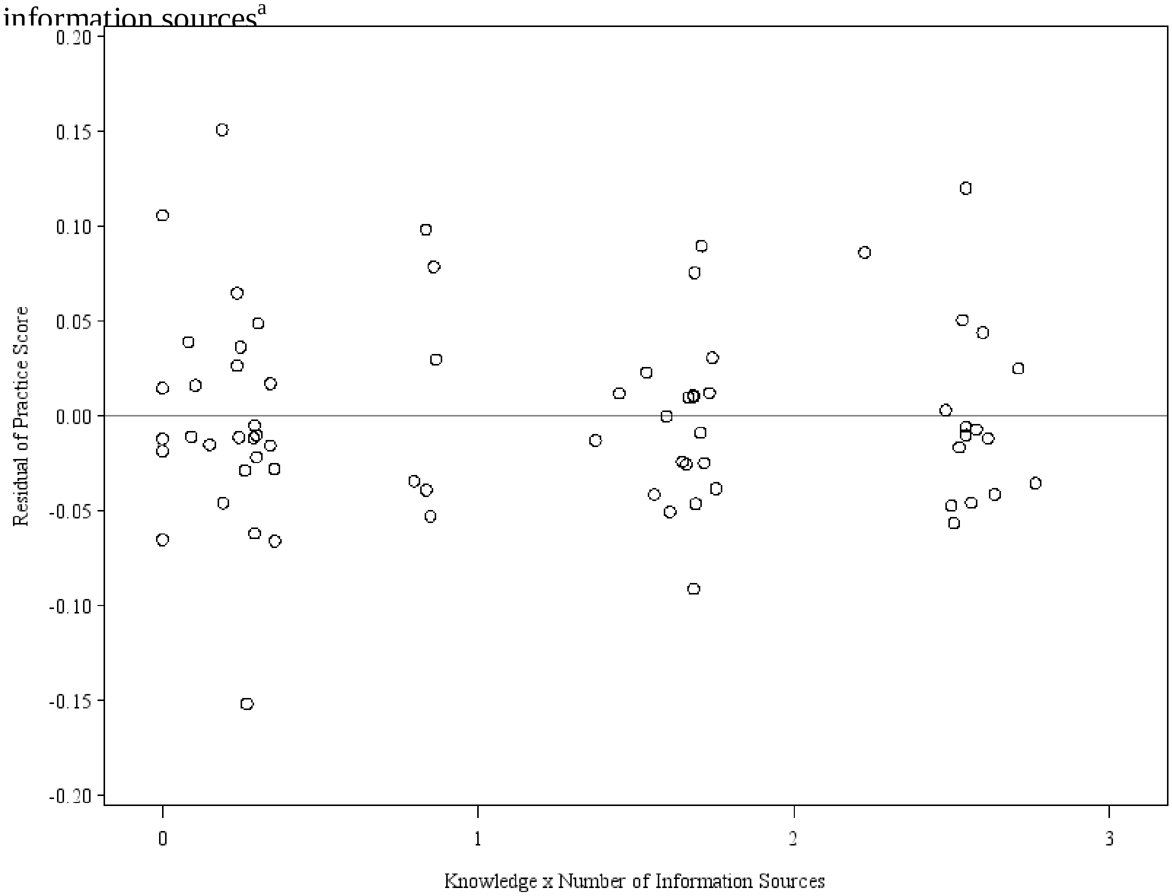
[a]Solid reference line denotes residual of zero.

Figure 13. Scatterplot of residuals of practice score vs. Pesticide applicator[a]



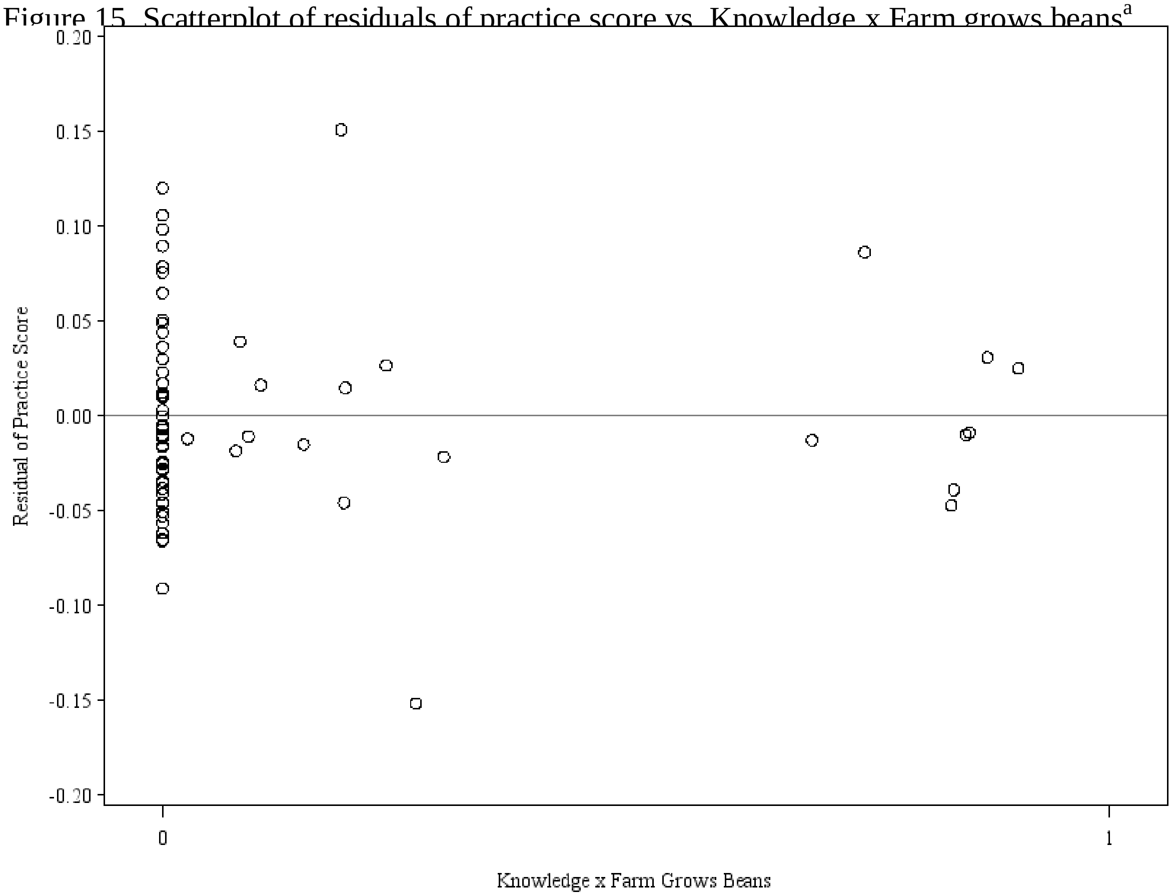
[a]Solid reference line denotes residual of zero.

Figure 14. Scatterplot of residuals of practice score vs. Knowledge x Number of information sources[a]



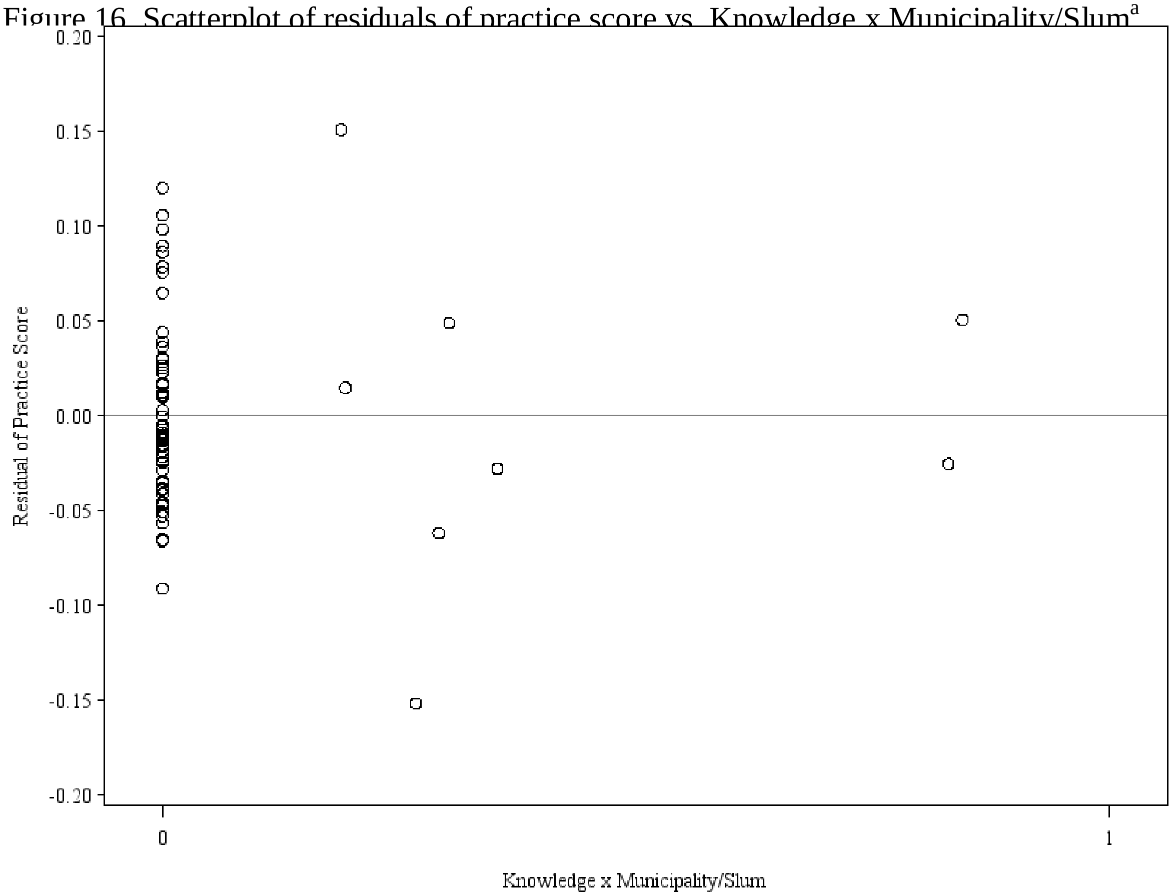
[a]Solid reference line denotes residual of zero.

Figure 15. Scatterplot of residuals of practice score vs. Knowledge x Farm grows beans[a]



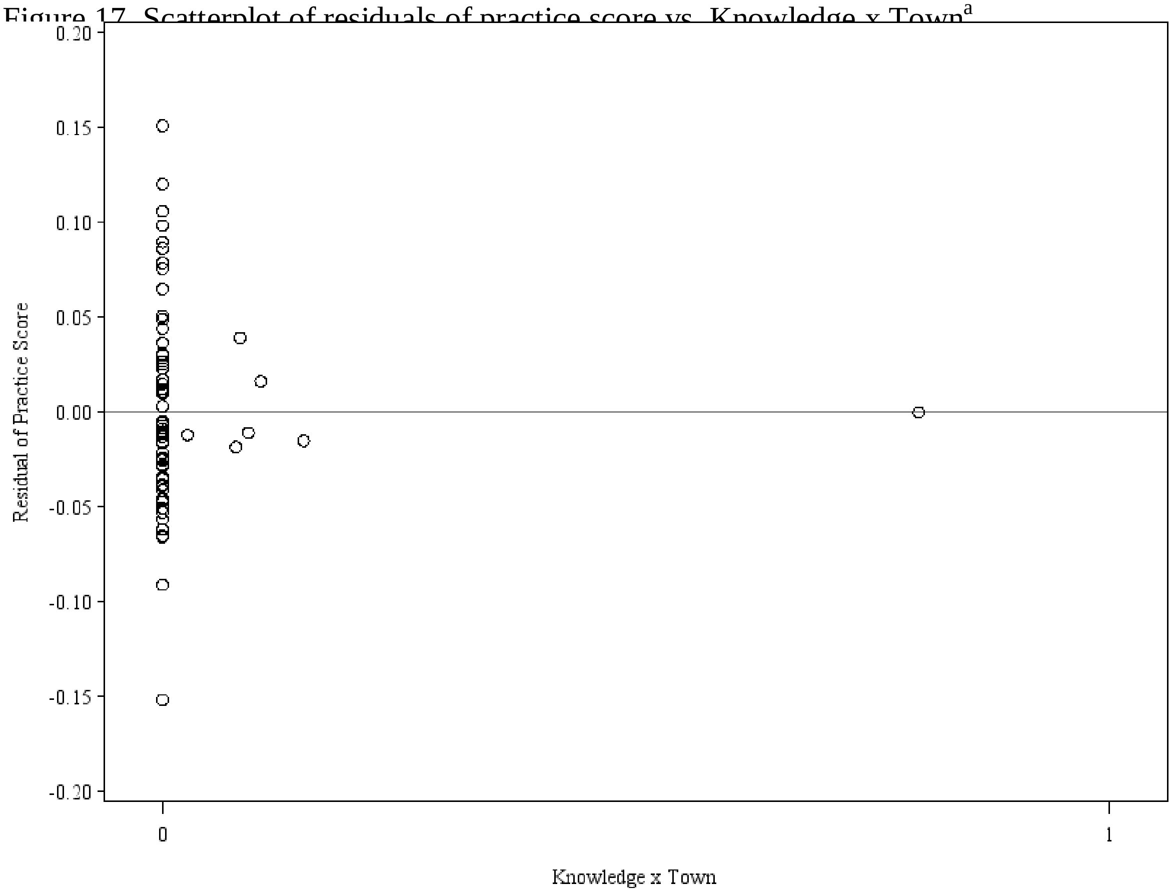
[a]Solid reference line denotes residual of zero.

Figure 16. Scatterplot of residuals of practice score vs. Knowledge x Municipality/Slum[a]



[a]Solid reference line denotes residual of zero.

Figure 17. Scatterplot of residuals of practice score vs. Knowledge x Town[a]



[a]Solid reference line denotes residual of zero.