Obstacles to integrated pest management adoption in developing countries

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Despite its theoretical prominence and sound principles, integrated pest management (IPM) continues to suffer from anemic adoption rates in developing countries. To shed light on the reasons, we surveyed the opinions of a large and diverse pool of IPM professionals and practitioners from 96 countries by using structured concept mapping. The first phase of this method elicited 413 open-ended responses on perceived obstacles to IPM. Analysis of responses revealed 51 unique statements on obstacles, the most frequent of which was "insufficient training and technical support to farmers." Cluster analyses, based on participant opinions, grouped these unique statements into six themes: research weaknesses, outreach weaknesses, IPM weaknesses, farmer weaknesses, pesticide industry interference, and weak adoption incentives. Subsequently, 163 participants rated the obstacles expressed in the 51 unique statements according to importance and remediation difficulty. Respondents from developing countries and high-income countries rated the obstacles differently. As a group, developing-country respondents rated "IPM requires collective action within a farming community" as their top obstacle to IPM adoption. Respondents from high-income countries prioritized instead the "shortage of well-qualified IPM experts and extensionists." Differential prioritization was also evident among developing-country regions, and when obstacle statements were grouped into themes. Results highlighted the need to improve the participation of stakeholders from developing countries in the IPM adoption debate, and also to situate the debate within specific regional contexts.

sustainable agriculture | technology adoption | collective action dilemma

Feeding the 9,000 million people expected to inhabit Earth by 2050 will present a constant and significant challenge in terms of agricultural pest management (1–3). Despite a 15- to 20-fold increase in pesticide use since the 1960s, global crop losses to pests—arthropods, diseases, and weeds—have remained unsustainably high, even increasing in some cases (4). These losses tend to be highest in developing countries, averaging 40–50%, compared with 25–30% in high-income countries (5). Alarmingly, crop pest problems are projected to increase because of agricultural intensification (4, 6), trade globalization (7), and, potentially, climate change (8).

Since the 1960s, integrated pest management (IPM) has become the dominant crop protection paradigm, being endorsed globally by scientists, policymakers, and international development agencies (2, 9–15). The definitions of IPM are numerous, but all involve the coordinated integration of multiple complementary methods to suppress pests in a safe, cost-effective, and environmentally friendly manner (9, 11). These definitions also recognize IPM as a dynamic process in terms of design, implementation, and evaluation (11). In practice, however, there is a continuum of interpretations of IPM (e.g., refs. 14, 16, 17), but bounded by those that emphasize pesticide management (i.e., "tactical IPM") and those that emphasize agroecosystem management (i.e., "strategic IPM," also known as "ecologically based pest management") (16, 18, 19). Despite apparently solid conceptual grounding and substantial promotion by the aforementioned groups, IPM has a discouragingly poor adoption record, particularly in developing-country settings (9, 10, 15–23), raising questions over its applicability as it is presently conceived (15, 16, 22, 24).

The possible reasons behind the developing countries' poor adoption of IPM have been the subject of considerable discussion since the 1980s (9, 15, 16, 22, 25–31), but this debate has been notable for the limited direct involvement from developing-country stakeholders. Most of the literature exploring poor adoption of IPM in the developing world has originated in the developed world (e.g., refs. 15, 16, 22). An international workshop, entitled "IPM in Developing Countries," was held at the Pontificia Universidad Católica del Ecuador (PUCE) from October 31 to November 3, 2011. Poor IPM adoption spontaneously became a central discussion point, creating an opportunity to address the apparent participation bias in the IPM adoption debate.

It was therefore decided to explore the topic further by eliciting and mapping the opinions of a large and diverse pool of IPM

Significance

Integrated pest management (IPM) has been the dominant crop protection paradigm promoted globally since the 1960s. However, its adoption by developing country farmers is surprisingly low. This article reports 51 potential reasons why, identified and prioritized by hundreds of IPM professionals and practitioners around the world. Stakeholders from developing countries prioritized different adoption obstacles than those from high-income countries. Surprisingly, a few of the obstacles prioritized in developing countries appear to be overlooked by the literature. We suggest that a more vigorous analysis and discussion of the factors discouraging IPM adoption in developing countries may accelerate the progress needed to bring about its full potential.

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professionals and practitioners from around the world, including many based in developing countries. The objective was to generate and prioritize a broad list of hypotheses to explain poor IPM adoption in developing-country agriculture. We also wanted to explore differences as influenced by respondents' characteristics, particularly their region of practice. To achieve these objectives, we used structured concept mapping (32), an empirical survey method often used to quantify and give thematic structure to open-ended opinions (33).

We know of only one other similar study that characterizes obstacles to IPM. It was based on the structured responses of 153 experts, all from high-income countries (30). Our survey was designed to progress from unstructured to structured responses, and to reach a much larger and diverse pool of participants, particularly those from the "Global South." Considering that the vast majority of farmers live in developing countries (34), it would seem imperative that the voices from this region be heard.

Results

Fig. 1 provides a summary of the study's results. The study began with a brainstorming phase that used an open-ended question that asked participants to identify one obstacle to IPM adoption in developing countries. We received 413 responses, 80% of which came from professionals and practitioners based in developing countries (Table S1). Most participants (56.4%) had more than 10 y of experience in developing-country agriculture. They were demographically diverse (Table S1), although with an important male bias (75.5%), but nevertheless reflecting the wider discipline of crop protection. After eliminating redundancies and editing for conciseness and clarity, we generated statements on 51 unique obstacles (Table 1), which were then used in subsequent steps of the concept mapping. The obstacle most frequently cited was "insufficient training and technical support to farmers" [coded as "outreach weakness" (OUT)-1; Table 1], accounting for 12.8% of total responses. This was followed by "lack of favorable government policies and support" [coded as "weak adoption incentive" (INC)-1], accounting for 9.4% of total responses. Later, 12 respondents sorted the obstacles into similar groups. Their responses were submitted to multidimensional scaling (MDS) analysis, which identified six distinct clusters (Fig. S1) that were designated as follows: FMR, for "farmer weaknesses"; INC, for "weak adoption incentives"; IPM, for "IPM weaknesses"; OUT, for "outreach weaknesses"; PST, for

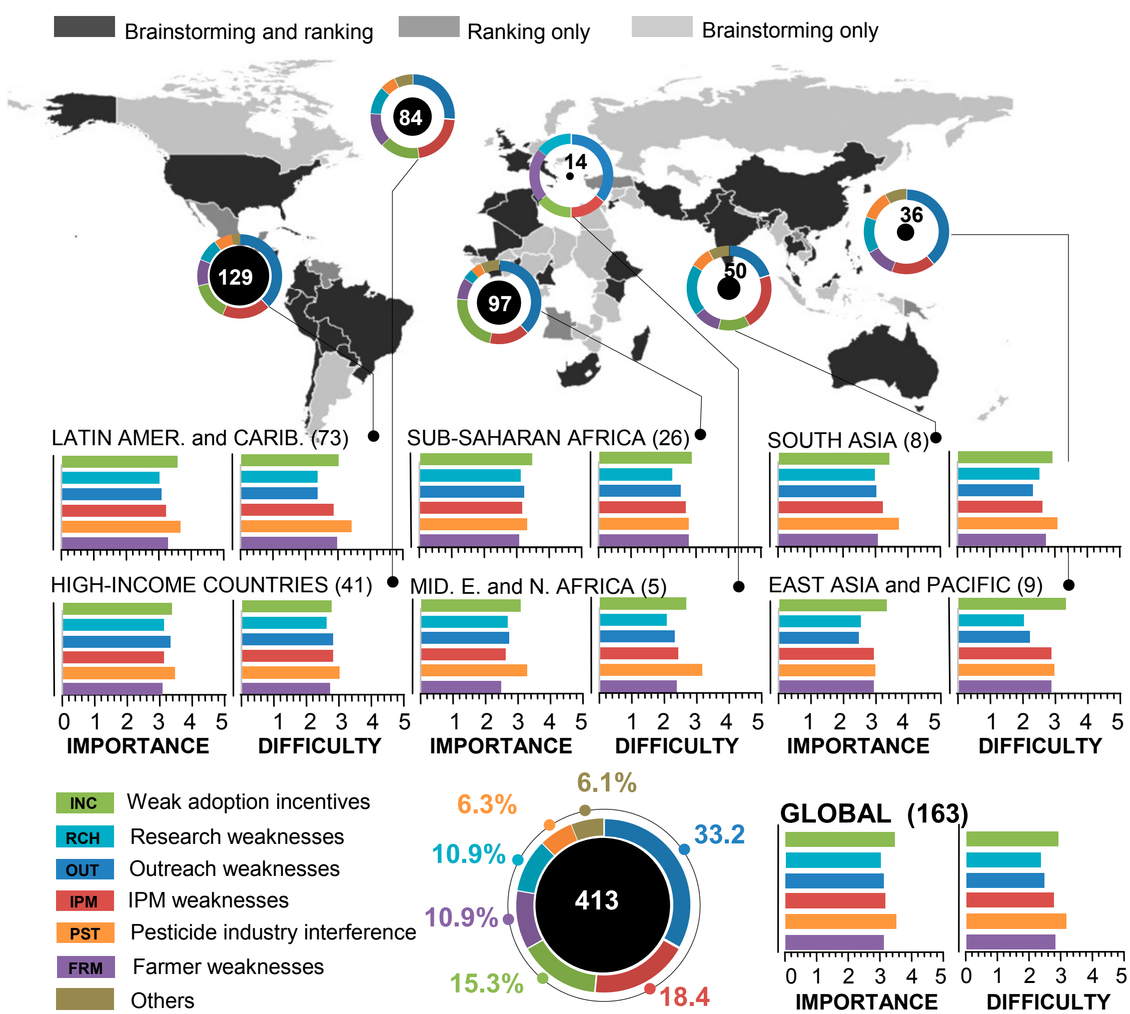

Fig. 1. Summary of a concept map identifying obstacles to IPM in developing countries. The world map captures the global participation in developing the concept map. Doughnut charts represent the proportion of open-ended responses that matched one of six obstacle themes or were otherwise assigned to the generic category "others." The size of the circle inside each doughnut is proportional to the number (labeled in or next to it) of open-ended responses. Bar charts represent ratings on a scale from 1 to 5, ranging from least to most important or difficult obstacle. The number of rating responses is presented in parentheses next to the region's name. Responses from Europe and Central Asia were omitted from the graph because of poor representation.

"pesticide industry interference"; and RCH, for "research weaknesses" (Table 1).

A total of 163 participants (74.8% of whom were from developing countries) rated each obstacle according to importance and remediation difficulty. Participants in the rating phase of concept mapping were roughly similar to those in the brainstorming phase, except for an increased proportional representation from Latin America and the Caribbean (Table S1). Statistical analyses conducted on the responses showed significant differences between ratings of participants originating from high-income countries and those from developing countries, particularly for ratings on difficulties (Fig. 2). As a group, developing-country participants rated

Table 1. Frequencies of 51 unique obstacles to IPM adoption in developing countries discovered by reviewing 413 free-listed statements on obstacles

Code*	Obstacle	Frequency
OUT-1	Insufficient training and technical support to farmers	53
INC-1	Lack of favorable government policies and support	39
FMR-1	Farmers have low levels of education and literacy	22
IPM-1	IPM too difficult to implement compared with conventional management with pesticides	18
PST-1	Powerful influence of pesticide industry	16
INC-2	Shortage of funding for IPM, especially long-term funding	16
OUT-2	Limited access to IPM inputs, like resistant cultivars and biopesticides	15
OUT-3	Limited access to IPM extension publications and knowledge	13
IPM-2	Costs of IPM are much more apparent than benefits	13
FMR-2	Farmers uninterested in changing habitual management practices	11
OUT-4	IPM too difficult to explain and understand	10
RCH-1	Shortage of interinstitutional collaboration in IPM; e.g., between universities and private sector	9
OUT-5	Shortage of well-qualified IPM experts	9
FMR-3	Farmers are too risk averse	8
IPM-3	IPM requires collective action within farming community	8
INC-3	Lack of market incentives for farmers to adopt IPM, consumers want high quality at lowest price	8
RCH-2	Insufficient IPM research	7
IPM-4	IPM too expensive	7
RCH-3	IPM research poorly oriented to needs of farmers	7
OUT-6	Shortage of IPM training programs in universities and other training institutions	7
OUT-7	Lack of IPM guidelines for many pests and diseases, both old and emerging	6
PST-2	Pesticides promoted too heavily by salespeople	5
OUT-8	Shortage of IPM guidelines focused on crop health instead of specific pests	5
IPM-5	Shortage of practices and products as effective as chemical pesticides	5
OUT-9	Shortage of well-qualified extensionists	5
IPM-6	Conventional management with pesticides responds well to needs of farmers	4
OUT-10	Farmers unaware of IPM	4
FMR-4	Farmers have limited understanding of unintended effects of pesticides	4
IPM-8	IPM too labor-intensive	4
IPM-7	IPM unsuitable for smallholder agriculture because farmers grow too many crops, each demanding unique IPM program	4
RCH-4	Shortage of interdisciplinary collaboration in IPM; e.g., between pathologists and rural sociologists	4
PST-3	Access to pesticides too easy and unrestricted in rural areas	3
IPM-10	Farmers become disillusioned with IPM because experts overestimate its benefits	3
IPM-11	IPM combines many practices but farmers want just the single best	3
OUT-13	IPM extension publications are difficult to understand for farmers	3
OUT-11	Poor understanding of mechanisms behind successful extension programs	3
OUT-12	Shortage of pest identification services	3
IPM-9	Benefits of pesticides are much more apparent than their negative effects	3
RCH-6	Experts underestimate legitimate role of pesticides in IPM	2
IPM-12	Farmers cannot make IPM priority, have more important problems to address	2
RCH-7	Insufficient attention to biological control	2
RCH-8	Insufficient attention to host plant resistance	2
RCH-5	Insufficient attention to participatory methods	2
IPM-13	IPM not very effective when pest populations are very high	2
RCH-9	Many IPM recommendations are not evidence-based or research-based	2
PST-4	Weak regulation of pesticide industry	2
RCH-10	Insufficient attention to cultural practices, like crop rotations and intercropping	1
RCH-12	Insufficient attention to decision-support tools	1
RCH-13	Insufficient attention to gender issues	1
RCH-11	Insufficient attention to traditional and local knowledge	1
OUT-14	IPM guidelines not location-specific	1

Twenty-five of the 413 free-listed statements were omitted due to incompleteness, incomprehensibility, or other errors.

*Letter coding describes the key themes grouping the obstacles: FMR, farmer weaknesses; INC, weak adoption incentives; IPM, IPM weaknesses; OUT, outreach weaknesses; PST, pesticide industry interference; RCH, research weaknesses. The numbers refer to the rank order of the statement within its group (i.e., lower numbers indicate greater frequency).

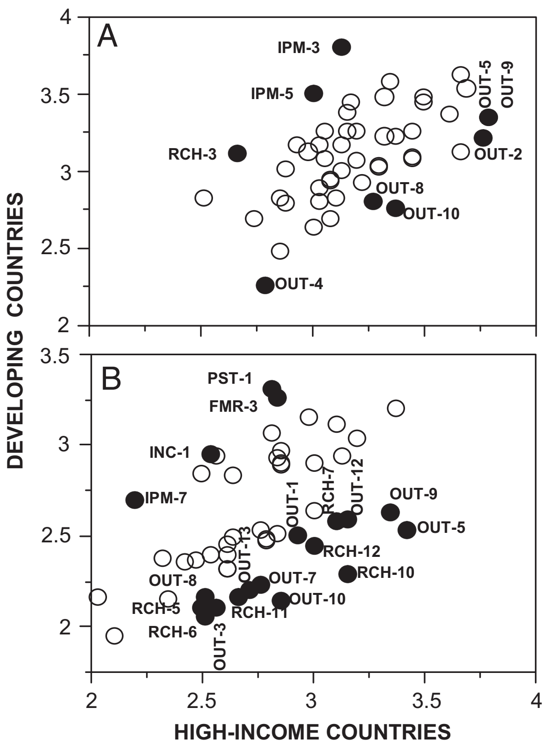

Fig. 2. Respondents from high-income and developing countries rated 51 unique obstacles in terms of their importance (*A*) and the difficulty (*B*) of solving them. Differences in ratings are based on a scale from 1 to 5, ranging from least to most important or difficult obstacle. Solid circles represent obstacles that were rated significantly differently (df = 161; $P \leq 0.05$). Labels represent codes for obstacle themes. FMR, farmer weaknesses; INC, weak adoption incentives; IPM, IPM weaknesses; OUT, outreach weaknesses; PST, pesticide industry interference; RCH, research weaknesses.

the statement "IPM requires collective action within a farming community" (IPM-3) as the most important obstacle. This rating differed significantly with that from high-income country participants, who rated it 28th of 51 responses for importance (df = 161; $F = 12.56$; $P < 0.01$; Fig. 2).

Analyses of ratings by region pointed to overall agreement on the importance and remedial difficulty for most of the 51 obstacles (Table S2). However, top-rated statements differed, often significantly (Table 2). For example, high-income countries rated the statement "shortage of well-qualified extensionists" (OUT-9) as one of the two most important obstacles to IPM in developing countries, but there was low agreement on its importance and difficulty across regions (Table 2).

Statistical analyses conducted on obstacle themes (clusters) showed less agreement by region than those conducted on the obstacles themselves (Table 3 and Table S2). Nevertheless, regions notably agreed on the importance of "weak adoption incentives," which was the top-ranked theme for Asia and sub-Saharan Africa (Table 3).

Discussion

Our objective was to elicit and prioritize a broad list of hypotheses to explain relatively low IPM adoption in developing countries. Our list of 51 obstacles to IPM adoption is reasonably comprehensive, but not necessarily exhaustive. For example, the list did not include the argument that, under conditions of low productivity that are common in developing countries, the yield saved by IPM vs. doing nothing may be too inconsequential to justify adoption (15). According to this argument, IPM is economically justifiable only under conditions of high productivity under which the cost of investment will be covered by increased revenue (15).

A retrospective review of our open-ended responses revealed the statement "…in regions with low yields, the economic incentive for IPM is very limited," which we simplified and coded as "IPM is too expensive" (IPM-4). However, of course, much depends on pest pressure and the extent of losses incurred by farmers. Even within subsistence systems that have relatively low productivity, a high degree of pest pressure could make IPM important. Indeed farmers may be using practices that help suppress pest numbers without necessarily being aware of the effect.

Given the ambitious scope and reach of our survey, we believe these types of omissions or simplifications are unlikely to substantially influence the outcome of our study. Indeed, many of the points raised in this study have been reported before (16), and should not be surprising. The failure of extension to function as a vehicle providing technical support and training to farmers, the lack of investment in research, and the prominence of pesticide-based solutions have long been put forward as reasons for poor IPM adoption. What is interesting is that these issues have persisted as long as they have. Clearly, all the calls for action that have been expressed since the early IPM adoption studies of the 1980s (35) have gone unheard.

However, some obstacle statements in our list appeared to be new to the literature on IPM adoption. Most noteworthy was the statement "IPM requires collective action within a farming community." This was ranked by developing-country respondents as their single most important obstacle to IPM adoption (Fig. 2). The recognition that pest management is most effective when implemented collectively at the regional level precedes IPM itself, and gave rise to the development of area-wide pest management (36) and metapopulation theory (37). Indeed, some pest management decisions are subject to a collective action dilemma (38), whereby the payoffs from adopting a technology depend on whether others adopt it too (39, 40). For example, smallholder farmers in Peru are encouraged to plow their previous-season potato fields to kill overwintering weevils before they colonize newly planted fields, but this practice is ineffective if their neighbors do not also plow their fields (41).

This phenomenon may be particularly acute for preventive, as opposed to therapeutic, management tactics, which are in fact the most heavily championed by IPM (13, 23). However, collective action may be more important for IPM in developing countries because pests can more easily move between farms that are small and therefore separated by short distances. Aware of

Table 2. Ratings by region for the most important obstacles to IPM adoption in developing countries

	Importance					Difficulty				
Code*	HIC	Asia	LAC	SSA	*P* value†	HIC	Asia	LAC	SSA	*P* value†
OUT-5	3.78	3.29	3.47	3.27	0.228	3.41	2.71	2.51	2.65	0.000
OUT-9	3.78	3.24	3.22	3.73	0.064	3.34	2.53	2.51	3.12	0.001
IPM-9	3.32	3.82	3.55	3.15	0.106	3.20	3.35	3.05	2.73	0.306
INC-2	3.68	3.41	3.48	3.85	0.821	3.10	3.00	3.08	3.27	0.874
IPM-3	3.12	3.41	4.05	3.54	0.000	2.83	2.71	3.11	2.73	0.085

HIC, high-income countries; LAC, Latin America and the Caribbean; SSA, sub-Saharan Africa.

*The statistical significance of the importance and difficulty of an obstacle according to rating by region was derived through multiple regression analyses using sex, education and field of expertise as covariates. Larger *P* values suggest greater agreement across regions.

†The letter coding describes six obstacle themes: FMR, farmer weaknesses; INC, weak adoption incentives; IPM, IPM weaknesses; OUT, outreach weaknesses; PST, pesticide industry interference; RCH, research weaknesses.

Table 3. Ratings by region for the most important themes of obstacles to IPM adoption in developing countries

	Importance					Difficulty				
Code*	HIC	Asia	LAC	SSA	*P* value†	HIC	Asia	LAC	SSA	*P* value†
FRM	3.04	2.96	3.26	3.03	0.011	2.70	2.76	2.95	2.75	0.030
PST	3.45	3.31	3.65	3.28	0.001	2.99	3.00	3.38	2.77	0.000
IPM	3.11	3.04	3.21	3.14	0.163	2.79	2.73	2.84	2.63	0.089
OUT	3.31	2.70	3.07	3.21	0.000	2.80	2.25	2.35	2.50	0.000
RCH	3.10	2.71	3.02	3.11	0.000	2.59	2.22	2.34	2.26	0.000
INC	3.36	3.35	3.53	3.44	0.205	2.76	3.10	3.00	2.85	0.006

HIC, high-income countries; LAC, Latin America and the Caribbean; SSA, sub-Saharan Africa.

*The statistical significance of the importance and difficulty of an obstacle according to rating by region was derived through multiple regression analyses using sex, education and field of expertise as covariates. Larger *P* values suggest greater agreement across regions.

†The letter coding describes six obstacle themes: FMR, farmer weaknesses; INC, weak adoption incentives; IPM, IPM weaknesses; OUT, outreach weaknesses; PST, pesticide industry interference; RCH, research weaknesses.

the requirement for collective action in IPM, farmer field schools routinely integrate this concept into their otherwise technical training programs, obtaining good results (42, 43). It is all the more surprising, therefore, that the literature on IPM adoption appears to have overlooked the collective action dilemma, which is potentially inherent to IPM, as an obstacle to its adoption.

Another key observation is that participants from developing countries often disagree with those from high-income countries on the importance of their own obstacles to IPM adoption (Fig. 2 and Tables 2 and 3). As a group, developing-country participants appear to worry significantly more about weaknesses inherent within IPM itself (e.g., IPM-3, IPM-5; Fig. 2), whereas their counterparts in high-income countries appear to worry significantly more about local capacity for implementation (e.g., OUT-5, OUT-9; Fig. 2).

This difference in perspective has not been reported in previous studies on obstacles to IPM adoption, yet is very interesting. The developed world appears to show greater faith in IPM as a desirable approach to crop protection and to consider the issue of nonadoption more to do with the ability of the developing world to implement it. Considering that the adoption of IPM in the developed world has also been questioned (16), this is an intriguing stance. However, in the developing world, this same issue is much less about capacity and more about IPM itself. Differential prioritization is also evident when developing-country region is taken into account (Table 2) and when obstacles are grouped into themes (Table 3). These findings highlight the value of improving the active participation and representation of developing-country experiences and perceptions in the IPM adoption debate.

The intention of this article is not to question the value of IPM for developing-country agriculture. On the contrary, it is because we recognize IPM's potential merits that its poor adoption seems paradoxical and worth further analysis. Indeed, this study echoes previous ones that have critically explored IPM adoption in the developing world. One is left wondering why the situation has been little improved in the more than 30 y that have passed since the problems of adoption were first raised. After all, IPM is built on some very sound principles (44). All agree that alternatives such as an extensive and unfettered use of pesticides could seriously damage the environment and indeed human health. However, why is it that, after all of the investment in IPM research and substantial promotion by major international agencies as well as national governments, and after all of the warnings about poor adoption, we are still where we are? In the developed world, the tendency has not been to question the practicability of IPM, but maybe there are questions here that need to be asked rather than avoided. We suggest a more vigorous analysis and discussion of the factors discouraging IPM adoption in developing countries may accelerate the progress needed to bring about its full potential.

Materials and Methods

As noted earlier, the survey was conceived and designed during a 4-d international workshop entitled "IPM in Developing Countries," held in Ecuador, in November 2011. The participants included biological and social scientists with significant experience in developing-country agriculture. Each workshop participant was responsible for both responding to the survey and actively promoting it within his or her own extended network of colleagues. To facilitate its dissemination, the survey was prepared in three languages—English, Spanish, and French—and conducted on the Internet, by using the Web-based platform Survey Monkey.

The concept map had three phases: brainstorming, rating, and sorting. During brainstorming, respondents were asked to use 50 or fewer words to complete the phrase: "One significant obstacle to IPM in developing countries is . . ." We considered the possibility of asking respondents for their own definition of IPM, but the research team decided against it. The authors were, of course, aware that IPM is open to different interpretations (e.g., refs. 14, 16, 17), but, when we reviewed the literature, we found that differences were small, relative to the commonalities, and they were of degree, not of kind. The continuum lies between those who see a legitimate role of pesticides within the IPM "toolbox" (i.e., the "tacticians") and those who do not (i.e., the "strategists") (16, 18).

Not surprisingly, considerable agreement exists over various other IPM components (17). Thus, by not asking each respondent to define IPM, or indeed providing one ourselves, we could cast a wider net for capturing responses to our research question. We presumed a similar rationale that discouraged Wearing (30) from providing a definition for IPM in his survey. In effect, we allowed each respondent to use his or her own vision of IPM, even though these might be complex in terms of what is seen as the central (core) and as the peripheral (desirable but not core) features, when answering questions. Although these would have been interesting to explore in the survey, as they would have provided a frame for addressing the questions, they would have probably increased the process's complexity. We favored the term "obstacle" over "barrier" because the latter, although more commonly used, is more likely to imply insuperability.

Respondents also provided the following nonidentifying demographic information: country where they are currently based, sex, highest level of education, sector, and years of developing-country IPM experience. The brainstorming session was open for 11 wk (November 7, 2011, through January 13, 2012), eliciting 413 open-ended responses. Twenty-five responses were omitted from analysis because of incompleteness, incomprehensibility, or other errors. The remaining responses were carefully studied and edited for conciseness and clarity and then consolidated into a list of 51 unique obstacle statements. We carefully chose our words to clearly separate key mechanisms that are often confounded in IPM adoption literature. For example, we included both "farmers are too risk averse" (FMR-3) and "farmers are uninterested in changing their habitual management practices" (FRM-2) to separate risk aversion (i.e., fear of an uncertain payoff) from conservatism (i.e., resistance to revise current practices) in farmer decision-making.

During the rating phase of the survey, participants were asked to rate each of the 51 unique obstacles according to their importance and the difficulty in solving them. We also asked respondents to provide their field of professional expertise, in addition to the demographic descriptors requested during brainstorming. Ratings were based on a scale from 1 to 5 (where 1 indicates "not important at all" or "not difficult to solve" and 5 indicates "extremely important" or "extremely difficult to solve"). Because this phase of the survey demanded substantially more time to complete than the brainstorming phase, we promoted it for 6.5 mo (March 8, 2012, through September 22, 2012), obtaining 163 responses.

In the final phase of the survey, 12 respondents, including nine authors of the present paper, volunteered to independently sort the obstacle statements into groups that "belong together" or "share a common theme." They were allowed to create as many or as few groups as they considered appropriate, based on their own criteria. These responses were then structured into an aggregate proximity matrix, which captured how frequently a pair of obstacle statements was placed in the same group (45). The matrix was then submitted to MDS analysis to derive statistically significant clusters. The MDS goodness of fit was estimated with a stress function, with values

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close to zero indicating a good fit. The stress value of the six-cluster MDS solution was 0.196, indicating a good fit.

Cluster dissimilarity was further tested by using an analysis of similarities that generated a statistical parameter *R*, which indicated the degree of separation between groups (where a score of 1 indicated complete separation and a score of 0 indicated no separation). After this analysis, we examined and discussed the obstacle statements within each cluster to identify their unifying theme and propose a suitable cluster name.

To visually examine global patterns within our results, we adopted the World Bank regional classification system for developing countries (http://data.worldbank.org/about/country-classifications/country-and-lending-groups), and consolidated responses from high-income countries into a single group.

We applied one-way ANOVA to identify differences in perceptions between high-income countries and developing countries of the importance and difficulty of resolution for each obstacle statement. Responses from South and East Asia and the Pacific were consolidated into a single group, and poorly represented regions were omitted. Multiple regression analyses were then applied to identify differences in ratings of statements and their cluster themes by region, using sex, education, and field of expertise as covariates. Because of an unbalanced representation, all social sciences were grouped into a single expertise category.

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