Assessing Integrated Pest Management Adoption: Measurement Problems and Policy Implications

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ABSTRACT

For more than a decade, the U.S. government has promoted integrated pest management (IPM) to advance sustainable agriculture. However, the usefulness of this practice has been questioned because of lagging implementation. There are at least two plausible rationales for the slow implementation: (1) growers are not adopting IPM - for whatever reason - and (2) current assessment methods are inadequate at assessing IPM implementation. Our research addresses the second plausibility. We suggest the traditional approach to measuring IPM implementation on its own fails to assess the distinct, biologically hierarchical components of IPM, and instead aggregates growers' management practices into an overall adoption score. Knowledge of these distinct components and the extent to which they are implemented can inform government officials as to how they should develop targeted assistance programs to encourage broader IPM use. We address these concerns by assessing the components of IPM adoption and comparing our method to the traditional approach alone. Our results indicate that there are four distinct components of adoption – weed, insect, general, and ecosystem management – and that growers implement the first two components significantly more often than the latter two. These findings suggest that using a more nuanced measure to assess IPM adoption that expands on the traditional approach, allows for a better understanding of the degree of IPM implementation.

INTRODUCTION

Integrated pest management (IPM) employs a variety of chemical, biological, and cultural mechanisms to eliminate crop pests with the goal of minimizing the human and environmental risks of harmful pesticides and other agricultural practices (EPA 1993; NCIPM 1994). Policy makers have shown considerable desire to promote IPM. For instance, in the United States (U.S.) the Clinton Administration established a national goal to implement IPM on 75% of U.S. crop acres by year 2000 (Jacobsen 1996). To achieve this goal, the U.S. Department of Agriculture developed a strategic plan that emphasizes “develop(ing) methods and conduct(ing) programs to accurately measure progress” (Jacobsen 1996). However, researchers suggest that implementation has been slow, and that farmers rarely move beyond incorporating cost-effective, targeted pesticide application (Zalucki and others 2009).

There are at least two plausible rationales for the slow implementation: (1) growers are not adopting IPM - for whatever reason - and (2) current assessment methods are inadequate. In addressing the latter point, the traditional approach to assessing IPM adoption is to rely on checklist inventories of practices and assess IPM as a monolithic management technique (e.g., Jasinski and others 2001). Researchers typically develop a list of IPM practices, survey growers by phone or mail, and sum adopted practices to calculate an overall adoption score (McDonald and Glynn 1994; Shennan and others 2001; Jasinski and others 2001; Malone and others 2004; Robertson and others 2005). However, the types and numbers of IPM practices included across surveys vary considerably (even for similar crops), which affects the accuracy of adoption estimates.

Similarly, variations also exist in how researchers arrive at their overall IPM score. Scores may be directly weighted because some practices are considered “more important” *a priori*

(Shennan and others 2001; McDonald and Glynn 1994; Robertson and others 2005). Yet, determination of weights is arbitrary and lacks consensus within the research community. In other instances, surveys emphasize some IPM practices more than others thereby indirectly giving these practices more weight in their overall IPM score. Both situations inadvertently misrepresent growers' IPM adoption.

Another factor impeding assessment of IPM adoption is that the implementation process is generally regarded as a binary event (Nowak and others 1996). In actuality, it more likely encompasses identifiable stages (Nowak and others 1996). We predict that these stages will cluster around particular management components which growers readily adopt or de-emphasize because of crop, location, and market needs and that the traditional method of summing IPM practices fails to account for this. By identifying these IPM clusters, government officials can allocate scarce resources towards targeted programs that encourage less prevalent, but equally beneficial IPM components.

We address these concerns by developing a nuanced approach of assessing IPM adoption that accounts for the *components* of IPM implementation. We define an IPM component as the individual IPM practices that aggregate into common agricultural management themes. We begin by using the traditional summation approach to assess implementation and compare it to our proposed methodology for cotton growers in North Carolina. Using principal components analysis, we ascertain whether clearly defined components of IPM exist among homogeneous growers of a given crop within a geographic region. If so, then distinct components of IPM likely exist among heterogeneous growers as well. We posit that if growers implement IPM based on particular management foci, a more sensitive localized approach may be needed to account for IPM implementation and determine progress towards achieving national IPM adoption goals.

Such an approach would also offer greater potential value to local government officials trying to promote widespread IPM adoption.

THE PRACTICE OF ASSESSING IPM ADOPTION

IPM generally is defined as an adaptive pest management system that utilizes all suitable techniques and methods to maintain the pest population at levels below those causing environmental and economic harm (Kogan 1998; Speight and others 1999). Originally conceptualized to involve only the judicious use of insecticides, IPM has evolved to include the agricultural management of all types of pests (weeds, pathogens, nematodes, etc.) and an understanding of ecosystem and food-web processes. Additionally, IPM includes societal factors (Wearing 1988; Bajwa and Kogan 1997; Ehler 2006), such as incorporating information put forward by farmers that leads to revisions and updates of IPM standards for a given crop or region. Within the U.S., IPM received support from the Nixon and Carter Administrations. However, national focus did not occur until 1992 when the National IPM Forum brought together 600 U.S. scientists, growers, educators, regulators, food processors, marketers, agribusinesses, and environmental and other public policy activists to call for government leadership related to IPM (Jacobsen 1996). Following on the heels of this forum, in 1993 the Clinton Administration's U.S. Department of Agriculture (USDA), Environmental Protection Agency and Food and Drug Administration testified before Congress stating by the year 2000 their goal was to have IPM practices implemented on three-quarters of the nation's crop acres (Jacobsen 1996).

To put this national IPM goal into practice, in 1994 the USDA developed a strategic plan for a department-wide IPM Initiative. The plan emphasized four objectives, one of which was to "develop methods and conduct programs to accurately measure progress toward the 75 percent

IPM goal" (Jacobsen 1996). In response to the federal IPM goal, previous research has largely relied on the use of surveys to assess IPM adoption as a single encompassing practice (e.g., McDonald and Glynn 1994; Shennan and others 2001; Jasinski and others 2001; Malone and others 2004; Robertson and others 2005). In each instance, researchers developed a list of IPM practices and surveyed growers either by phone or mail surveys. Growers were then assigned a single IPM score based on a summation of practices employed. However, one critical aspect that complicates the ability of government agencies and researchers to assess IPM adoption is the complexity of the practice itself, and how different communities regard it.

The scientific community generally regards pest management to be part of a continuum. At one end of the continuum is conventional agriculture, which includes the application of broad-spectrum pesticides at crop-specific calendar dates (Kogan 1998). Marginal adoption of IPM involves the selective use of pesticides, crop rotation to reduce pest build-up in a local area, and inaction thresholds of pest densities below which pesticides are not used because pest control is not economically profitable (Kogan 1998). Complete adoption of IPM includes population-level practices such as incorporating biorational pesticides; adopting other, general (community-level) biological processes for pest control such as multi-crop interactions, associational resistance (Barbosa and others 2009), or biological control; and including ecosystem level approaches such as tree borders to increase insectivorous bird abundance and reduce wind-aided soil losses (Kellerman and others 2008). This view of complete adoption arises from the traditional paradigm that biological systems are ordered hierarchically – that biological systems operate as a nested continuum of natural systems from population to ecosystem-level scales (Odum and Barrett 2004) and that growing practices which more accurately mimic functioning ecosystems will present the least human and environmental risks (Lewis and others 1997; Groom and others

2005). The "integrated" aspect of IPM, therefore, refers to the idea that effective, reduced-risk pest management incorporates integrated, hierarchical levels of biological organization, in addition to using (i.e., integrating) multiple growing practices and pest management techniques.

Similarly, the extension service community, considers IPM adoption to take place in a series of stages identified by the USDA as prevention, avoidance, monitoring, and suppression[1] . Growers are considered to have adopted IPM if they utilize practices that can be classified into three of the four PAMS stages. Reliance on this approach emerged as growers and policy makers increasingly recognized that in practice IPM adoption was implemented in a piecemeal fashion (McDonald and Glynn 1994), where growers pick and choose among multiple management practices. The PAM approach to IPM adoption normally occurs along a continuum, with practices largely reliant on prophylactic control measures that exist at one end and pesticides to multiple-strategy biologically intensive approaches on the other (Coble 1998). Thus, the PAMS approach appears to adopt a view of IPM similar to that of the scientific community inasmuch as biologically intensive approaches imply the employment of ecosystem-level techniques.

However, a shortcoming of the PAMS definition is that growers may adopt strategies from three or more of the PAMS stages, and yet fail to manage pests in a way that is recognized to be complete IPM adoption from the perspective of the scientific community. For example, a grower may plant a transgenic crop bred for pest-resistance (avoidance), scout fields for pests (monitoring), and use economic thresholds for pesticide application (suppression). Although these practices would constitute minimal IPM adoption, the overall approach is not biologically intensive or integrated at community or ecosystem levels of biological organization. Moreover, in spite of the emergence of PAMS, in practice IPM adoption is typically assessed by researchers

[1] See USDA Regional IPM Centers Information System. *The Practice of Integrated Pest Management (IPM). The PAMS Approach* (www.ipmcenters.org/Docs/PAMS.pdf) for examples of activities related to each of the four IPM practices.

and government by summing grower practices rather than categorizing individual practice as prevention, avoidance, monitoring, or suppression.

Adding to the complexity regarding of measuring IPM adoption thresholds is that the general public tends to view IPM as a binary event that either exists or not (Nowak and others 1996). These differing perceptions complicate how IPM is assessed and understood.

Other IPM factors contributing to IPM assessment problems relate to the fact that surveys of growers' activities have varied greatly in their emphasis given to certain IPM practices. In some instances, scores were weighted because some practices were considered *a priori* to be "more important" while other practices were given less weight (Shennan and others 2001; McDonald and Glynn 1994; and Robertson and others 2005). However, the process of determining these weights is subjective and lacks agreement among the research community. The outcome of an unbalanced IPM adoption scale is that the checklists can inadvertently misrepresent grower behaviors. For instance, growers who are high in one IPM component, like weed management, may not be high on other components. As such, IPM adoption scales that include a disproportionate number of items related to weed management would conclude that these growers have "high" degrees of IPM adoption while another IPM scale that includes more items related to other IPM components would rank the same growers as having "low" degrees of IPM adoption. Moreover, while the national IPM goal is useful in initiating a target for IPM adoption and opening a discussion about the merits of these practices, it generally does not encourage an analysis beyond the creation of overall IPM scores.

We anticipate that adoption stages cluster around particular management components which growers readily adopt or de-emphasize because of their crop, location, market needs, or other factors, such as technical difficulty and product availability. For example, weeds may be a problem for a specific crop (or location), whereas damaging insect pests may not, and a grower may implement IPM techniques exclusive to that weed problem but may or may not do so manner that constitutes complete IPM adoption. However, by relying on traditional IPM measures (which arrive at an overall IPM score), researchers necessarily de-emphasize the fact that growers may focus on implementing particular components of IPM (over others) and do so in a comprehensive way. For instance, within a particular region, overall IPM adoption may be low, in large part because growers have implemented few general management and ecosystem management practices. However, growers within this same area may implement extensive weed management and insect management practices.

In the absence of this knowledge, local policy makers are challenged with determining how they should allocate their scarce resources towards encouraging more widespread IPM adoption. By understanding how local growers are implementing IPM and what practices they have chosen to emphasize, local officials have an opportunity to design more targeted programs that address less prevalent, but equally beneficial IPM components.

We address these research concerns by utilizing a novel empirical approach to ascertain whether clearly defined components of IPM exist among homogeneous growers with respect to crop and geographic region. If so, then it is likely that distinct components of IPM exist among heterogeneous growers as well. While previous research (Hammond and others 2006) has successfully used a check-list approach to identify farm characteristics (e.g., farm size or type of crop or commodity) that contribute to IPM adoption among heterogeneous growers, we address concerns that growers are less likely to adopt more complex, difficult to implement multi-species and ecosystem-level IPM techniques (Speight and others 1999). We do so by first determining if such categories exist and then assessing the degree to which they are adopted by growers implementing pest management on similarly sized farms, in a given region, for a single crop. Our position is that if growers implement IPM based on particular management foci (such as weed management and other factors), a more sensitive localized approach to IPM measurement may be needed to account for their implementation of these management practices. Such an approach can assist policy makers with more accurately assessing IPM prevalence. It also would offer information about how growers are implementing IPM within their region and the obstacles that prevent more widespread IPM adoption. The following section describes our approach.

METHODS

Data Source

To examine relationships of interest, we examined cotton growers in eastern North Carolina. By selecting a single crop and location, we sought to control the significant variation in IPM adoption that typically exists across crops and regions. We chose cotton because it is not expected to meet the stringent cosmetic quality standards applied to consumable crops (e.g., fruits and vegetables). Such standards encourage little tolerance for superficial product irregularity and therefore advance calendar spraying of insecticides. For cotton, cosmetic quality matters less than fiber quality, making growers more likely to consider implementing IPM practices. Moreover, cotton's economic value is affected more by crop quality than is the case for other crops such as hay or alfalfa. Consequently, while cotton growers have flexibility with respect the crop's cosmetic appearance, they have greater economic pressure to make effective decisions regarding amounts of pest damage and potential IPM practices. Focusing on a single crop also allowed us to control for crop-specific variations in alternative weed control technologies, ecological factors (Fernandez-Cornejo and Jans 1996), and variation in the number of relevant insect pests. We limited our analysis to cotton production in eastern North Carolina counties (Edgecombe, Martin, Pitt, and Johnston County). Since cotton is prevalent in this region (NCDACS 2006), our population of growers was relatively large. Evaluating this four-county area also permitted us to control for confounding abiotic and biotic (i.e. pest) and socioeconomic factors which may affect IPM adoption across broader regional settings.

A list of growers operating conventional (non-organic) farms from these counties was compiled with assistance from state extension agents. Between June and August 2006, 94 growers were contacted by telephone. Twenty-two growers (23.4%) agreed to be interviewed, which is a rate comparable to that reported in other IPM surveys (e.g., 24.6% in Malone and others 2004; 22% in Hammond and others 2006). Growers were interviewed at a location of their choosing (typically in their fields), and interviews were tape-recorded.

To control for potential biases associated with interviewer effects (Pedhauzur and Schmelkin 1991), one of the study's authors, trained in primary data collection, performed all interviews, adhered to a standardized interview structure, and guaranteed growers' anonymity. An advantage to this approach is not only that instrument effects were minimized, but also that respondents could seek clarification regarding the intent of each question, and receive consistent responses. Interviewer effects were further reduced by incorporating Nederhof's (1984) suggestion that pertinent questions should involve forced-choice items.

Growers' mean age was 49.9 years, and similar to the mean age for cotton growers in North Carolina (53 years) (USDA NASS 2002). The mean number of acres of cotton planted in 2005 was 764.9, slightly higher than the state mean acreage per farm (~442 acres/farm) (USDA NASS 2002).

Data Analysis

To develop our preliminary IPM scale, we reviewed existing scholarship to determine the range of IPM practices previously evaluated. We found 7 published studies that had assessed IPM adoption by considering a variety of grower practices for crops such as corn, cotton, grains, fruits and vegetables. After removing crop-specific practices, we identified 18 items (Table 1) consistently acknowledged in the scholarly literature as IPM best practices. We asked growers whether they had used each of these practices in the previous two growing seasons. Growers responded by indicating “yes” or “no.” The first 17 survey items were coded “yes” = 1, and “no” = 0. The last item was reversed coded so that “yes” = 0.

Before administering the survey, we validated our instrument by reviewing items with state extension personnel specializing in cotton production. Additionally, the survey was pilot-tested with two growers who were asked to comment on whether any of the questions needed clarification.

We analyzed grower interview responses using two approaches. First, we followed the typical procedure of summing growers’ IPM practices to arrive at an overall implementation score (percent of complete IPM adoption). Next, we used principal components analysis (PCA) to assess the utility of a monolithic IPM score versus assessing distinct components of IPM adoption. Once unique IPM components were identified, we then used the traditional summation approach to calculate an IPM implementation score for each component. Doing so allowed us to compare the degree of implementation among IPM components. We utilized a two-sided t statistic to determine if mean levels of IPM implementation differed statistically across components.

In undertaking the PCA, we began by examining our data to determine which survey items were appropriate for inclusion in our final scale (DeVellis 1991). This step was particularly important since previous IPM surveys using the traditional approach had not verified the quality of their IPM scales. Problems associated with poor scale quality would reduce the internal reliability, or the degree to which a scale produces similar results if used again in a similar setting, thereby diminishing the overall quality of a measure. To examine our scale's internal reliability, we utilized Cronbach's α, the most widely accepted internal reliability measure (Cronbach 1951, O'Sullivan and others 2003), which accounts for the total number of items in the scale, the sum of the variances of the items, and the variance of the total score (Pedhazur and Schmelkin 1991). Resulting α coefficients range between 0-1 with more highly correlated items being closer to 1 (O'Sullivan and others 2003). Alpha scores of 0.6-0.8 are considered sufficient indicators of internal consistency (Nunnally 1978). An acceptable Cronbach's α indicates that the items or subparts of the instrument measure aspects of the same phenomenon (Pedhazur and Schmelkin 1991).

A scale might be unreliable for several reasons, including weak or no variability among items, item ambiguities, and low item correlations (DeVellis 1991). To address low variability in our responses, we removed survey items that failed to distinguish IPM adopters from non-adopters. In such instances, growers answered either all "yes" or all "no" for that item, causing no variation among responses. Item ambiguities are caused by poorly worded survey questions that reduce a scale's performance, whereas low item correlations are related to survey questions that are unrelated to other survey items (DeVellis 1991). To identify these concerns, we calculated an α value for all remaining items in the IPM scale and for the scale minus each of the remaining items. If α values increased with the deletion of an item, this would suggest potential problems related to item ambiguity or low item correlation. In such instances, we re-examined the rationale for including them, assessed how they related to other items, and reviewed interview transcripts to identify sources of weak correlation. After removing questionable items, α was recalculated to ensure that remaining items improved the α value (DeVellis 1991).

Once the final IPM scale was established, we used PCA with varimax rotation and Kaiser normalization (Tabachnick and Fidell 2001). In the absence of determining the reliability of our IPM scale, we would have little confidence in the results of our PCA since they would be based on potentially spurious correlations. Since correlated survey variables are aggregated into a single component, PCA addresses the problematic issue that plagues unbalanced surveys, and which potentially bias the traditional IPM measurement approach.

PCA represents components as vectors, or axes that signify linear combinations of original variables. Each identified axis is uncorrelated to other axes and is given a score (eigenvalue) that represents the amount of variance in the data that it explains. Survey items are then given scores (factor loadings) that represent how they contribute to each component. If growers' responses to items load as a single aggregated axis, we would have evidence that growers adopted IPM as a single technique, yielding evidence for the merits of utilizing a monolithic IPM score. Such a finding would offer support for the traditional approach of assessing IPM adoption by summing IPM practices. However, if responses aggregated along multiple axes (with high eigenvalues), this outcome would suggest that growers adopt IPM based on specific "components" of management focus. These findings would offer evidence of the limitations of the traditional summation approach to assessing IPM adoption. Components with an eigenvalue greater than one were retained. All analyses were estimated using SPSS (v 10.0).

RESULTS

Traditional Summation Approach

Using a checklist summation approach, average IPM adoption within our sample was 75% – growers adopted 13.6 of the 18 IPM items (see Figure 1). Overall, growers in this area fall short of Jasinski and others’s (2001) adoption standard that growers utilize at least 80% of survey items to be considered IPM adopters, indicating that government officials should work with growers to help them meet the national goal. However, these findings offer little information regarding what IPM themes government should emphasize in its assistance programs in an effort to encourage broader IPM adoption

Principal Components Analysis

In undertaking our proposed IPM measurement approach, we first examined survey items to assess their variability and reliability. Prior to conducting analyses, we identified and removed four invariant items that failed to distinguish IPM adopters from non-adopters because all growers responded similarly. All growers responded “yes” to items 1 (scouting fields), 2 (using economic thresholds for insects), and 15 (sampling soil for nutrients), and all growers responded “no” to item 18 (calendar-based spraying). At the time, economic thresholds and non-calendar based spraying for cotton pests were emphasized heavily by North Carolina extension agencies, and extension agents often provided free soil sampling services. Likewise, extension agencies and pesticide companies provided scouting services as a means of education or product promotion, respectively. Thus, these practices were universally employed. These findings suggest that within this sample government officials’ assistance programs that promote these matters have been successful.

An ambiguous question elicits unreliable data because it can be interpreted in ways that deviate from the question’s central intent. In step with DeVellis’ (1991) concern that the items comprising a measurement scale be free of ambiguities, five other survey items (items 3, 5, 10, and 17) were removed. Removal of these items increased the scale’s α-value. The first ambiguous item, item 3, was identified after responses were examined by a cotton extension specialist for their face validity. In his opinion, responses for item 3 (using economic thresholds for herbicides) were artificially inflated because there were no well published economic thresholds for the most common weeds seen in cotton. Consequently, item 3 was removed.

The second questionable scale item (item 5) was identified by evaluating response frequencies. Only 1 grower failed to rotate his crops. Interview transcripts revealed that this grower rotated crops on a four year cycle. However, since the survey asked only for the most recent two years, none of his cotton acres had moved. If we credit this grower with rotating crops, there was no variation among responses; therefore, item 5 was removed.

A third item (item 10 – selecting seeds for drought tolerance) was *negatively* correlated with many other survey items. The most probable reason was that this particular practice was not relevant at the time for Southeast cotton growers. While drought resistance is a major consideration for seed selection in the western U.S., most cotton grown in the Southeast during our survey did not require more moisture than the environment provided and local seed distributors did not carry such varieties (Luttrell 1994). Also, all growers responded that they used genetically modified seeds, which were only produced by a few vendors, limiting the growers' ability to select alternative traits. Because this item likely was influenced by local availability, item 10 was removed.

Item 17 (hiring a consultant trained in IPM) was ambiguous because some growers answered "no" since their consultants provided in-kind services (for example, one grower's brother was a consultant, and therefore was not 'hired'). Other growers were confused about whether the state extension agents and chemical company representatives were considered 'consultants'. Because of these ambiguities, item 17 was removed from the scale.

Item 16 (contacting the extension service) was poorly correlated with other survey items. The most likely reason is that communications with an extension agent may or may not change a grower's subsequent IPM behavior. For growers who do change subsequent management behaviors, these changes may be related to one IPM practice or another. As a consequence, these communications are not strongly correlated with any particular IPM practice. Because of this issue, item 16 was removed from the scale.

After modifying our IPM items according to DeVellis' (1991) criteria, our pared scale of IPM practices consisted of nine items (see Table 1). These items represent Kogan's (1998) full continuum of IPM practices—from minimal adoption (selective application of pesticides) to community-level processes (items 8,9,11). The resulting Cronbach's α was 0.614, indicating sufficient internal reliability of our scale. These findings point to another limitation of the traditional summation approach in that the reliability of the original 18-item IPM scale was poor and question ambiguity associated with mail surveys can lead to inaccurate IPM adoption estimates.

PCA separated the nine survey items into four principal components having eigenvalues >1 and accounting for 68.8% of variance in growers' responses (Table 2). The three items (selecting insecticides, fungicides, and herbicides that have low environmental impacts; alternating pesticides having different modes of action or using multiple modes of action for herbicides; and using reduced-till, no-till, or conservation tillage) loaded on the first component and were categorized as "weed management" strategies.

The two items (alternating mode or using multiple modes of action for insecticides and selectively applying pesticides in hotspots) that weight the second component are considered "insect management." Selective pesticide application could also be considered a weed (herbicide) treatment. However, in the population we surveyed, all growers used broadly-applied

Round-up™ as their primary herbicide, so any selectively applied pesticides were, in fact, insecticides.

The three items (planting cover crops, planting buffer zones, and timing plantings to minimize the risk of outbreaks) comprised the third component, and were categorized as "general management" because these practices improve plant health and reduce soil erosion. Finally, two items (planting buffer zones and using biological control) loaded on the fourth component, and were categorized as "ecosystem management". While buffer zones can function as an erosion prevention measure, they can also serve as alternate habitat for biological control agents, which may explain why this item loaded on both components. This point emphasizes the fact that an advantage of using the multivariate approach to analyzing survey data is that it allows for some overlap in categories such that factors may have weight on multiple ordination axes.

Our next step was to sum grower practices within each IPM component identified in our PCA. Results show that approximately 79% of growers were undertaking weed management, 76% were utilizing insect management, 62% were undertaking general management practices, and 55% were utilizing ecosystem management practices (Table 2). These findings indicate that when applying Jasinski and others's IPM definition, many growers in this area were close to meeting IPM expectations for weed and insect management, in that implementation among the two did not differ statistically. However, they were less likely ($p<0.05$) to implement general IPM management practices, such as timing their plantings to minimize pest outbreaks and planting cover crops. They also were less likely ($p<0.05$) to use ecosystem management techniques such as using biological controls or utilizing plant buffer zones.

DISCUSSION AND CONCLUSION

While IPM has been promoted by the U.S. government for decades, its widespread implementation has been slow. We suggest that this situation may in part relate to the traditional approach to assessing IPM implementation, and the subsequent assistance programs that are put forward by government officials. We address these concerns by assessing the components of integrated pest management adoption. Our results suggest that in this setting there are four broader management components: weed management, insect management, general management, and ecosystem management. Because the analysis did not produce a single management focus, our findings indicate that, rather than adopting all IPM practices as a single unit or as a truly "item by item" approach, growers within this region adopt broader components of IPM practices based on common management foci. For example, a grower who adopts weed management practices may not adopt ecosystem management practices.

By partitioning the various components of IPM adoption, one contribution of our approach is that it more accurately reflects growers' IPM practices and overcomes issues related to scale emphasis. That is, although many IPM practices appear repeatedly in researchers' traditional IPM scales, scales are arbitrarily prone to having more emphasis placed on certain practices than others, which can inadvertently misrepresent grower behaviors. For instance, our results show that many growers adopted weed and insect management, but not general and ecosystem management practices. As such, IPM adoption scales that include a disproportionate number of items related to weed and insect management (and that are then summed to arrive at a general IPM score) would rank these growers having greater degrees of IPM adoption while another IPM scale that includes more items on ecosystem quality would rank the same growers as having lower degrees of IPM adoption. Our suggestion is that surveys assessing IPM adoption should begin with the list of practices provided in Table 1, and utilize the summation approach, but couple it with Cronbach's α and PCA or other appropriate ordination techniques. Doing so would remove the unintentional weighting associated with multiple items measuring similar IPM components, and offer a more objective way to assess IPM adoption generally. Items omitted from our survey because they were not applicable to cotton growers would need to be re-incorporated as appropriate for studies of other crops.

In contrasting the summation approach with PCA, another contribution of this research is that our proposed measurement technique offers greater information to government officials. The results of this research allow government to determine whether growers within a region are implementing IPM components uniformly. To the extent that growers as a whole are emphasizing some components over others, government can use this information during outreach to encourage the greater overall adoption of lagging (but equally important) IPM components. The approach we propose can assist this process. It also offers policy makers information about the possible barriers that may exist to adopting certain IPM components, such as access to effective ecosystem management information or poor diffusion of general IPM technology (Wearing 1988).

Future research would benefit from understanding why growers fail to adopt more complex, strategic components of IPM. While we controlled for crop and geographic location, differences among the four groups of IPM adopters identified may represent underlying ecological variation among farms. For instance, adopters of weed control may not emphasize insect control because insect pests may be less of an economic concern in areas dominated by weed problems and vice versa. If true, this would substantiate arguments by Zalucki and others (2009) that IPM is best implemented at local or landscape levels (i.e. area-wide management). Future research also should consider which IPM components more effectively control pests and if effectiveness varies with crop or location. Understanding these issues would bridge the theoretical and practical concerns of understanding IPM adoption and assist policy makers in achieving more widespread IPM implementation (Eshuis and Stuiver 2005; Ehler 2006). Further, we recommend that additional scholarship is needed towards developing a more comprehensive set of IPM questions – that demonstrate high internal reliability – to obtain a more comprehensive understanding of growers' IPM practices. The value and true meaning of our results and any future research assessing IPM adoption will depend on the quality of the questions that are included in the surveys and interviews related to growers' practices.

In summary, this study develops an innovative method to assess IPM adoption that accounts for the components of IPM implementation. Our results indicate that this approach has merit even when assessing IPM practices of homogeneous growers. It circumvents inadvertent misrepresentation of grower behaviors because of unbalanced checklist surveys, ensures the validity of the IPM scale, and systematically assesses specific components of IPM adoption. Understanding growers' implementation of these components offers government officials crucial information towards designing targeted outreach efforts that encourage growers to adopt less used, but potentially beneficial IPM techniques. By focusing attention on growers' implementation of IPM components, government officials and researchers alike may more accurately understand IPM adoption and the obstacles preventing IPM's more widespread use and effectiveness.

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Table 1: Integrated Pest Management Practices Evaluated in Previous Studies*

IPM Practice (Survey Item)	Study
1. Scout your fields for insects, weeds, and diseases	Drost and others 1996, Malone and others 2004, McDonald and Glynn 1994, Fuglie and Kascek 2001, Jasinski and others 2001, Hammond and others 2006
2. Use economic thresholds to determine when to apply insecticides for insect control	Malone and others 2004, McDonald and Glynn 1994, Fuglie and Kascek 2001, Jasinski and others 2001, Hammond and others 2006
3. Use economic thresholds to determine when to apply herbicides for weed control	Malone and others 2004, McDonald and Glynn 1994, Fuglie and Kascek 2001, Hammond and others 2006
4. Select insecticides, fungicides, and herbicides that have low environmental impacts	Malone and others 2004, McDonald and Glynn 1994
5. Crop rotation	Drost and others 1996, McDonald and Glynn 1994, Jasinski and others 2001, Hammond and others 2006
6. Rotate the mode of action or use multiple modes of action for herbicides	Malone and others 2004, Hammond and others 2006
7. Rotate the mode of action or use multiple modes of actions for insecticides	Malone and others 2004, Hammond and others 2006
8. Plant cover crops	Drost and others 1996, Malone and others 2004, McDonald and Glynn 1994
9. Plant buffer zones	Jasinski and others 2001
10. Select seeds based on drought tolerance or disease resistance	Malone and others 2004, Jasinski and others 2001, Hammond and others 2006
11. Use biological control to reduce insects, weeds, and diseases	McDonald and Glynn 1994, Fuglie and Kascek 2001, Hammond and others 2006
12. Use reduced-till, no-till, or conservation tillage	Luttrell 1994, Drost and others 1996, Malone and others 2004, Fuglie and Kascek 2001, Jasinski and others 2001
13. Time your plantings to minimize the chance of pest outbreaks	Malone and others 2004, Jasinski and others 2001, Hammond and others 2006
14. Selectively apply pesticides in "hotspots" as opposed to blanket applications	Malone and others 2004, McDonald and Glynn 1994, Jasinski and others 2001, Hammond and others 2006
15. Sample your soil for nutrients to fertilize to the extent needed	Drost and others 1996, Fuglie and Kascek 2001, Jasinski and others 2001
16. Contact the extension service for advice about a specific IPM problem	Jasinski and others 2001
17. Hire a consultant who has been trained in Integrated Pest Management	Jasinski and others 2001, Hammond and others 2006
18. Use calendar-based spraying for insects other than thrips	Malone and others 2004, Jasinski and others 2001, Hammond and others 2006

* Bolded items represent those included in the pared IPM scale, which were included in the PCA.

Figure 1. Percent Adoption of Individual IPM Practices by North Carolina Cotton Growers

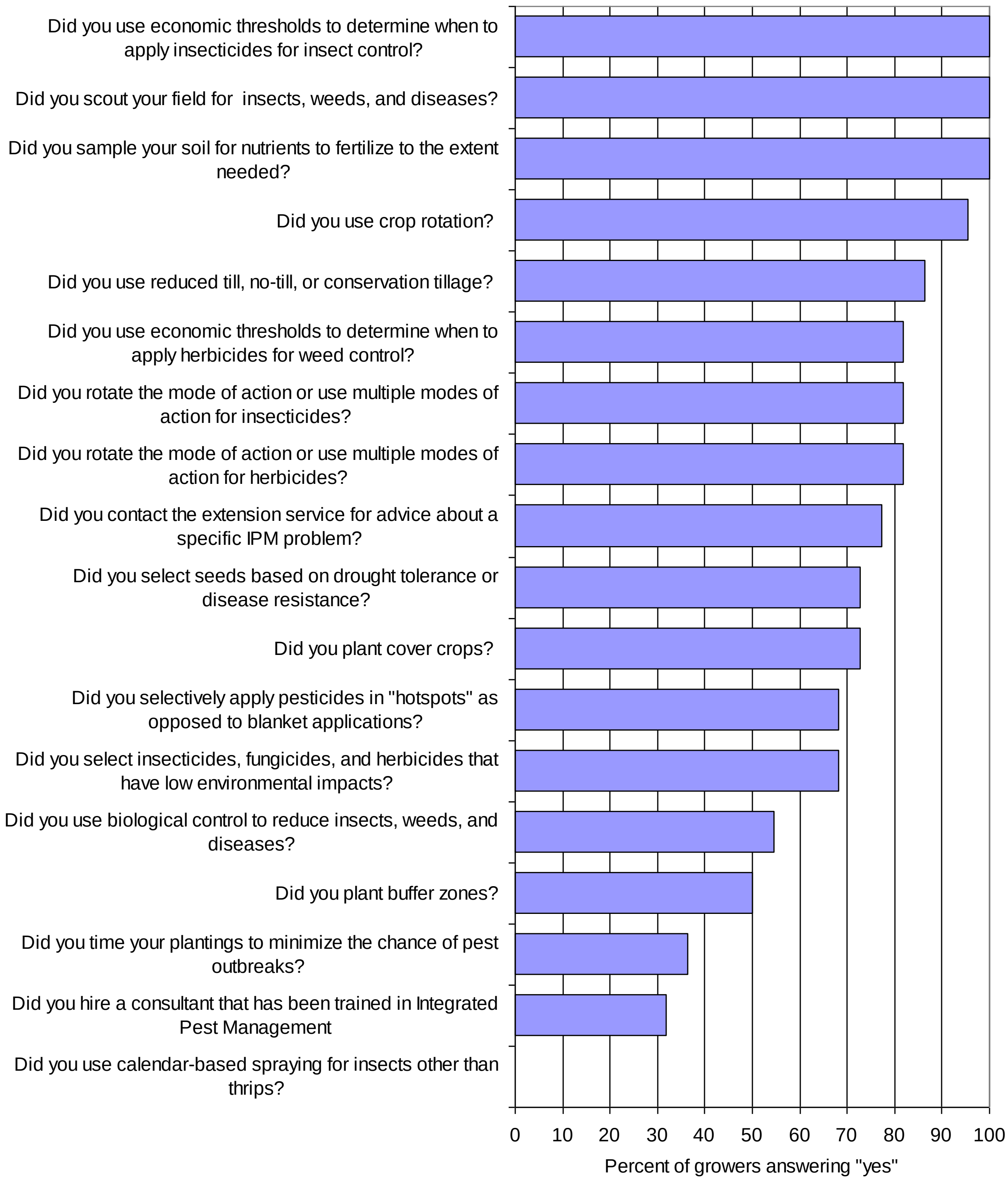

Table 2: Principal Components of IPM Adoption[*]

	IPM Component			
Survey Item	***Weed Management***	***Insect Management***	***General Management***	***Ecosystem Management***
Did you select insecticides, fungicides, and herbicides that have low environmental impacts?	**.741**	-.058	-.011	.322
Did you rotate the mode of action or use multiple modes of action for herbicides?	**.752**	-.080	.476	.046
Did you use reduced-till, no-till, or conservation tillage?	**.799**	.197	-.073	-.329
Did you rotate the mode of action or use multiple modes of action for insecticides?	.194	**.746**	.052	.274
Did you selectively apply pesticides in hotspots?	-.129	**.852**	.095	-.029
Did you time your plantings to minimize the chance of pest outbreaks?	.097	.064	**.828**	-.162
Did you plant cover crops?	.038	.398	**.513**	.216
Did you plant buffer zones?	-.034	-.015	.532	**.574**
Did you use biological control?	.057	.260	-.118	**.795**
Percent of growers implementing bolded IPM items	***79%***	***76%***	***62%***	***55%***

[*] Bolded items have the greatest explained variance in growers' responses. Extraction method was principal component analysis with Kaiser normalization.