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RESEARCH ARTICLE

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Abstract The huge research efforts to develop integrated pest management (IPM) have failed to reduce pesticide use and to foster IPM adoption by farmers. Indeed, despite five decades since the concept of integrated control and threshold theory was developed, and four decades since IPM programs have been implemented in USA, Asia, Latin America, Australia, and India, the widespread use of complex IPM practices has not been adopted. This failure can be explained by IPM complexity, policy restrictions, and counteracting forces of the pesticide industry. This article is a study of drivers that rule the adoption or rejection of IPM by 150 farmers from the Indian state of Punjab. Cotton was cultivated under an insecticide resistance management-based IPM program. This program was implemented in Punjab from 2002 to 2007. A rating scale was developed to measure farmers' perceived attitudes. An adoptability index was developed. Results show that farmers exhibited very different adoption attitudes. Specifically, farmers adopted widely practices that have no complexity, higher economic advantage, and observability. IPM practices with adoptability indices higher than 0.60 have been widely adopted. The predicted adoptability and effective actual adoption of IPM practices were well correlated with a correlation coefficient of 0.88. Technological attributes complexity and relative economic advantage induced a variation of 99 % in the adoptability. Overall the findings show that relative economic advantage, benefit visibility, compatibility with past experiences, and complexity are the most effective drivers in predicting adoption or rejection. Whereas, unexpectedly, socio-personal and economic factors used by most scientists are relatively insignificant. The new methodological frame can be applied to predict the adoption of agricultural innovations.

Keywords IPM · IPM attributes · Adoptability · Adoption

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1 Introduction

In India, many integrated pest management (IPM) programs have been implemented to reduce the overreliance on pesticides (mainly insecticides) in cotton and rice. The first IPM program in these crops was conducted under the Operational Research Project (1974–1975). Under this project, location-specific IPM technologies were developed in both crops. But it was only in the mid 1980s that the government of India re-oriented its plant protection strategy. Since then, several new IPM programs were implemented in India; these include: the Food and Agriculture Organization (FAO)-Inter Country Program for IPM in rice crop in 1993, the Regional Program on cotton-IPM by the Commonwealth Agricultural Bureau International (CABI) in 1993; the FAO-European Union IPM program for cotton in 2000; the National Agricultural Technology Project for IPM in 2000; and most recently, the Insecticide Resistance Management (IRM)-based IPM program in cotton (Fig. 1) by the Central Institute for Cotton Research (CICR), Nagpur in 2002 (Peshin et al. 2007). CICR, Nagpur and the Asian Development Bank, CABI, and the Directorate of Plant Protection Quarantine and Storage, Government of India, are promoting IPM to farmers since 1994. However, regardless of these efforts, the adoption of IPM practices has remained low (Peshin et al. 2009a).

The main reason for the low adoption of IPM practices among Indian farmers is the requirements for new knowledge and analytical skills associated with newer

Fig. 1 Training session in insecticide resistance management farmer's cotton field. The farmers were imparted with skill training in cotton fields for observing insect pests and their natural enemies present in cotton ecosystem during the Insecticide Resistance Management (IRM)-based Integrated Pest Management program in cotton. In case of complex technologies like IPM, farmers' fields should be used as a laboratory for imparting hands-on training to farmers

technologies. Other reasons include program efforts of the implementing agencies, policy requirements, counteracting forces such as pesticide lobby, and IPM technology attributes. The attributes of a technology as perceived by farmers are considered important for determining the rate of adoption. Roger (1962, 1983, 1995, 2003) generalized five attributes of an innovation causing variance in the rate of adoption of a technology, namely relative advantage (economic benefits, social prestige, initial cost, saving of time and effort, immediacy of reward), compatibility (perceived as consistent with the existing values, past experience, and needs of potential adopters), complexity (defined as the degree to which an innovation is perceived as relatively difficult to understand and use), trialability (an innovation may be experimented with on limited basis before it is adopted), and observability (visibility of the benefits). These technological attributes affect the rate of adoption from 49 to 87 % (Roger 2003). The research that studies the effect of the attribute variables of a technology on the rate of adoption or adoption per se has been, however, meager (1 %) compared to socio-personal/socio-economic variables (58 %) (Roger 2003). The adoption studies in different disciplines namely rural sociology, economics, agroforestry, and extension education have also mostly analyzed the role of socio-economic variables effecting the adoption (Roger 2003; Pattanayak et al. 2003). This has led to the diffusion theory not being utilized to predict the likely adoption of technologies. Fliegal and Kivlin (1966) have worked on the technological attributes but in ex post study, to determine the farmers' perception of attributes to explain the rate of adoption. In marketing diffusion, the Bass forecasting model is the most significant impetus to predict the diffusion of new consumer products (Bass 1969). The Bass forecasting model reduced the uncertainty associated with introduction of a new product in the market place and this model was used by Kodak, IBM, and other large US corporations. Bass model has also been used to predict the diffusion of educational ideas (Lawton and Lawton 1979), pesticide use in coco (Akinola 1986), and pest management (Rebaudo and Dangles 2011). Bass model made a contribution to the prediction to forecast rate of adoption at future time periods based on interpersonal communication channels, mass media, and time.

Predicting the adoptability of agricultural technologies developed by scientists at experimental stations/universities may help take into account the farmers' perceptions about them. This in turn will provide researchers with empirical data, so that future research grants curtail wasteful expenditure. For example: Millions of taxpayers' money have been spent on the development of IPM technologies in the past five decades for reducing pesticide use (Grieshop and Pence 1990; Peshin et al. 2009a), without widespread adoption by farmers. Millions of taxpayers' money have also been spent on IPM extension (Kenmore 1997; Bartlett 2005; Peshin et al. 2009b), without much success in scaling up adoption (Bartlett 2005). The prevailing model should be the farmers' perceptions about the attributes related to technology development as opposed to the technologists' tendency to predict the adoptability, thereby overcoming innovation biases.

This paper develops a normative method for predicting the adoption of agricultural technologies disseminated when put to trial at farmers' fields. Thus, adoptability (likely adoption at future time periods) of IPM technologies in cotton was quantified, based on five technological attributes proposed by Roger (1962), namely relative advantage, compatibility, observability, trialability, and complexity. The major premise of this study is that technological characteristics are the most effective drivers in predicting the adoption or rejection of a technology by farmers.

2 Material and methods

2.1 Sampling plan

The study was conducted in three cotton-growing districts of the state of Punjab (India): Bathinda, Ferozepur, and Mansa. These districts were selected purposively as they were being covered under the IRM-IPM program, and account for 70 % (356,000 out of 509,000 ha) of the total area under cotton cultivation in Punjab. The IRM program is implemented in Punjab since 2002 by the Punjab Agricultural University (PAU), Ludhiana India. Under the program, farmers are provided training in IPM. From each district, a sample of five villages was selected randomly; thus, a total number of 15 villages were selected for the study. In each village, ten farmers under the IRM-IPM program were selected, for a total sample of 150 farmers (experimental group) selected for the study. The descriptive demographics of the farmers are given in Table 1.

2.2 Integrated pest management practices disseminated under insecticide resistance management program

The IPM practices disseminated under the insecticide resistance management program included:

Timely (April) sowing of cotton crop Completion of the sowing of cotton in April to ensure early maturity of the crop and avoidance of the late-season attack of bollworms, primarily American bollworm (*Helicoverpa armigera*).

Cultivation of the Punjab Agricultural University-recommended varieties of cotton/Bt cotton Cultivation of early maturing (160–170 days) varieties (Ankur 651, White gold, LHH-144, F-1861, LH-1556) resistant to cotton leaf curl virus and jassid (*Amrasca bigutula*). Since 2005, the Punjab Agricultural University (PAU) recommends Bt cotton varieties resistant to bollworms.

Seed dressing/treated seed Seed dressing with Emisan-6, 0.5 g plus Streptocycline, 0.25 g/kg of seed, and smearing with imidacloprid at the rate of 5g/kg seed for preventing diseases and damage by cotton jassid or sowing of treated seed of the above-recommended varieties available in the market.

Sampling for economic threshold level of insect pests The farmers in the IRM villages were trained in need-based and judicious use of insecticides based on the economic threshold levels (ETL) for the insect pests. The ETL for different insect pests is: 5 % damage in shed-fruiting bodies for bollworms (*H. armigera*, *Earias vittella*, and *Pectinophora gossypiella*), appearance of yellowing and curling along leaf margins on 50 % of plants in the case of jassid (*A. bigutula*), and six adults per leaf or appearance of honeydew on 50 % plants for whitefly (*Bemisia tabaci*).

Insecticide resistance management strategy Zero spray until day 90 after sowing to conserve natural enemies such as *Chrysoperla carnea*, *Coccinella septempunctata*, *Geocoris spp.*, *Zelus spp.*, and spiders; no organophosphates/carbamates/synthetic pyrethroids until 90 days after sowing; 90–110 days after sowing, use synthetic pyrethroids/organophosphates/carbamates against *E. vittella* based on sampling for economic threshold level; 110–140 days after sowing, use profenophos/quinalphos/triazophos for young larvae, or chlorpyriphos/acephate for older larvae of *H. armigera*. Use spinosad/indoxacarb if above insecticides fail to control older larvae of *H. armigera*. During this period, use triazophos/ethion for management of *B. tabaci*, chorpyriphos/acephate/endosulfan/quinalphos for control of *Spodoptera litura*. After 140 days after sowing, use clorpyriphos/indoxacarb/spinosad/quinalphos against *H. armigera*, ethion/

Table 1 Descriptive statistics of the insecticide resistance management trainee farmers

	District Bathinda	District Ferozepur	District Mansa	Overall for three districts
Education (% farmers)				
I. Illiterate	6	8	16	10
II. Up to primary	10	18	12	13
III. Middle	18	26	26	23
IV. Matriculate	36	36	32	35
V. 10+2	14	8	14	12
VI. Graduate and above	16	4	0	7
Telephone connection (% farmers)	84	66	64	71
Total operational landholding (ha) (I+II−III)	461.20	675.00	377.00	1,513.20
I. Owned	415.80	611.80	352.40	1,380.00
II. Leased-in	53.00	74.80	29.60	157.40
III. Leased-out	7.60	11.60	5.00	24.20
Average operational landholding (ha)	9.22	13.50	7.54	10.09
Farm size[a] (% farmers)				
I. 1–2 ha (small)	6	4	2	4
II. 2–4 ha (semi-medium)	20	12	24	19
III. 4–10 ha (Medium)	46	40	56	47
IV. >10 ha (Large)	28	44	18	30
Area under cotton crop (ha)	313.00	428.20	217.65	958.85
Percentage area under cotton crop	67.87	63.44	57.73	63.37

[a]Categorization of farm size is based on the categories used by the directorate of economics and statistics, Ministry of Agriculture, Government of India in: Agricultural statistics at a glance, 1994

triazophos against *B. tabaci* and rotate the chemical groups/compounds to prevent the build up of resistance against insecticides.

2.3 Adoptability index

Adoptability is the likely adoption of IPM practices based on innovation attributes. A rating scale was constructed to study the farmers' perceived attitudes towards the IPM practices described above. Four scores (continua) were given to each response category. A score of 2, 1, and 0 was given to "highly," "somewhat," and "disagree," respectively; a no numerical score was given to "don't know" answers [this was done to eliminate the response of those IPM farmers who were ambiguous in their response]. The IPM attributes selected were relative advantage, compatibility, observability, trialability, and complexity. Relative advantage, compatibility, observability, and trialability positively affect the adoption of a technology, whereas complexity is negatively related to adoption of a technology (Roger 2003). Thus, the adoptability of a technology is the sum total of positive and negative attributes. In addition to the scale items, open-ended questions were included to analyze the farmers' perceived attitudes towards selected IPM practices. Open-ended questions helped to clear up any misunderstanding to detect ambiguity and make better estimates of the IRM-IPM farmers' perceived attributes of the selected IPM practices. The open-ended questions also helped to identify the farmers' perceived "risks" associated with practices like ETL and other IRM strategies. However, "risk" attribute of the selected IPM practices was not in the constructed scale items. Out of 150 cotton growers selected for the study, the adoptability scale was assigned to 146 farmers.

The equations developed to quantify the adoptability of the selected IPM practices are:

$$\text{Index of positively related innovation attribute api} = \frac{\text{Sum of score of n repondents}}{\text{Maximun score obtainable}} \quad (1)$$

$$\text{Index of negatively related innovation attribute aqi} = \frac{\text{Sum of score of n repondents}}{\text{Maximum score obtainable}} \quad (2)$$

Index of an attribute can range from 0 to 1.

The indices of positively related attributes relative advantage, compatibility, observability, and trailabilty and negatively related attribute complexity for each of the selected IPM practices were calculated based on the farmers' response on the four-point continuum of adoptability rating scale. For example: relative advantage of timely sowing of cotton was rated "highly" by 133 and "somewhat" by 9 farmers. Four farmers disagreed and there was no farmer who expressed the opinion "don't know". Based on the scoring pattern to each response category, a score of 2, 1, and 0 was given to "highly," "somewhat," and "disagree," respectively. Thus the sum of the scores of 146 respondents was 275 and the maximum score obtainable by 146 respondents was 292 (146×2=292, in case all the respondents response falls in the continua "highly" with a score of 2). The sum of score of 146 respondents (275) was divided by the maximum score obtainable (292) to get the index of relative advantage of timely sowing. Similarly the attribute indices of other positively related attributes for each of the practice were calculated by employing Eq. 1 and for negatively related attribute "complexity" by Eq. 2 (See Table 2).

$$\text{Adoptability index(AI) of a technology Y} = \frac{\sum_{i=1}^{n_1} \mathrm{ap_i}}{n_1} - \frac{\sum_{i=1}^{n_2} \mathrm{aq_i}}{n_2} \quad (3)$$

Where, ap_i=positively related attributes of a technology; aq_i=negatively related attributes of a technology; n_1=number of positively related attributes of a technology; n_2=number. of negatively related attributes of a technology; $N=n_1+n_2$. Adoptability index can range from (−) 1 to (+) 1.

By summing up the indices of positively related attributes (ap_i) calculated by Eq. 1, and dividing it by the number of positively related attributes (n_1=4) and subtracting from it the index of negatively related attribute (aq_i) calculated by Eq. 2 and divided by n_2=1, namely complexity, we get the adoptability index of a practice. For example, the relative advantage, compatibility, observability, and trailabilty indices of timely sowing were 0.94, 0.58, 0.93, and 1.00, respectively. The sum of *api* of these four attributes is 3.45 and dividing it with the number of positively related attributes (n_1=4) it is equal to 0.86. All the respondent farmers rated timely sowing not being complex (aq_i=0). Thus adoptability index of the timely sowing worked was 0.84 (Table 3).

2.4 Reliability of the scale

A pilot test of the adoptability scale was conducted to determine the reliability of this tool. The pilot test was administered to 25 non-sampled IRM-IPM trained cotton growers from among the villages covered under the IRM-IPM program, but not selected for the sample. Test–retest reliability coefficient was found out by Spearman's correlation. At the time of pre-testing of the rating scale, three response categories: "yes,"

Table 2 Response of famers and attribute indices

Practice	Attribute	Farmers response on four-point continuum (number of farmers)				Sum of score of 146 respondents	Attribute index[b]
		Highly (2)	Somewhat (1)	No (0)	Don't know[a]		
Timely sowing	Relative advantage	133	9	4	0	275	0.94
	Compatibility	29	111	6	0	169	0.58
	Observability	131	11	4	0	273	0.93
	Trailabilty	146	0	0	0	292	1.00
	Complexity	0	0	146	0	000	0.00
Recommended resistant varieties (other than Bt cotton)	Relative advantage	28	36	60	22	092	0.32
	Compatibility	28	51	44	23	107	0.37
	Observability	45	10	70	21	100	0.34
	Trialability	146	0	0	0	292	1.00
	Complexity	0	0	146	0	000	0.00
Bt cotton	Relative advantage	142	4	0	0	288	0.99
	Compatibility	88	13	10	35	189	0.65
	Observability	142	4	0	0	288	0.99
	Trialability	146	0	0	0	292	1.00
	Complexity	0	0	146	0	000	0.00
Seed dressing	Relative advantage	65	40	15	26	170	0.58
	Compatibility	70	7	55	14	147	0.50
	Observability	58	10	55	23	126	0.43
	Trialability	146	0	0	0	292	1.00
	Complexity	104	5	28	9	213	0.73
Treated seed	Relative advantage	65	40	15	26	170	0.58
	Compatibility	70	7	55	14	147	0.50
	Observability	58	10	55	23	126	0.43
	Trialability	146	0	0	0	292	1.00
	Complexity	0	0	146	0	000	0.00
Economic threshold level	Relative advantage	74	10	15	47	158	0.54
	Compatibility	26	34	74	12	86	0.29
	Observability	63	4	12	67	130	0.45
	Trialability	146	0	0	0	292	1.00
	Complexity	72	18	42	14	162	0.55
Insecticide management	Relative advantage	80	32	22	12	192	0.66
	Compatibility	66	42	35	3	174	0.60
	Observability	89	16	18	23	194	0.66
	Trialability	146	0	0	0	292	1.00
	Complexity	15	20	110	1	50	0.17

[a] "Don't know" were not scored as these farmers had no knowledge about these practices

[b] Attribute index (ap_i and aq_i) has been calculated by using Eqs. 1 and 2

"no," and "don't know" were provided for measuring the IRM-IPM farmers' perceived attributes on the selected IPM practices. Farmers at the time of pre-testing responded with different response categories namely: "highly," "somewhat," "disagree," and "don't know". Accordingly, the response categories were modified. The test–retest reliability coefficient of rating scale was 0.79.

2.5 Regression analysis

Stepwise regression model was used for predicting and making statistical inferences about the effect of five attribute indices (relative advantage, compatibility, observability, trialability, and complexity) on the adoptability indices and proportion of actual adoption (percentage of farmers) of seven IPM practices(timely sowing, use of resistant

Table 3 Adoptability and adoption of selected IPM practices

Practice	Indices of attributes[a]					Adoptability index (AI)	Actual adoption (% farmers)
	Relative advantage (ap_1)	Compatibility (ap_2)	Observability (ap_3)	Trailability (ap_4)	Complexity (aq_1)		
Timely sowing	0.94	0.58	0.93	1.00	0.00	0.86	74
Recommended resistant varieties (Other than Bt cotton)	0.32	0.37	0.34	1.00	0.00	0.51	29
Bt cotton	0.99	0.65	0.99	1.00	0.00	0.91	89
Seed dressing	0.58	0.50	0.43	1.00	0.73	−0.10	05
Treated seed	0.58	0.50	0.43	1.00	0.00	0.63	72
Economic threshold level	0.54	0.29	0.45	1.00	0.55	0.02	07
Insecticide resistance management	0.66	0.60	0.66	1.00	0.17	0.56	42

[a] ap_1, ap_2, ap_3, and ap_4 (in general ap_i) are positively related attribute indices and aq_1(in general aq_i) is negatively related attribute index

varieties, Bt cotton, seed treatment, treated seed, economic threshold level, and pesticide use strategy).

$$Y_i = b_0 + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 \quad (4)$$

Where, Y_i represents the dependent variable: adoptability indices/percentage of farmers adoption of ith practice whose values were being modeled, b_0 is the Y-intercept and x_1 to x_5 represent the independent variables (attribute indices of relative advantage, compatibility, observability, trailabilty, and complexity) included in the model. Linear regression was employed for finding the relationship between adoptability indices and percentage of actual adoption of IPM practices by the farmers. Regression analysis model was run by using SPSS 14.0 software.

3 Results and discussion

Using the rating scale to find out the degree of relative advantage, compatibility, observability of benefits, trialability, and complexity of the selected IPM practices, the response of farmers was recorded and is given in Table 2. The attribute indices of the selected IPM practices were calculated by applying Eqs. 1 and 2 (Table 2). The adoptability indices of the selected IPM practices were estimated using Eq. 3 (Table 3).

3.1 Adoptability of April sowing of cotton

The farmers were asked whether there are benefits with April sowing of cotton. Farmers gave different reasons for April sowing. All these reasons can be categorized into relative advantage. The farmers also indicated that these benefits of timely sowing were visible in terms of getting higher crop yield due to less damage of insect pests. The practice is not compatible with sowing of cotton after harvesting of wheat, as the farmers with large landholdings were not able to get their field ready for cotton sowing in April. About ten reasons/relative advantages of April sowing were reported by cotton growers. The compatibility of April sowing with the crop sequence (cotton–wheat) and requirement of pre-sowing irrigation greatly influenced the timely sowing. However, non-availability of canal irrigation for pre-sowing irrigation was the major constraint as 79 % farmers reported shortage and non-availability of canal water as the major limiting factor. Timely sowing of cotton (between mid April and first week of May) was completed by 74 % of the farmers. Out of which 22 % had completed sowing in April, whereas 52 % started sowing in April but completed in the first week of May.

The indices of relative advantage, compatibility, observability, trialability, and complexity of the timely sowing of cotton were 0.94, 0.58, 0.93, 1.00, and 0.00, respectively (Table 2). The overall adoptability of April sowing of cotton was 0.86 (Table 3). The extent of adoption of the timely sowing was 74 %.

3.2 Adoptability of the Punjab Agricultural University-recommended varieties and Bt cotton

During the study period, it was observed, a growth of private seed companies producing hybrid seeds. These companies have a vast network of sale agents to popularize their varieties. Under Punjab conditions, the Punjab Agricultural University recommends cultivation of varieties which are resistant to cotton leaf curl virus. The Punjab Agricultural University has also developed its own varieties (mostly non-hybrid) and it also recommends the selected private sector hybrid varieties. The adoption of the Punjab Agricultural University-recommended varieties (other than Bt cotton) was poor. The respondent cotton growers listed many constraints in the adoption of the Punjab Agricultural University-recommended resistant varieties. The Punjab Agricultural University-recommended varieties have small loculi size, loculi that are problematic for picking. The Punjab Agricultural University developed resistant varieties (LHH-144, LH-1556 and FL 1861) were hardly preferred for the reason that these were low yielding. Thus, the relative advantage in terms of yields and compatibility in terms of picking affect the selection of a variety. The respondent cotton growers reported about Bt cotton being resistant to bollworm complex (*H. armigera* and *E. vittella*) (97 %), especially *H. armigera* (which devastated cotton production in 1995), higher yielding (87 %), saving on pesticide expenditure (84 %), easy to adopt (72 %) and compatible with farming systems of Punjab (60 %).

The farmers' preference for selecting a variety is affected by the degree of relative advantage. The important attributes which influence the farmers' adoption decisions of a variety are: higher yield, less pest loss, and good seed quality (the components of relative advantage). The Punjab Agricultural University-recommended varieties (excluding Bt cotton) had relative advantage index of 0.32, compatibility index of 0.37, and observability index of 0.34 (Table 2). Although divisible technologies had 100 % trialability, this variable had no bearing on its adoption. The adoptability index of the Punjab Agricultural University-recommended varieties was 0.51, mainly because of trialability index equal to 1 (Table 3). If the trialability index was not considered for calculating adoptability index, it will be equal to 0.34. Compared to this, the adoptability index of transgenic cotton varieties was very high (0.91). The extent of adoption of the Punjab Agricultural University-recommended varieties was 7 %, covering 6 % of the cotton area. The adoption of Bt cotton was 89 %.

3.3 Adoptability of seed dressing and treated seed

The cotton growers' perceived constraints in treating the cotton seed before sowing were socio-personal. However, 94 % reported using pre-treated seeds of private companies but were not sure about their benefits. The hybrid and Bt cotton seeds marketed by the seed companies are mostly treated. The IRM-IPM farmers listed relative advantage of treated seed in terms of less jassid infestation, less termite attack, and reduced infestation of diseases. The adoptability index of seed treatment was negative (−0.10). The adoptability index of the treated seed was high at 0.63 (Table 3). The indices of attributes of seed treatment and treated seed were: relative advantage 0.58, observability of benefits 0.43, compatibility 0.50, and trialability1.00. However, there was significant difference in complexity attribute index between seed dressing (0.73) and treated seed (0.00) (Table 2) which is the main reason for the difference in adoptability indices of these two.

3.4 Adoptability of economic threshold level of insect pests

Under the IRM-based IPM program, scientists recommended economic threshold levels (ETLs) of *H. armigera*, *Amrasca bigultula*, and *B. tabaci* among other insect pests. These technologies have been recommended by the Punjab Agricultural University between 1979 and 1991 (PAU 1979, 1991). The farmers had no awareness or knowledge about ETLs prior to the IRM program. After the IRM program, cotton growers were asked to list the reasons for the adoption or rejection of the sampling for determining the economic threshold level of insect pests.

The attributes listed by farmers were: reducing pesticide use and pesticide expenditure (40 %), judicious use of pesticide (21 %), and observability of the benefits (79 %). The farmers reported that application of thresholds is not compatible with their skills, previous pest management practices, or landholdings. Also, the application of thresholds was perceived as a complex technology to apply for all the insect pests. The positively related attribute indices of ETL were: relative advantage (0.54), compatibility (0.29), observability (0.45), and trialability (1.00) and the negatively related attribute index of complexity was 0.55 (Table 2). The adoptability index of economic threshold level was 0.02. Though during the IPM intervention, 44 % of farmers calculated economic threshold level for one or more insect pests with the help of trainers, overall the adoption of economic threshold levels for cotton pest complex was 7 % (Table 3). Thus, it can be predicted that the adoptability of economic threshold level in Punjab was doubtful.

3.5 Adoptability of insecticide resistance management strategy

In India, pesticide use in the state of Punjab is the highest (923 g/ha, Agnihotri 2000). In cotton, it is 2.580 kg/ha in transgenic varieties and 6.440 kg/ha in non-Bt varieties (Peshin et al. 2007). The farmers spray heavily in cotton to save it from the ravages caused by pests. Despite heavy use of pesticides (mainly insecticides) in cotton, the cotton productivity declined to an all time low of 179 kg/ha in 1998–1999. The extent of insecticide use in cotton is 100 % but the use of insecticides according to good agricultural practices is low. The selection of the right insecticide, the right dosage, and the right dilution are not as per recommendation. The majority of farmers use either under- or over-dose applications with insecticides (Peshin et al. 2012). The IRM farmers were trained in insecticide resistance management. Pest management is a complex technology for farmers to master (Litsinger et al. 2009). Under the IRM program, different strategies were adopted to make farmers aware about the judicious use of insecticides. The attribute indices of the insecticide resistance management were: relative advantage (0.66), compatibility (0.60), observability (0.66), and complexity (0.17). The overall adoptability index of the recommendations was 0.56 (Table 3). Farmers reported the recommendations to be beneficial in reducing pesticide use and expenditure.

3.6 Predicting the adoptability of IPM practices

Timely sowing of cotton and adoption of Bt cotton have highest adoptability indices; therefore, highest adoption. In case of timely sowing, the complexity is zero and the compatibility, relative advantage of the practice, and the observability of the benefits by the units of adoption significantly contribute to its wider adoption. There are no counteracting forces limiting its adoptability. In the case of Bt cotton, besides the technology attributes, seed companies have propelled its higher rate of adoption. The same farmers (with constant socio-personal and economic characteristics) adopted widely the practices which have no complexity (zero), higher relative advantage, and observability (more than 0.90) (Tables 2, 3, and 4). This implies that the effect of these attributes of innovations drive the rate of adoption in case of simple and easy to adopt technologies. But in case of technologies, which are difficult to use and require "how to do" knowledge, skills, and labor, complexity attribute index affects its adoptability. IPM practices having low complexity indices are most likely to affect adoptability compared to observability and relative advantage.

Sampling for ETL has a relative advantage index of 0.54 and is equally complex (complexity of 0.55) and therefore has low adoption. Complexity of ETL is the most important attribute for predicting its adoption. The adoption of sampling for determining ETLs of pests by the farmers to make pesticide use decisions has been questioned by scientists all over the world. Entomologists consider ETLs as the basic requirement for making pesticide decisions and ETL is considered as the first step towards level one IPM (Kogan 1998), even though there are opinions contrary to this, which question the utility and adoptability of ETL at farmers' level (Zadoks 1985; Benthley and Andrews 1996; van de Fliert 1998).

3.7 Regression analysis

Stepwise regression model fitted with the attribute and adoptability indices; at step 1, the attribute variable significant at 1 % level in predicting the adoptability of IPM practices was "complexity" with R^2=87 % (Table 4). At step 2, complexity and relative advantage caused a variation of 99 %. The attribute variable trialability was redundant. The other attribute variables were excluded in the model due to colinearity. The attribute variables significantly affecting actual adoption by farmers were: complexity, relative advantage, and observability. Complexity variable caused a variance of 62 % in adoption of the IPM practices (Table 4). The relative contribution of each of the three attributes, in order of importance for predicting the adoptability and adoption of IPM practices are: complexity, relative advantage, and observability.

Table 4 Stepwise regression estimates of attributes affecting adoptability and adoption

Model	Variable	Coefficient	Standard error	*t* value	*p* value	
Dependent variable: adoptability						
Step 1	Constant	0.730	0.070	10.364	0.000	F=35.002
	Complexity	−1.186	0.200	−5.918	0.002	p=0.002
						R^2=0.87
Step 2	Constant	0.307	0.040	7.693	0.002	F=25.367
	Complexity	−1.056	0.041	−25.929	0.000	p=0.000
	Relative advantage	0.602	0.053	11.304	0.000	R^2=0.99
Dependent variable: adoption						
Step 1	Constant	0.642	0.097	6.607	0.001	F=10.775
	Complexity	−0.908	0.277	−3.283	0.002	p=0.022
						R^2=0.62
Step 2	Constant	0.119	0.149	0.800	0.468	F=26.317
	Complexity	−0.747	0.152	−4.905	0.008	p=0.005
	Relative advantage	0.744	0.199	3.735	0.020	R^2=0.89
Step 3	Constant	0.063	0.074	0.848	0.459	F=78.997
	Complexity	−0.934	0.089	−10.458	0.002	p=0.002
	Relative advantage	2.137	0.386	5.544	0.012	R^2=0.97
	Observability	−1.361	0.365	−3.735	0.033	

The scatter diagram and trendline for linear regression analysis between adoptability indices and actual adoption of IPM practices in cotton crop was significant with R^2=0.88 (Fig. 2). This implies that adoptability of IPM practices affected the actual adoption by 88 %. The adoptability indices and actual adoption were highly correlated (r=0.941, p=0.002).

Thus, it can be inferred that the group of farmers having the same socio-personal and economic attributes will exhibit different adoption behavior for different innovations. Therefore, agricultural innovations should not be treated as equal units of analysis. Researchers should take the innovation attributes and constraints faced by farmers into consideration before recommending technologies which are partially compatible with the farming system. Some IPM practices either do not fit with the farming system, or are too complex. Timely sowing does not fit in the wheat–cotton crop rotation but fits in the rapeseed mustard–cotton crop rotation. However, timely sowing of cotton has higher relative advantage and observability, thus higher adoptability.

The applied researchers have the ethical responsibility of linking farmers and extension agencies in technology development. The responsible conduct of research demands that scientists have an obligation to act in ways that serve the farmers. Taxpayers' money that grants the support to agriculture research is wasted when scientific recommendations have low adoptability. It has been five long decades since the concept of integrated control and threshold theory was developed (Stern et al. 1959) and four decades since IPM programs have been implemented in USA (Kogan 1998), Asia (Kenmore 1997; Pontius et al. 2002), Latin America (Swezy et al. 1986; Ramalho 1994), Australia (Wilson et al. 2004), and India (Peshin et al. 2007; Kranthi and Russell 2009), but without widespread adoption of complex IPM practices by the farmers (van de Fliert 1998; Peshin and Kalra 2000; Roger 1995; Norris et al. 2002; Peshin et al. 2009b). Thus, the policy planners and scientists should re-direct their research priorities and ask, "For whom are the IPM technologies developed?" Farmers' perceptions about the technological attributes need to be taken into consideration during the technology development process, rather than the technologists' prediction about the adoptability in order to overcome innovation biases. The dissemination researchers should study the determinants of adoptability of technologies instead of focusing on individual socio-personal and economic characteristics. The attributes of a technology are the strongest predictor of adoptability of a technology (Bussey et al. 2000).

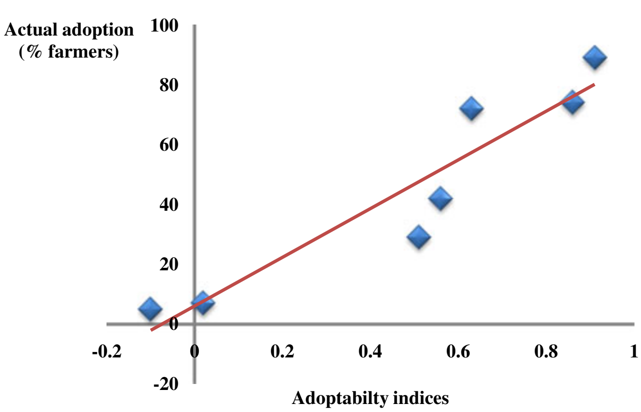

Fig. 2 Regression of adoptabilty indices on adoption. There is a significant relationship between the predicted adoptability indices and actual adoption of integrated pest management practices in cotton crop (y=5.949+81.52x with R^2=0.88, $d.f.$=6, F=38.33). Thus adoptabilty indices can be worked out, based on the innovation attributes, to predict future adoption of innovative agricultural technologies

4 Conclusion

The methodological framework developed to forecast the adoptability of agricultural innovations in general and IPM practices in particular offers plausible answers to the researchers to predict the extent to which farmers will adopt a new technology. The sampled group of 146 farmers exhibited different adoption attitudes towards different IPM practices such that the attributes of the IPM practices as perceived by these growers affected their future adoption. Practices having the higher adoptability indices namely timely sowing of cotton (AI=0.86), cultivation of Bt cotton (AI=0.91), and use of treated seed (AI=0.63) have been adopted by more than 72 % cotton farmers in Punjab. The negatively related attribute complexity and positively related attribute relative advantage of a practice caused a variance of 99 % in the adoptability of IPM practices. The variation of 97 % in actual adoption was caused by three technological attributes complexity, relative advantage, and observability. The complexity attribute associated with IPM has the highest effect on the adoptability and adoption of a particular IPM practice. The model developed has significant predictive value as adoptability indices were significantly associated with actual adoption with R^2=0.88, and were highly correlated (r=0.941). The attributes of a technology are the strongest predictor of adoptability of a technology and therefore, it is suggested that for dissemination of IPM practices among farmers to occur, there is the need to focus on testing the technology for its adoptability by employing the methodological frame work presented in this article, before undertaking extension efforts.

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References

Agnihotri NP (2000) Pesticide consumption in India—an update. Pestic Res J 12:150–155

Akinola AA (1986) An application of Bass model in the analysis of diffusion of cocoa spraying among Nigerian cocoa farmers. J Agr Econ 37(3):395–404. doi:10.1111/j.1477-9552.1986.tb01607.x

Bass FM (1969) A new product growth model for consumer durables. Manag Sci 13(5):215–227

Bartlett A (2005) Farmer Field Schools to promote Integrated Pest Management in Asia: The FAO Experience, Case Study presented to the Workshop on Scaling Up Case Studies in Agriculture, International Rice Research Institute, 16–18 August 2005, Bangkok

Benthley J, Andrews K (1996) Trough the road blocks: IPM and Central American small-holders. Sustainable Agricultural Programme Gatekeeper Series 56. International Institute for environment and Development, London

Bussey JM, Dormody TJ, VanLeeuwen D (2000) Some factors predicting the adoption of technology education in New Mexico Public Schools. J Tech Edu 12(1):4–17

Fliegal FC, Kivlin JE (1966) Attributes of innovations as factors in diffusion. Am J Sociol 72(3):235–248

Grieshop J, Pence R (1990) IPM research results: statewide IPM's first 10 years. Cal Ag 44(5):24–26. doi:10.3733/ca.v044n05p24

Kenmore PE (1997) A perspective on IPM. LEISA 13:8–9

Kogan M (1998) Integrated pest management: historical perspective and contemporary developments. Annu Rev Entomol 43:243–270. doi:10.1146/annurev.ento.43.1.243

Kranthi KR, Russell DA (2009) Changing trends in cotton pest management. In: Peshin R, Dhawan AK (Eds) Integrated pest management: innovation-development process, vol. 1. Springer, Berlin, pp. 495–537. doi:10.1007/978-1-4020-8992-3_17

Lawton SB, Lawton WH (1979) An autocatalytic model for diffusion of educational innovations. Edu Adm Quart 15(1):19–53

Litsinger JA, Libetario EM, Canapi BL (2009) Eliciting farmers knowledge, attitudes, and practices in the development of integrated pest management programs for rice in Asia. In: Peshin R, Dhawan AK (Eds.) Integrated pest management: dissemination and impact, Vol. 2. Springer, Berlin. doi:10.1007/978-1-4020-8990-9_5

Norris RF, Caswell-Chen EP, Kogan M (2002) Concept in integrated pest management. Prentice-Hall of India Private Ltd, New Delhi

Pattanayak SK, Mercer DE, Sills E, Yang JC (2003) Taking stock of agroforestry adoption studies. Agroforest Syst 57(3):173–186. doi:10.1023/A:1024809108210

PAU (1979, 1991) Package of practices for crops of Punjab-Kharif. Punjab Agricultural University, Ludhiana, India

Peshin R, Kalra R (2000) Integrated pest management: adoption and its impact on agriculture. Classical Publishing Company, New Delhi, India

Peshin R, Dhawan AK, Vatta K, Singh K (2007) Attributes and socio-economic dynamics of adopting Bt-cotton. Econ Polit Weekly 42 (52):73–80

Peshin R, Dhawan AK, Kranthi K, Singh K (2009a) Evaluation of the benefits of an insecticide resistance management programme in Punjab in India. Int J Pest Manag 55(3):207–220. doi:10.1080/09670870902738786

Peshin R, Bandral RS, Zhang WJ, Wilson L, Dhawan AK (2009b) Integrated pest management: a global overview of history, programs and adoption. Pp 1–49. In: Peshin R, Dhawan AK (Eds) Integrated pest management: innovation-development process, vol.1. Springer, Berlin. doi: 10.1007/978-1-4020-8992-3_1

Peshin R, Dhwan AK, Singh K, Sharma R (2012) Farmers' perceived constraints in the adoption of integrated pest management practices in cotton crop. Indian J Ecol 39(1):123–130

Pontius J, Dilts R, Bartlelt A (2002) From farmer field schools to community IPM-ten years of IPM training in Asia. FAO Community IPM Programme Jakarta, Indonesia

Ramalho FS (1994) Cotton pest management: part 4—a Brazilian perspective. Annu Rev Entomol 39:563–578. doi:10.1146/annurev.en.39.010194.003023

Rebaudo F, Dangles O (2011) Coupled information diffusion—pest dynamics models predict delayed benefits of farmer cooperation in pest management programs. PLoS Comput Biol 7(10):1–10, E1002222. Open access journal. doi:10.1371/journal.pcbi.1002222

Roger EM (1962) Diffusion of innovations. The Free Press, New York, USA

Roger EM (1983) Diffusion of innovations (3rd ed.). The Free Press, New York, USA

Roger EM (1995) Diffusion of innovations (4th ed.). The Free Press, New York, USA

Roger EM (2003) Diffusion of innovations (5th ed.). The Free Press, New York, USA

Stern VM, Smith RF, van den Bosch R, Hagen KS (1959) The integrated control concept. Hilgardia 29:81–101

Swezy SL, Murray DL, Daxal RG (1986) Nicaragua's revolution in pesticide policy. Environment 28:6–9

van de Fliert E (1998) Integrated pest management: springboard to sustainable agriculture. In: Dhaliwal GS, Heinrichs EA (eds) Critical issues in insect pest management. National Agricultural Technology Information Centre, Ludhiana, India, pp 285–304

Wilson LJ, Mensak RK, Fitt GP (2004) Implementing integrated pest management in Australian cotton. In: Horowitz AR, Ishaaya I (eds) Insect pest management—field and protected crops. Springer, Berlin, pp 97–118

Zadoks JC (1985) On the conceptual basis of crop loss assessment: the threshold theory. Annu Rev Phytopathol 23:455–473