Adoption, impact and discontinuance of integrated pest management technologies for pigeon pea in South India

Article *in* Outlook on agriculture · September 2011

DOI: 10.5367/oa.2011.0055

5 authors, including:

Ramarao Ca
Central Research Institute for Dryland Agriculture, India

Mathukumalli Srinivasarao
Central Research Institute for Dryland Agriculture, India

Srinivas Karlapudi
Indian Council of Agricultural Research

Anil KUMAR Patibanda
Acharya N G Ranga Agricultural University

Adoption, impact and discontinuance of integrated pest management technologies for pigeon pea in South India

C.A. Rama Rao, M. Srinivasa Rao, K. Srinivas, A.K. Patibanda and C. Sudhakar

Abstract: *The adoption and impact of integrated pest management (IPM) were examined for pigeon pea cultivation in Andhra Pradesh, India. Summer ploughing and spraying of Neem Seed Kernel Extract (NSKE) were the most regularly adopted components of IPM for pigeon pea. A logistic regression analysis showed that age, education, participation in community-based organizations, ability to recognize the insect pests, and farm size influenced the decision to adopt IPM significantly. There were variations in the extent of IPM adoption among farmers. The adoption of IPM led to reduced use of insecticides and increased net returns. Furthermore, the use of new-generation insecticides led to a discontinuation of IPM practices.*

Keywords: *pigeon pea; logistic regression; IPM; IPM adoption; IPM impact*

C.A. Rama Rao (corresponding author) is Principal Scientist and M. Srinivasa Rao and K. Srinivas are Senior Scientists at the Central Research Institute for Dryland Agriculture, Hyderabad 500059, India. E-mail: carrao@crida.ernet.in; msrao@crida.ernet.in; ks@crida.ernet.in. A.K. Patibanda is an Assistant Professor in the Department of Plant Pathology, Agricultural College, Bapatla 522101, Andhra Pradesh, India. C. Sudhakar is a Research Officer at the Agricultural Research Station (ANGRAU), Tandur, Rangareddy District, Andhra Pradesh, India.

The incidence of insect pests and diseases is one of the major yield reducers in pigeon pea crop, which is the main source of protein in India. Because of this high incidence of pests, the use of chemical insecticides increased rapidly, leading to indiscriminate use and the consequent development of resistance by the pod borer *Heliothes armigera*. This increase was also responsible for the higher cost of cultivation and chemical residues creeping into the food. Since the crop is grown by resource-poor small-scale farmers in the rainfed regions, there is also a need to develop and transfer cheaper and safer pest management strategies to the farmers cultivating the crop. Emphasis has thus been given to the promotion of integrated pest management (IPM) methods. IPM combines different means of pest control to manage pests below economic threshold levels with the minimum possible use of chemical insecticides.

Technology adoption is influenced by: farmer-specific variables that determine the ability of the farmer to access and understand technology-related information and inputs; farm-specific variables that determine the relevance and feasibility of the technology; and technology-specific traits (Feder *et al*, 1984; Adesina and Zinnah, 1993; Lapar and Pandey, 1999). Furthermore, the adoption of a technology is also influenced by the adoption of other technologies. In the case of pest management, the availability and use of highly effective new-generation insecticides would have a potential impact on the adoption of IPM practices.

In this paper, we identify the factors that influence the adoption decisions of farmers with respect to IPM in pigeon pea and analyse the farm-level impact of adopting IPM technologies. We also observe how farmers respond to the availability of more effective chemical insecticides *vis-à-vis* the adoption of certain components of IPM.

Methodology

Study region and data

The data were obtained from farmers in the Rangareddy district of Andhra Pradesh in southern India. Pigeon pea is grown extensively in this district (Commissionerate of Agriculture, 1999). Three villages (Kokat, Saipur and Rudraram) where there had been past efforts to promote IPM technologies were selected in consultation with the state Department of Agriculture.

The district has a semi-arid tropical climate with a mean temperature of 31.7°C and a mean annual rainfall of 781 mm, most of which occurs during the south-west monsoon (June–September). More than 75% of the cropped area is rainfed with no access to irrigation. The IPM technologies promoted were: the use of pheromone traps, spraying applications of NPV biopesticides, neem-based formulations, clipping of tender tips, hand removal of larvae, and growing border crops. The importance of practices such as summer ploughing, intercropping and crop rotation was also highlighted, as these had been adopted by some farmers for other agronomic advantages.

The selection of farmers was random and interactive. First, a farmer was randomly selected from the list of all the farmers in the village. We then ascertained whether he or she was growing pigeon pea and what pest management practices he or she was following. Depending on the response, the farmer was classified either as an IPM adopter or a non-adopter. Following Rama Rao *et al* (2007), a farmer was considered to be adopting IPM if he or she followed at least four different pest control technologies. Such a classification may not be ideal, but we chose to follow this approach, considering that IPM emphasizes the integration of different means of pest management. Further, initial interactions with the farmers indicated that farmers who were largely dependent on chemical insecticides did not follow other methods of pest management, such as biological and mechanical practices. This process was repeated until a sample of 30 IPM farmers and 30 non-IPM farmers was identified for each village, making a total sample of 90 adopters and 90 non-adopters. Data related to farm and household characteristics, adoption of pest management technologies, input use, productivity and prices were obtained using a pre-tested schedule by interviews. The interviewer was an entomologist trained in conducting interviews for obtaining information from the farmers. The data collected were for the agricultural year 2004–05.

Analytical methods

Factors influencing adoption. The decision to adopt or not to adopt IPM essentially takes the form of a binary variable and, therefore, can be analysed with logit or probit models (Harper *et al*, 1990). These models relate the dependent and independent variables non-linearly (Gujarati, 2004).

In this study, the decision to adopt IPM was regressed on a set of independent factors: farmer's age (X_1), education (X_2), family labour availability (X_3), participation in social groups (X_4), ability to recognize the pests and natural enemies (X_5), farm size (X_6), proportion of area under pigeon pea (X_7), and access to irrigation (X_8). The specifications and measurement of these variables are given in Table 1. Multivariate logistic regression, as given below, was used to examine the influence of these factors on the adoption decision:

$$Y = \mathrm{Ln}(P/(1-P)) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 \quad (1)$$

where P is the probability that the farmer would be an IPM adopter and the βs represent the regression coefficients estimated by the maximum likelihood method.

Table 1. Specification and measurement of independent variables included in the logistic regression model.

Variable	Unit	Measurement
Age of farmer	Years	Farmer's response to question
Education	Years of schooling	Farmer's response to question
Family labour availability	Number of adults in household	Number of adult males in household + 0.67 times the number of adult females in household. Any individual over 14 years of age is considered an adult
Participation in social groups/ community-based organizations	Dummy variable 1 if participating, 0 if not	Ascertaining whether the farmer is a member of any community-based organization (self-help groups, user groups, etc)
Ability to recognize pests and natural enemies	Numerical score	To ascertain whether farmers could identify pests and natural enemies they were asked to describe the organisms with respect to appearance, feeding behaviour, damage symptoms, etc (local names of the organisms and photographs were used)
Farm size	ha	Size of landholding operated by farmer
Proportion of area under pigeon pea	Percentage	Area sown to pigeon pea as percentage of total farm size
Access to irrigation	Percentage	Area of irrigated land as percentage of total land farmed

These coefficients represent the change in the log of odds of adoption of IPM for a unit change in the corresponding independent variable. We computed the e^{β}, which gives the odds ratio associated with change in the independent variable. The analysis was done using SPSS 12.0.

Measuring the extent of IPM adoption. Adoption can also be measured as an extent or degree of adoption. IPM usage can be considered as a continuum spanning the complete dependence on chemical insecticides at one end to a combination of a wide range of cultural, mechanical, biological and chemical means at the other. To understand the extent of IPM adoption, we attempted to measure IPM adoption as a weighted score. The weighted scores were computed as follows. First, a list of all the plant protection practices followed by the IPM farmers was developed. Then, these practices were divided into four categories – cultural, mechanical, biological and chemical. These categories were given different weights according to their importance in IPM. Thus the four categories were given weights of 0.30, 0.20, 0.35 and 0.15 respectively. These figures were arrived at in consultation with the entomologists working on pest management in pigeon pea. Then, the number of practices followed in each category was multiplied by the respective weight and summed over all the categories to obtain a weighted score of IPM adoption for the farmer. Thus, the IPM score, Z, of a farmer is given by:

$$Z = \Sigma w_j n_j \qquad (2)$$

where w is the weight of the jth category (j = 1 to 4), and n is the number of practices belonging to the jth category adopted by the farmer

After computing the individual IPM scores, farmers were divided into three categories – low, medium and high adoption – by taking the 35 and 70 percentile scores as cut-off points (Rama Rao *et al*, 2007). Thus farmers whose scores were equal to or below the 35 percentile were categorized as low adopters, those falling between the 35 and 70 percentiles were categorized as medium adopters and those scoring greater than the 70 percentile were classified as high adopters.

Farm-level impact of IPM. The impact of adoption of IPM technologies was examined by following a 'with and without' approach, wherein the mean values of the key parameters, such as the use of plant protection chemicals, cost of cultivation, yield and net returns of the 'IPM' farmers, were compared with those of the non-IPM farmers. Health hazards due to exposure to chemical insecticides are an important ill effect associated with the use of insecticides. The reduction in the number of incidents of farm workers falling sick due to exposure to insecticides is therefore considered an important benefit of the adoption of IPM. The number of such 'sick events' due to exposure to insecticides on IPM farms was compared with those of non-IPM farms. The differences were tested for their statistical significance applying the t-test for continuous variables (input use, yield, etc) and the χ^2 test for categorical variables (number of sick events).

Discontinuance of IPM technologies and use of more effective insecticides. While interacting with farmers, it was observed that some of the farmers stopped using certain components of IPM, especially spraying of NPV, erection of pheromone traps, shaking of plants, following the use of newer and more effective chemical insecticides such as spinosad, indoxocarb or thiocarb. Farmers apply these chemicals both as a prophylactic and as a routine chemical spray, irrespective of the incidence of pests. Since these chemicals are highly effective and selective against the pod borer, they have a potential impact on the continued adoption of other components of IPM. Therefore, we tested the hypothesis that farmers who had used such chemicals would have discontinued the adoption of some components of IPM earlier than those who had not used them before. In other words, did the IPM practices 'survive' longer with the farmers who did not use these new-generation insecticides than with those who used them as a means of plant protection?

In order to test this hypothesis, data were collected from a sample of 50 farmers in the same villages who were then adopting IPM or had used IPM previously. The selection of the sample was random and interactive. First, a farmer was randomly selected and it was ascertained whether he or she had adopted or was adopting biological and mechanical components of IPM. If the answer was 'yes', information was obtained on how long he or she had been using IPM components (such as NPV, pheromone traps, shaking of plants, etc), and whether he or she had used the new insecticides. If the answer was 'no' another farmer was randomly selected again and the process was repeated until we had identified a sample of 50 farmers.

Data collected on the number of years for which the farmer had been using IPM and whether he or she had used the new-generation insecticides and stopped using IPM was subjected to the Kaplan–Meier survival analysis. This analysis is concerned with studying the time elapsed before an event of interest (Chan, 2004) occurs. This analysis was used to compare the mean survival time of IPM practice between two groups. The difference between the mean survival times of the two groups was tested for its significance using the log rank test (http://bmj.bmjjournals.com).

Results and discussion

Table 2 lists different components of IPM recommended for pigeon pea and the frequency of adoption of each practice. It can be observed that ploughing during summer before sowing the crop was the component of IPM most adopted by farmers. Most of the IPM farmers (about 90%) also rotate crops such as sorghum, maize and pearl millet with pigeon pea to break pest build-ups. These practices of summer ploughing and crop rotation also have agronomic advantages. However, few farmers followed such practices before efforts to promote IPM in these villages were initiated. The pest management effects of these practices were then better understood. The adoption frequency of the practices in the case of non-IPM farmers is lower. Spraying of NSKE and neem oil was found to have been adopted by as many as 75% of the sample farmers. The adoption of biological means of pest management, such as NPV and *Bacillus thuringiensis*, is not so popular because of poor availability. In order for

Table 2. Adoption of different components of IPM by farmers.

Practice	Adopters (%)	Non-adopters (%)
Summer ploughing	97	38
Use of resistant varieties	92	46
Crop rotation	90	30
Spraying NSKE or neem oil	75	10
Spraying of conventional insecticides	72	75
Spraying NPV	7	0
Hand picking	63	28
Clipping off tender tips	53	12
Erecting bird perches	47	8
Spray of spinosad	30	91
Intercrops	27	3
Border crops	22	0
Pheromone traps	17	0
Spray of profenophos	15	18

Table 3. Characteristics of adopters and non-adopters of IPM growing pigeon pea, Rangareddy district, Andhra Pradesh, India.

Characteristic	Mean (SD)	
	Adopters	Non-adopters
Age	42 (12.6)	43 (13.6)
Schooling	6.7 (11.4)	2 (3.0)
Adults	3.9 (1.6)	3.8 (1.9)
Children	1.2 (1.1)	0.9 (1.2)
Memberships[a]	47	41
Ability	6 (1.6)	4.4 (2.0)
Farm size	4.36 (3.4)	3.64 (3.3)
Crop area	82.6 (19.6)	86.7 (18.9)
Irrigated area	6.4 (13.9)	4.8 (13.2)

[a]This is a categorical variable which can take either 1 or 0 and hence no SD is given.

Table 4. Logistic regression results for adoption of IPM for pigeon pea, Rangareddy district, Andhra Pradesh, India.

Variable	β	SE	Wald	Odds ratio
Constant	–2.72*	1.82	2.24	
Age	–0.02**	0.02	1.27	0.98
Schooling	0.32*	0.08	16.84	1.37
Adults	0.17	0.15	1.15	1.18
Memberships	1.33*	0.53	6.16	3.77
Ability	0.54*	0.13	16.19	1.72
Farm size	–0.04**	0.03	2.32	0.96
Crop area	–0.02	0.01	1.13	0.98
Irrigated area	–0.002	0.02	0.01	0.99
Negelkerke R^2				0.46
–2logLL[a]				115.31*
Percentage correct classification[b]				74.8
Sensitivity[c]				71.7
Specificity[d]				78.0

Note: *Significant at 1%; **Significant at 10%. [a]Follows χ^2 distribution with 9 df; [b]Based on a 50–50 classification scheme; [c]Prediction of farmers adopting IPM who were classified correctly; [d]Prediction of farmers not adopting IPM who were classified correctly.

these components of IPM to be effective, the time and method of application are very critical (for example, NPV has to be applied during the cooler hours of the day and with adjuvants to reduce photodegradation and enhance efficacy) (Ravindra and Jayaraj, 1988). Since many farmers are unaware of these finer aspects of the use of biorationals, they often do not obtain the potential benefits.

Factors influencing adoption

The characteristics of IPM farmers and non-IPM farmers are presented in Table 3. The adopters of IPM differed significantly from the non-adopters in their ability to identify insect pests and in their number of years of schooling. Furthermore, the IPM farmers had more adult family labour available per household and were members of social organizations such as farmers' clubs, user groups or self-help groups. However, the IPM farmers had sown about 83% of land to pigeon pea, compared with 87% in the case of non-IPM farmers. The average farm size of IPM farmers was about 4.36 ha, compared with 3.64 ha for non-IPM farmers. These differences, however, are not statistically significant.

Table 4 gives the logistic regression coefficients along with the significance levels, odds ratio and model fit statistics in the form of Negelkerke R^2, log likelihood and the percentage correct classification. The model estimated was found to be a significantly good fit, as can be seen from all three criteria. The Negelkerke R^2 was about 0.46 and the log likelihood (–2 log LL) of 115.31 was significant at 1%. The model predicted about 75% of the cases correctly as either adopters or non-adopters. Furthermore, the model predicted 72% of adopters and 78% of non-adopters correctly.

An examination of the logistic regression coefficients indicates that the age of the farmer, schooling, participation in social groups and ability to recognize pest and natural enemy species influenced the adoption decision significantly. As can be seen from the table, each year of schooling increased the odds of adoption of IPM by 37%. Similarly, as the age of the farmer increases by one year, the odds decrease by 2%. The regression coefficient associated with age was, however, found to be significant only at 10%. Thus, younger and educated farmers are more likely to adopt IPM technologies. This inference is not surprising, because the younger farmers are more ambitious and more receptive to the newer technologies, and their education will place them in a better position to obtain the relevant information and the necessary inputs (Tilak, 1993; Rama Rao *et al*, 1997). Participation in social groups also influenced the adoption decision significantly. A farmer who is a member of a social group is 3.77 times more likely to be an adopter than one who is not and enhances his or her social capital in terms of access to information and resources. Furthermore, various development programmes also emphasize technology transfer through self-help groups, user groups, etc, to accelerate and widen the uptake of the technologies. Thus the highly positive and significant influence of social capital as represented by participation in social organizations is tenable. IPM technologies require more labour than a dependence on chemical insecticides alone, and so it becomes difficult to adopt IPM technologies on larger farms. Practices such as shaking the plants, clipping off tender tips, erection of pheromone traps and sprays of NPV are particularly difficult for farmers growing larger areas of pigeon pea. Thus bigger farms with larger acreages under pigeon pea are less likely to take up IPM, and this is reflected in the negative coefficients for farm size and area under pigeon pea. The positive coefficient for labour endowment as measured by the number of adults per household, though not significant, only reinforces this observation. It is worth noting that farmers with larger farms and more area under castor are also more likely to adopt chemical plant protection measures (Rama Rao *et al*, 1997). In addition, access to irrigation is highly correlated to the access and use of other purchased inputs such as fertilizers. The relatively greater assured returns from irrigated crops might also attract more managerial attention from the farmers, and consequently access to irrigation may discourage IPM adoption. However, the observed non-significant coefficient indicates that the variable acted both ways.

Thus the variables associated with human and social capital (age, education, pest recognizing ability and participation in social organizations) and the relative resource endowments (farm size and human labour availability) influenced the IPM adoption decision significantly. It is acknowledged that the IPM components are more knowledge-intensive (CGIAR, 2000) and more labour-intensive.

Extent of adoption

In the above analysis, a farmer was considered to be an IPM adopter if he or she adopted at least four different components of IPM. However, there can be variations in the extent of adoption of different components of IPM. In order to measure the extent of adoption, scores were computed for all the IPM farmers. This study measured IPM adoption based on the absolute number of components, as IPM is essentially an integration of different means of pest management adapted to local situations.

The findings are presented in Table 5. Thirteen different components of IPM were followed by the IPM farmers. Seven of the thirteen were cultural practices, three were chemical, two biological and one mechanical. A farmer adopting all 13 practices in his or her effort to manage pests below the economic threshold levels would get a score of 3.6. The scores of the farmers were found to vary between 1.5 and 3.3, with an average score of 1.98. About 45% of the farmers scored below 1.85 (35 percentile) and were classified as low adopters. Only 20% achieved high adoption scores (> 2.15, the 70 percentile). The remaining 35% were classified as medium adopters, with scores between 1.85 and 2.15. Thus, there was clear variation in adoption within the adopters.

Table 5. Extent of IPM adoption in pigeon pea, Rangareddy district, Andhra Pradesh, India.

Category	Weight	Number of practices followed
Chemical	0.15	3
Cultural	0.30	7
Biological	0.35	2
Mechanical	0.20	1
Total	1.00	13
Maximum possible score	3.6	
Average score	1.98	
Range of scores	1.5–3.3	
Low adopters[a] (%)	45	
Medium adopters[a](%)	35	
High adopters[a] (%)	20	

Note: Scores less than 1.85 indicate low adopters; 1.85–2.15 medium adopters; and more than 2.15 high adopters.

Farm-level impact of IPM

The farm-level impact of IPM was observed by comparing the use of chemical insecticides and yields of IPM farmers with those of non-IPM farmers. As a result of the adoption of IPM components, there was a steep decline in the use of chemical insecticides from about 9 l ha^{-1} in the case of non-IPM farmers to about 5 l ha^{-1} in the case of IPM farmers (Table 6). This also resulted in a saving of expenditure on plant protection chemicals. It is interesting to note as well that IPM farmers applied more organic manures than the non-IPM farmers. The adoption of IPM was also associated with marginally higher yields of crop. The cost savings together with the increased yields resulted in significantly higher net returns (an increase of 160%) from IPM farms compared with non-IPM farms.

Another important benefit of IPM adoption is the reduction in the incidence of health hazards associated with the use of chemical insecticides. It was observed that about half the farmers reported at least one incident of falling sick because of exposure to insecticides compared

Table 6. Farm-level impact of adoption of IPM for pigeon pea, Rangareddy district, Andhra Pradesh, India.

Parameter	IPM farms	Non-IPM farms	Change (%)	F-value	*p*
Farmyard manure (t ha^{-1})	5.4	3.7	45.9	4.12	0.05
Chemical nutrients (kg ha^{-1})	67	61	9.8	4.18	0.05
Chemical insecticides (l ha^{-1})	5	9	44.4	125.9	< 0.01
Yield (q ha^{-1})	13	11	18.2	4.09	0.05
Expenditure on insecticides (rupees ha^{-1})	2,500	5,400	–53.7	184.3	< 0.01
Cost of cultivation (rupees ha^{-1})	12,340	16,580	–25.6	118.4	< 0.01
Net returns (rupees ha^{-1})	6,268	2,400	161.2	132.1	< 0.01
Incidence of sick events (number)	5	45	–90	5.6[a]	0.02

Note: US$1 = approximately rupees 43.65. [a]χ^2 statistic.

Table 7. Results of Kaplan-Meier survival analysis for survival of IPM *vis-à-vis* use of new insecticides.

Group	Number	Events (number)	Censored (number)	Censored (%)	Mean (years)	SE	95% CI
Users of new insecticides	22	18	4	18	3.17	0.22	2.73–3.61
Non-users of new insecticides	28	6	22	79	5.15	0.30	4.56–5.75

Note: Event: farmer discontinuing IPM practices. Censored: farmer still continuing IPM practices and no information available if and when the farmer discontinues IPM practices.

with 5 out of 90 IPM farmers. These health hazards would further lead to expenditure on health care as well as loss of wages during the period of illness.

Discontinuance of IPM technologies

The results of the Kaplan–Meier survival analysis are presented in Table 7. As can be seen, out of 50 sample farmers, 22 had used the new chemicals and 28 had not used them. Eighteen farmers (82%) in the former group had stopped using IPM compared with six (21%) in the latter group (Table 7). Practices such as spraying NPV, use of pheromone traps, shaking plants, summer ploughing and so forth were discontinued as a result of the use of these new-generation insecticides. Furthermore, 79% of the farmers who had not used the new chemicals still continued to use IPM, compared with 18% of the users of new chemicals. It was also observed that the farmers who used these chemicals adopted IPM for an average of three years compared with five years in the case of farmers who had never used them. The log rank value was 14.88, which was significant at less than 1%. Thus the use of more effective chemical insecticides led to the discontinuation of IPM by the farmers. It was also observed that the application of these chemicals was so effective that no larvae of the pod borer (*H. armigera*) were present subsequently, thus affecting the on-farm preparation of NPV solution, an important component of IPM. While farmers have a strong economic rationale for such practices (for example, it was observed that one spray of spinosad was equivalent to 3–4 sprays of conventional chemicals such as endosulfan, and the adoption of IPM needs more labour and continual attention to the crop), it is important for researchers to examine the possible consequences of such chemicals and to educate the farmers accordingly. Continued use of these chemicals and discontinuation of IPM practices may result in a changing pest scenario, which will require an altogether different strategy – requiring extra resources for its development and adoption by the farming community.

Conclusions

An examination of the adoption of different components of IPM showed that farmers adopted methods such as summer ploughing, spraying of NSKE and other cultural practices, which fit well into routine cultivation practices. The adoption of biological agents such as NPV, *B. thuringiensis* and *Trichogramma* is limited because of constraints on availability as well as uncertainty about their effect. Age, education and a farmer's membership of social organizations, plus the ability to identify pests, are the important personal characteristics that influence the decision on whether to adopt IPM. Farm size was observed to have a negative impact on the probability of adoption, whereas the family labour endowment had a positive effect. Variations were observed in the extent of adoption. The use of more effective chemical insecticides discouraged the adoption of biological and mechanical components of IPM. The adoption of IPM led to a reduced use of insecticides and increased profits from pigeon pea cultivation.

Acknowledgments

The authors are thankful to Dr Y. S. Ramakrishna, Director, CRIDA, Hyderabad, and Dr K. P. R. Vittal, Director, CAZRI, Jodhpur, for their support. They acknowledge the efforts of Mr P. Naraiah and Ms B. Malathi, Senior Research Fellows in data collection, compilation and analysis. This work is an output of the project 'Assessment of Adoption and Impact of Integrated Pest Management in Rainfed Crops' (Project No 3030834022) funded by the Indian Council of Agricultural Research. The views are, however, those of the authors and do not necessarily reflect the views of the organizations to which they belong.

References

Adesina, A. A., and Zinnah, M. M. (1993), 'Technology characteristics, farmers' perceptions and adoption decisions', *Agricultural Economics*, Vol 9, pp 297–311.

CGIAR (2000), *An Evaluation of the Impact of Integrated Pest Management Research at the International Agricultural Research Centres*, Food and Agricultural Organization of the United Nations, Rome.

Chan, Y. H. (2004), 'Biostatistics 203. Survival analysis', *Singapore Medical Journal*, Vol 45, pp 249–256.

Commissionerate of Agriculture (1999), *State Agricultural Profile*, Commissionerate of Agriculture, Andhra Pradesh, Hyderabad.

Feder, G., Just, R. E., and Zilberman, D. (1984), 'Adoption of agricultural innovations in developing countries: a survey', *Economic Development and Cultural Change*, Vol 33, pp 255–297.

Gujarati, D. N. (2004), *Basic Econometrics*, Tata McGraw-Hill Book Company, New Delhi.

Harper, J. K., Rister, E., Mjilde, J. W., Bastinan, M. D., and Way, M. O. (1990), 'Factors influencing adoption of insect management technology', *American Journal of Agricultural Economics*, Vol 72, pp 997–1005.

Lapar, M. L. A., and Pandey, S. (1999), 'Adoption of soil conservation: the case of Philippine uplands', *Agricultural Economics*, Vol 21, pp 241–256.

Rama Rao, C. A., Srinivasa Rao, M., and Reddy, Y. V. R. (1997), 'Predicting the adoption of plant protection measures using a logit model', *International Journal of Pest Management*, Vol 43 pp 299–302.

Rama Rao, C. A., Srinivasa Rao, M., Naraiah, P., Malathi, B., and Reddy, Y. V. R. (2007), 'Profitability of cotton on a pest management continuum in Guntur district of Andhra Pradesh', *Agricultural Economics Research Review*, Vol 20, pp 273–282.

Ravindra, R. J., and Jayaraj, S. (1988), 'Efficacy of NPV with adjuvants as high volume and ultra-low volume applications against *Heliothis armigera* in chickpea', *Tropical Pest Management*, Vol 34, pp 441–444.

Tilak, T. B. G. (1993), 'Education and agricultural productivity in Asia: a review', *Indian Journal of Agricultural Economics*, Vol 48, pp 187–200.