Ind. Jn. of Agri. Econ.
Vol. 60, No. 4, Oct.-Dec. 2005

An Econometric Analysis of Green Technology Adoption in Irrigated Rice in Pondicherry Union Territory

A Pouchepparadjou, P. Kumaravelu and Lalith Achoth*

I

INTRODUCTION

Providing adequate supplies of food and improving the health of rapidly increasing population are the two greatest challenges today. By the year 2020, the world may have to support some 8.4 billion people. Even though enough food is being produced in aggregate to feed everyone, some 800 million people still do not have access to sufficient food. The annual rate of food production in tropical developing nations is less than 1 per cent, while in most of these countries population is growing at the annual rate of 2 per cent. Thus there is a serious gap between food supply and demand.

India, which was threatened by hunger and mass starvation in the 1960s, is now self-sufficient in staple foods even though our population has more than doubled. Apart from this success, the following serious concerns remain for the future: first, hunger and malnutrition persist in India often because, the pattern of agricultural growth failed to benefit the poor adequately. Second, agricultural demand will grow along with population growth and rising per capita income, and this will warrant continuing increases in agricultural productivity. Yet growth in yield appears to be decreasing, while the prospects for expanding cropped and irrigated areas are limited. Third, if not checked, environmental problems associated with agriculture could threaten future levels of agricultural productivity as well as the health and well being of rural people.

The Indian agricultural scenario has changed tremendously with the adoption of modern agricultural technology, viz., high-yielding varieties, chemical fertilisers, assured irrigation and improved agronomic practices during the late sixties and seventies. Under such an intensive cropping system, pests have emerged as the major problem. To overcome losses under such pests, prophylactic pest control measures mostly with chemical pesticides were adopted. However indiscriminate use of

---

*Associate Professor (Agricultural Economics), Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal-609 603 (Union Territory of Pondicherry), Lecturer, Adiparasakthi Agricultural College, Kalavai, Tamil Nadu and Associate Professor (Agricultural Economics), University of Agricultural Sciences, Bangalore-560 024, respectively.

This study is a part of their project entitled "Environmental, Socio-Economical and Institutional Aspects of Technology Adoption: Integrated Pest Management (IPM) in Rice Cultivation in the Union Territory of Pondicherry" funded by World Bank aided EMCaB project through Ministry of Environment and Forest, co-ordinated by Indira Gandhi Institute of Development Research, Mumbai.

pesticides in intensively cropped areas led to destruction of beneficial organisms, resistance against pesticides, resurgence of treated pests, pesticide residue in food chain, environmental pollution and pesticide associated health hazards.

In 1950-51, the consumption of pesticides in India was 2,350 tonnes and there was a steady increase up to 75,000 tonnes till 1990-91. From 1991-92 the consumption of pesticides started declining steadily and in 1996-97, it was 56,110 tonnes (Singhal, 1999). At present India is the largest manufacturer of pesticides among the South Asian and South African countries. The production of technical grade pesticides in the country was 1,02,240 tonnes in 1998-99. Of the total chemical pesticides consumed, cotton accounts for the maximum consumption of 45 per cent, rice 22 per cent and vegetables 9 per cent, followed by others.

Pesticides do not offer any long-term solutions to the pests; rather they create problems to human health and environment. In order to overcome the adverse affects due to over reliance on pesticides, the current thrust on plant protection is on promoting green technologies such as Integrated Pest Management (IPM), which is ecologically sound, economically viable and socially acceptable. IPM pest control methods deal with cultural, mechanical, biological and chemical practices. It is based on selective and timely application of pesticides and use of biological agents, including mass production and large-scale field release of natural predators of pests. The Government of India (GOI) reoriented its policy on plant protection during 1985 by adopting IPM as its cardinal principle and main plan of plant protection strategy in the overall crop production programme. It has taken a number of positive initiatives for the promotion of IPM. The Union Territory of Pondicherry is highly developed in agriculture in terms of highest cropping intensity, largest percentage of net area irrigated to net cultivated area, highest coverage of paddy area under high-yielding varieties in the country. The high input intensive rice cultivation in the Union Territory (U.T.) had one of the highest pesticides and fertiliser consumption per cropped hectare in the country. The Government of Pondicherry has changed its policy in 1994-95 with the introduction of IPM for rice as a centrally sponsored scheme through Farmer Field Schools (FFS) and since then the pesticide consumption has shown a declining trend. This study has been undertaken in the U.T. of Pondicherry to examine the level of IPM technology adoption by the rice growers, to evaluate the impact of IPM on pesticide use and yield and to identify the prime factors responsible for adoption of IPM techniques for different farm size holdings in two regions of U.T. of Pondicherry.

II

DATA AND METHODOLOGY

Sampling Design

The Union Territory of Pondicherry forms the universe of the study. It consists of four regions with agricultural activities dominant in the regions of Pondicherry and

Karaikal having larger geographical area and area under cultivation. The FSSs have been conducted in these two regions only and so these two regions were selected to undertake the present study. The FFSs, a programme by the Department of Agriculture of the Government of Pondicherry organises training programme to the farmers on various aspects of IPM. To select the respondents, 3 FFS villages were selected randomly in each of the two regions. From these villages, 30 farmers who were trained through FFS and 30 farmers who did not undergo such training were selected randomly. Likewise the selected sample size in each of the two regions was 225. Thus the total sample size was 450. The primary data were analysed using various statistical techniques to draw meaningful inferences. The tools of analyses used in the study were factor analysis, frontier production function, decomposition of output and logistic regression.

Factor Analysis

An adopter of IPM can completely or partially adopt the components.[1] Rather than to think of adoption and non-adoption of IPM as dichotomous one, it may be more appropriate to think of a complete adoption and complete non-adoption of IPM as a continuum. At one end of continuum lies IPM adopting farms, who adopt the entire package of IPM components. At the other end of the continuum lies the IPM non-adopting farm, which does not adopt any one of the IPM component. Many farms lie between the polar extremes of complete adoption and complete non-adoption of IPM components. Hence factor analysis is used to categorise farmers into adopters and non-adopters.

The adoption of each of the 26 components of IPM technology was given a score of “1” for adoption and “0” for non-adoption. These were subjected to Factor Analysis. Seven significant components emerged with Eigen roots greater than one. Therefore seven factor scores were obtained for each individual. These factor scores were weighted by their respective contribution to the total variance and then aggregated. The entire sample was grouped into two categories, viz., adopter (having scores above mean) and non-adopters (having scores below mean).

Frontier Production Function

Frontier Production function represents a maximum possible output for any given set of inputs making use of the best technology available, thus sets a limit or frontier on the observed values of dependent variable. In the sense that no observed value of output is expected to lie above this frontier. Any deviation of a farm from the frontier indicates the extent of farm's inability to produce maximum output from its given set of inputs and hence represents the degree of technical inefficiency.

A production process may be inefficient in two ways, only one of which can be detected by an estimated production frontier. It can be technically inefficient, in the sense that it fails to produce maximum output from a given bundle of inputs. The other type of inefficiency could be allocative inefficiency in the sense that the marginal revenue product of input might not be equal to the marginal cost of that input even though the technology is efficient. Allocative inefficiency results in utilisation of inputs in the wrong proportion with given input prices. Since, estimation of production frontiers is carried out with observations on output and inputs only, such an exercise cannot provide evidence on the matter of allocative inefficiency, and cannot be used to draw inferences about total or economic inefficiency (Schmidt and Lovell, 1979).

The technical efficiency in production was estimated by using the stochastic frontier production function. The stochastic frontier production function was independently proposed by Aigner *et al*. (1977) and Meeusen and van den Broeck (1977). The primary advantage of stochastic frontier production function is that it enables to estimate u_i and therefore also to estimate farm-specific technical efficiencies. The measure of technical efficiency is equal to the ratio of the production of the i-th farm to the corresponding production value if the farm effect u_i was zero (Jondrow *et al*., 1982). When output is measured in logarithms, the farm specific technical efficiency can be estimated as,

$$TE_i = \text{Exp}(-u_i) \qquad 0 < TE_i < 1$$

The various ratio γ explaining the total variations in output from the frontier level of output attributed to technical efficiencies can be computed as, $\gamma = \sigma^2 u / \sigma^2$ (Battese and Coelli,1988). The estimation of stochastic frontier production function made it possible to find out whether the deviation in technical efficiency from the frontier output is due to firm specific factors or due to external random factors (Battese, 1992). The stochastic frontier model can be represented as:

$$Y_t = f(X_i, ß) \exp(v_i - u_i)$$

where,

Y_t - production of i-th farm,

X_i - suitable function of the vector X_i of inputs for the i-th farm,

ß - vector of unknown parameters,

V_i - symmetric component of the error term,

u_i - non-negative random variable which is under the control of the farm.

Shanmugam and Palanisami (1993) proposed the following formula to estimate the technical, allocative and economic efficiencies.

$$TE = \frac{1}{m} \frac{\sum Y_t}{\sum \hat{Y}_t}$$

The farm specific efficiency or allocative efficiency is estimated by, AE = $\hat{Y}_t / \overline{Y_t}$, where $\hat{Y}_t$ is the maximum output of the farm t and $\overline{Y_t}$ is the output at the optimum level of all variable inputs. Farm-specific economic efficiency is estimated by the equation,

$$EE_i = (TE_i) \times (AE_i)$$

The technical efficiency of production has been analysed in frontier production function approach, which has been estimated by the method of Corrected Ordinary Least Square (COLS) technique. As a first step, Ordinary Least Square (OLS) is applied, which gives the best linear unbiased estimates. The intercept estimates is then corrected by shifting the function until no residual is positive and one is zero. Given the technical efficiency, input prices and output prices and the allocative efficiency, economic efficiency was obtained.

Decomposition of Changes in Output

Decomposition of output change is a technique used to factor out the effects of technology or an environmental damage or any other impact on production. To discern the pure impact of IPM technology on production of rice in the study area, this technique has been used. Superior technologies are expected to contribute significantly to output. The effect of IPM on the output of paddy has been studied using decomposition analysis where technology and the factor contribution of inputs have been quantified. The two groups considered were adopters and non-adopters.

Two separate production functions of Cobb-Douglas type were estimated for IPM adopted farms and non-adopting farms for paddy. The equations are estimated on per acre basis. The forms of the equations are specified below.

<u>Adopted farms</u>

$$\text{Log output}_A = \log A_A + a_A \log \text{Seed}_A + b_A \log \text{Urea}_A + c_A \log \text{OIF}_A + d_A \log \text{Wage}_A + e_A \log \text{OF}_A + f_A \log \text{OP}_A + g_A \log \text{Area}_A + h_A \log \text{LW}_A + i_A \log \text{PPC}_A + e_a$$

<u>Non-adopted farms</u>

$$\text{Log output}_{NA} = \log A_{NA} + a_{NA} \log \text{Seed}_{NA} + b_{NA} \log \text{Urea}_{NA} + c_{NA} \log \text{OIF}_{NA} + d_{NA} \log \text{Wage}_{NA} + e_{NA} \log \text{OF}_{NA} + f_{NA} \log \text{OP}_{NA} + g_{NA} \log \text{Area}_{NA} + h_{NA} \log \text{LW}_{NA} + i_{NA} \log \text{PPC}_{NA} + e_{na}$$

where,

Output is output value per acre in Rs.,
Seed is seed cost per acre in Rs.,
Urea is urea cost per acre in Rs.,
OIF is other inorganic fertiliser cost per acre in Rs.,

Wage	is total wage cost per acre in Rs.,
OF	is other fertiliser cost per acre in Rs.,
OP	is other operational cost per acre in Rs.,
Area	is area in acres in Rs.,
LW	is land water cost per acre in Rs.,
PPC	is plant protection chemicals per acre in Rs.,
e	is disturbance term.

The subscripts A and NA represent IPM-adopted and IPM - non-adopted farms, respectively. A is the scale parameter and a, b, c, d, e, f, g, h, and i are output elasticities with respect to various inputs used. The difference between equation of adopted and non-adopted farms is represented in the following form.

$$\text{Log}(\text{Output}_A/\text{Output}_{NA}) = \log(A_A/A_{NA}) + [(a_A - a_{NA})\log \text{Seed}_{NA} + (b_A - b_{NA})\log \text{Urea}_{NA} + (c_A - c_{NA})\log \text{OIF}_{NA} + (d_A - d_{NA})\log \text{Wage}_{NA} + (e_A - e_{NA})\log \text{OF}_{NA} + (f_A - f_{NA})\log \text{OP}_{NA} + (g_A - g_{NA})\log \text{Area}_{NA} + (h_A - h_{NA})\log \text{LW}_{NA} + (i_A - i_{NA})\log \text{PPC}_{NA}] + [a_A \log(\text{Seed}_A/\text{Seed}_{NA}) + b_A \log(\text{Urea}_A/\text{Urea}_{NA}) + c_A \log(\text{OIF}_A/\text{OIF}_{NA}) + d_A \log(\text{Wage}_A/\text{Wage}_{NA}) + e_A \log(\text{OF}_A/\text{OF}_{NA}) + f_A \log(\text{OP}_A/\text{OP}_{NA}) + g_A \log(\text{Area}_A/\text{Area}_{NA}) + h_A \log(\text{LW}_A/\text{LW}_{NA}) + i_A \log(\text{PPC}_A/\text{PPC}_{NA})].$$

The above equation apportions the differences in total value of output between the IPM adopted farms and the IPM non-adopted farms in the cultivation of paddy. The first term refers to the per cent change in total output per acre due to the shift in Scale parameter A. The second term estimates the effect of change in slope parameters also referred to as non-neutral technology change. These two terms in total give the value of effect of technology to the difference in output of adopters (in this case Integrated Pest Management) and non-adopters. The last term measures the contribution of change in output due to change in input levels.

Logistic Regression Analysis

The adoption of IPM practices may be influenced by several factors such as age, experience, and contacts with agricultural extension personnel among other factors. Therefore to understand the degree and direction of influence of each factor in the adoption of the technology, the logistic regression model was used. The model had been fitted for three groups of farmers, viz., marginal, small and the large. This has been done in order to understand the factors in each group, which will pave the way for being replicated in other situations and improve the level of adoption. The model relates the set of factors to a set of farmer characteristics and to estimate the probabilities of adoption due to the set of factors. Thus the relation will be represented as below:

$$P(Y) = 1/(1+e^{-y})$$

where,

Y = 1 if the farmer adopts and
Y = 0 if the does not adopt.

The model can be written as:

$$\ln (P/1\text{-}P) = \beta_1 + \beta_2\, AA + \beta_3\, A + \beta_4\, AI + \beta_5\, OI + \beta_6\, IPM + \beta_7\, E + \beta_8\, EX + \beta_9\, L + \beta_{10}\, M + \beta_{11} NLA + \beta_{12} OA + \beta_{13} PPC + \text{error}$$

where P is the probability of adoption.
The variables are

A is age of the farmers in years,
AI is agricultural income in Rupees,
OI is other income in Rupees,
E is years of education,
EX is experience in agricultural activities in years,
L is livestock value in Rupees,
NLA is non-land asset value in Rupees,
OA is operational area in acres,

And the dummy variables are

AA is approach made by Agricultural Extension Officer (0 = No; 1 = Yes),
IPM is whether attended IPM training (0 = No; 1 = Yes),
M is membership in organisation (0 = No; 1 = Yes),
PPC is whether reduced usage of Plant Protection Chemicals (0 = No; 1 = Yes).

III

RESULTS AND DISCUSSION

Frequency in Usage of PPC Chemicals in Nursery and Main Field

The comparison of pesticide consumption in both the categories can give an indication of the extent of reduction in pesticide. Moreover, as the information is collected in the same year, the influence of weather conditions that differ from year to year is eliminated.

The frequencies in the usage of pesticides in nursery and main-field are presented in Table 1. Paddy is vulnerable to infestations by pests mainly during the vegetative stage of the crop. The various pests like stem borer, leaf folder, brown plant hopper, gallmidge and earhead bug, etc., invade and cause damage to the crop. Hence the need to control them through any means is warranted by the farmer. Similarly pests are also prevalent in the seeds that may manifest itself into higher proportions during the later stages of the crop. Thus farmers resort to control these pests in the seed during the nursery phase of crop itself. The control of pests at this stage would minimise farmer's cost as it is considered as a precautionary step in pest control. The total number of applications undertaken has an influence on the pest and in turn on the environment.

TABLE 1. FREQUENCY IN USAGE OF PPC CHEMICALS IN NURSERY AND MAIN FIELD

Number of application (1)	Adopter		Non-adopters		Grand Total	
	Number (2)	Per cent (3)	Number (4)	Per cent (5)	Number (6)	Per cent (7)
Nursery						
One application	73	88.0	97	81.5	170	84.2
Two application	5	6.00	11	9.2	16	7.90
Three application	5	6.00	11	9.2	16	7.90
Grand Total	83	100.0	119	100.0	202	100.0
Main Field						
One application	58	76.3	113	68.1	171	70.7
Two application	15	19.7	49	29.5	64	26.4
Three application	3	3.9	3	1.8	6	2.50
Four application	-	0.0	1	0.6	1	0.40
Grand Total	76	100.0	166	100.0	242	100.0

Table 1 reveals the number of applications carried out in the nursery stage of the crop in both the adopter and non-adopter farms. Single application was prevalent in 88 and 81.5 per cent of adopter and non-adopters respectively. Non-adopter farms resorted to 2 or 3 applications of PPC in the nursery, whereas adopters rarely made 2 or 3 applications in the nursery.

In case of main field application, the percentage of farmers restricting to one application is found high in adopter farms (76.3 per cent) than non-adopter farms (68.1 per cent). Farms taking up second application are 19.7 and 29.5 per cent in adopter and non-adopter farms, respectively, while in the case of three applications it is 3.9 and 1.8 per cent of farms, whereas not a single farm in the adopter category had gone for four applications and it was 0.6 per cent in non-adopter category. This result is in concurrence with the findings of Fernandez-Cornejo, 1998; Hall and Dunean, 1984; Leake, 2000; Ogilvy *et al.,* 2000; Devarassou, 2002; Moorty *et al.*, 2002; Ameta *et al.,* 2004; Mohan *et al.,* 2004 and Puri *et al.,* 2004.

The cost incurred on PPC in paddy cultivation was Rs. 95 and Rs. 271 in the nursery and main field phase of crop growth in adopter farms (Table 2). In non-adopter farms it was Rs. 113 and Rs. 289.2, respectively, for the nursery and main field phase of the crop. The total PPC cost spent in non-adopter farms was higher than adopters' farms at Rs. 366 and Rs. 402.2 per acre respectively. The dependence on PPC by the non-adopters farms was also higher. Similar findings were also observed by Pingali and Rola, 1995; White and Wetzstein, 1995; Fernandez-Cornejo, 1998; Leake, 2000; Ogilvy *et al.,* 2000; Razack, 2000; Tamizheniyan, 2001; Devarassou, 2002; Moorthy *et al.,* 2002; Bashir *et al.*, 2003; Ameta *et al.,* 2004; Mohan *et al.,* 2004 and Puri *et al.,* 2004.

TABLE 2. COST OF PPC USED IN SAMPLE FARMS

(*Rs. per acre*)

Area of Application (1)	Adopters		Non-adopters	
	Actual cost (2)	Per cent (3)	Actual cost (4)	Per cent (5)
Nursery	95.0	26.0	113.0	28.1
Main field	271.0	74.0	289.2	71.9
Total	366.0	100.0	402.2	100.0

Economics of IPM Adoption

Farmers need not necessarily adopt a technically feasible alternative if it is not in concurrence with the objective of profit maximisation. The profitability is determined by the cost involved, crop productivity and output price. There was no difference in price received by the adopters and non-adopters of IPM. Thus given the output price, productivity and cost of technology are the main determinants of profitability. The detailed cost and returns of the adopter and non- adopters of IPM is presented in the Appendix. The IPM adopted farms generated net returns worth of Rs. 5,208 per acre, which is 26 per cent higher than the non-adopter farms (Table 3). This is in conformity with the results obtained by Antle and Pingali, 1994; Kenmore, 1997; Pretty, 1998; Shivaraya *et al.,* 1999; Birthal *et al.,* 2000; Razack, 2000; Vanden and Lestari ,2001; Devarassou, 2002; Hillocks, 2002; Moorthy *et al*., 2002; Dasgupta *et al.,* 2004;, Khan *et al.,* 2003; Mohan *et al.,* 2004; Puri *et al*., 2004 and Shetty, 2004. Thus, IPM emerges as an economic alternative to substitute predominantly chemical pest control technology.

TABLE 3. COST AND RETURNS UNDER ADOPTER AND NON-ADOPTER FARMS

(*Rs. per acre*)

Details (1)	Total Costs (2)	Gross Returns (3)	Net Returns (4)
Adopters	6,229	11,436	5,208
Non-adopters	6,050	10,197	4,147

Technical and Economic Efficiency of IPM Adoption

Economic Efficiency has been dichotomised into allocative efficiency and technical efficiency. The former deals with the allocation of resources for profit maximisation based on the prices of input and the other with management efficiency or realising the highest output with the given level of input use. The technical efficiency of the production has been analysed in the frontier production function framework, which has been estimated by method of Corrected Ordinary Least Squares.

The results of frontier functions along with optimum levels of each resource used in production has been computed and presented in the Table 4. Using this function the individual farmers efficiency levels were determined and the overall level of technical efficiency calculated and presented in the Table 5. The average level of technical efficiency was 0.35 among adopters and 0.37 among non-adopters. The levels of technical efficiency were more or less the same, for both adopters and non-adopters.

TABLE 4. FRONTIER PRODUCTION FUNCTION ANALYSIS

Details (1)	Adopter		Non-adopter	
	Coefficient (2)	Optimum level of inputs (3)	Coefficient (4)	Optimum level of inputs (5)
Constant	2.873**		3.824**	
Area	0.984**	2.567	1.110**	2.402
Wages	0.368**	1439.958	0.160**	520.803
Other operations	0.254**	993.276	0.200**	650.558
Seed	0.031^{NS}	119.962	0.158**	511.382
Manure and compost	0.000^{NS}	0.949	0.001^{NS}	3.275
Urea	-0.001^{NS}	49.785	-0.003^{NS}	121.500
Other inorganic fertilisers	-0.001^{NS}	519.557	0.030**	95.982
Plant protection chemicals	-0.002^{NS}	0.001	-0.003^{NS}	0.106
Land and water charges	-0.009**	0.000	0.000^{NS}	0.002
R^2	0.772		0.907	
Observations	188		262	

Note: ** Significant at 1 per cent level, NS - Not Significant.

TABLE 5. EFFICIENCY OF ADOPTER AND NON-ADOPTER FARMS

Efficiency (1)	Adopters (2)	Non-adopters (3)
Technical Efficiency	0.35	0.37
Allocative Efficiency	0.27	0.88
Economic Efficiency	0.09	0.32

Allocative efficiency deals with allotting resources consistent with the prices of inputs and output. The economic efficiency was derived from their allocative and technical efficiency levels. Economic efficiency was 32 per cent among non-adopters and 9 per cent among adopters. These results clearly show that IPM adopter farmers have greater potential than that of non-adopter farmers. Though these results are only indicative, they show that the adopter farmers can boost output through the use of best practice technologies of IPM.

The above results of efficiencies suggest that even though both the adopters and non-adopters are technically inefficient, the adopter is operating comparatively with lower allocative and economic efficiencies. Therefore there is great potential for IPM adopters to further increase output using available inputs and technologies more efficiently. The existing policies and programmes aimed at improving technical efficiency, extension and educational programmes should be the focus. One would expect that such programmes would also improve allocative efficiency and economic efficiency of adopter farms which in turn will increase the output from IPM technologies further.

Impact of IPM on Rice Production

The real impact of IPM technology can be understood only if they are standardised to comparable levels of scale, input use and the like. This can be accomplished by decomposing the change in output to its constituents like technology, scale and input use. A model proposed by Bislaiah (1977) is conventional to compare the difference in output between two groups. In this study, the two groups considered were the adopter and non-adopter groups. The effect of IPM on the output of paddy has been studied using decomposition analysis where technology and the factor contribution of inputs have been quantified.

TABLE 6. PRODUCTION FUNCTION ESTIMATES: ADOPTER AND NON-ADOPTER FARMS
DEPENDENT VARIABLE: TOTAL OUTPUT PER ACRE

Details	Adopter farms	Non-adopter farms
	Coefficient	Coefficient
(1)	(2)	(3)
Constant	2.8576	3.7317
Land lease and water charges	-0.0269	0.0011
Manure and compost	0.0020	0.0054
Other inorganic fertiliser	0.0329	0.0897
Other operations	0.2168	0.1914
Plant protection chemicals	-0.0121	-0.0055
Seed	0.1012	0.1548
Wages	0.3413	0.1405
Urea	0.0002	-0.0123
Area	0.9942	1.1087
Output(kgs)	1583.81	1313.76
R2	0.777	0.908
N	188	262

Table 6 reveals prima facie that the average output among the IPM adopter farms is higher than the non-adopter farms. It was 1583.81kgs/acre vis-à-vis 1313.76 kgs/acre in the non-adopter farms. The studies by White and Wetzstein, 1995; Kenmore, 1997; Pretty,1998; Shivaraya, *et al.,* 1999; Birthal *et al.,* 2000; Vanden and Lestari, 2001; Devarassou, 2002; Hillocks, 2002; Razack ,2002; Dasgupta, *et al.,* 2004 and Puri *et al.,* 2004 had come across with the same kind of result through the use of IPM. The output of paddy are substantially higher in the IPM adopted farms even as the cost of expenses towards PPC and other inputs was considerably lower in the adopted farms. Therefore it was felt necessary to identify the share of different sources of inputs and technology adopted to understand the impact arising due to adoption of the technology in the cultivation of paddy.

It could be inferred that the use of higher levels of urea in the non-adopter farms could have led to higher incidence of pests in farms leading to high expenses in the usage of plant protection chemicals, whereas in adopter farms the usage had been lower for both urea and plant protection chemicals. This could be confirmed from the negative signs of the coefficients for urea (-0.0123) and plant protection chemicals (-0.0055) respectively, whereas it was positive in the adopter farms for urea (+0.0002) and negative for plant protection chemicals (-0.0121).

The differences in the output of paddy per acre on adopter and non-adopter farms were decomposed into (a) neutral technological change, (b) non-neutral technological change and (c) inputs.

TABLE 7. OUTPUT DIFFERENCES DUE TO ADOPTION OF IPM AND INPUTS

Source of change (1)	Per cent share (2)
Changes in techniques used (IPM)	
Neutral technology	- 468.48
Non-neutral technology	+ 521.22
Technology	52.74
Changes in input used	
Land and water cost Manure and compost Other inorganic fertiliser Other operations Plant protection chemicals Seed Wages Urea Area	47.26
Changes due to inputs alone	47.26
Changes due to other factors	0.19
Total changes accounted	100.00

The results in Table 7 obtained from the decomposition analysis to study the contributions of input and technology to the output difference revealed that a change due to neutral technology is –468.48 per cent and that due to non-neutral technology is 521.22 per cent and the net change attributed to technology accounts for 52.74 per cent. In other words the contribution of technology to the higher output on IPM adopter farms is around 53 percent. This result is significant and suggests that IPM technology is an embodied technological change and requires the use of a complete package of practices. Only if this is done, the farmer will receive higher output. As a matter of fact if the IPM technology is adopted partially the yield levels will be much lower than the non-IPM farms. But the judicious use of resource and management practices can boost the yield levels by about 53 per cent. This increase in value of output was measured as the difference between IPM adopted and IPM non-adopted farms.

It was also observed that the contribution of usage of various inputs, *viz.,* seed, urea, other inorganic fertilisers, labour (wage), organic fertilisers, other operations, area, land lease and irrigation charges and plant protection chemicals is only about 47.3 per cent in the total change in output value in the IPM adopted farms.

Factors Influencing Adoption of IPM in Different Sizes of Farm Holdings

The adoption of IPM practices has been influenced by several factors such as age, experience and contact with agricultural extension personnel, etc. To understand the degree and direction of influence of each of these factors in the adoption of the technology the logistic regression model was used, the results of which are presented in Table 8.

TABLE 8. FACTORS INFLUENCING ADOPTION AND THEIR COEFFICIENTS

	Marginal		Small		Large	
Variable (1)	Coefficient (2)	Exp (b) (3)	Coefficient (4)	Exp (b) (5)	Coefficient (6)	Exp (b) (7)
AEO approach	1.4764**	4.37716	1.4459*	4.2457	0.2496	1.28351
Age	0.0274	1.02778	-0.0168	0.9833	-0.0157	0.98442
Agricultural income	0.0000137	1.00001	3.08E-07	1	6.86E-07	1
Attending of IPM training	-0.0302	0.97025	0.2516	1.2861	1.7986**	6.04118
Education	0.1208**	1.1284	0.0748	1.0777	0.0496	1.05085
Experience	-0.0091	0.99094	0.0248	1.0251	0.0224	1.02265
Livestock value	-0.0000056	0.99999	-0.0000077	1	0.0000212	1.00002
Membership	1.2459***	3.47606	1.4139**	4.112	0.9561*	2.60153
Non-land assets	2.06E-07	1	4.19E-07	1	-8.5E-08	1
Operational area	0.3314	1.39292	1.2741**	3.5755	-0.0169	0.98324
Other income	-0.000009	0.99999	-0.000002	1	-0.00000057	1
Attitude to reduce PPC	1.2797***	3.59556	1.2672*	3.5509	1.664**	5.28039
Constant	-4.9233	0.00728	-7.2516	0.0007	-3.4346	0.03224

Note: ***, ** and * Significant at 1, 5 and 10 per cent level, respectively.

The category of three groups of farms included 264, 85 and 101 farmers in marginal, small and large groups respectively. The analyses of factors that have influenced adoption in the marginal category of farms reveal that the adoption has been positively and highly significantly influenced by the membership in organisations and attitude to reduce the usage of PPC. Being a member of any organisation tends to increase the rate of adoption by 3.5 times and the intention to reduce PPC by 3.6 times respectively.

Similarly the education of the farmer and contacts made with agricultural extension personnel has both been significant and positive in influencing the rate of adoption of IPM. Similar studies made by Gandhi and Patel, 1997; Peshin and Kalra, 1997; Tripp and Ali, 2001 and Javier *et al.,* 2003 proved that education has positive impact on the adoption level of IPM. The other factors such as age, agricultural income, non-land assets, and operational area had a positive influence on adoption but these are not significant.

The scenario of the small farms regarding factors influencing adoption reveals that membership in organisations and operational area of farmers had been significant (five per cent level) and positive in influencing adoption by 4.1 and 3.6 times, respectively. Similarly the approach made by agricultural extension personnel and the attitude to reduce PPC had positively and significantly (10 per cent level) influenced adoption by 4.3 and 3.6 times for a unit increase in these variables. This corroborates with the other findings (Magnan, 1997; Page, 1997; Stoll, 1997; Heong *et al.,* 1998; Staver and Guharay, 2003 and Pedanda and Oka, 2003) that agricultural extension workers and training programmes through Farmer Field Schools greatly influenced the adoption level of IPM.

In the large farm category, attending IPM training and attitude to reduce PPC have had a positive and significant impact on adoption by 6.0 and 5.3 times respectively. Membership in organisation was positive and significantly (10 per cent level) influencing adoption by 2.6 times.

IV

CONCLUSION AND SUGGESTIONS

The choice of pest management technique is a function of cost and returns. The economic advantage of using IPM has to be well documented in order to persuade the farmers to adopt these methodologies. The agricultural extension personnel need to be trained so that they can disseminate effectively to the farmers, the economic advantages of IPM adoption since the monetary benefits are the major driving force behind the decisions made by the farmers. The analysis of the efficiencies suggests considerable room for productivity gains for IPM adopter farms so that they can enhance their income through better use of available resources given the state of technology. Policies to improve education and extension services by further investment in human capital and related factors are therefore recommended. Management of pest can be viewed as a common property problem that is best dealt with through effective collective action. Recognising the positive externalities of IPM, group action could be much more effective than individual action. Variations in the extent of IPM adoption by farmers call for the intensification of educational efforts by agricultural extension personnel.

There is need for reorientation of agricultural and environmental policies to introduce appropriate economic incentives and short-term subsidies which would account for positive externalities of the use of IPM; and withdrawal of taxes and special levies on pesticide use which would account for negative externalities of the use of IPM.

Government intervention to influence farmers' choice of technology can be justified by the environmental and public health implications of pesticide use. Hence orientation of research and technology policies to generate a steady supply of relevant pest management information and technologies, including adequate budget allocations for research, extension and training are required.

Received October 2004. *Revision accepted June 2005.*

NOTE

1. The components of IPM includes selection of good land site, soil testing, preparation of good nursery, summer ploughing, selection of pest resistant varieties, seed treatment, drying of seeds, maintaining optimum population, rogue spacing, avoiding use of excess nitrogen, alternate wetting and drying fields, timely weeding, crop rotation, clipping of seedlings, collection and destruction of insects, light traps, destruction of diseased plants, dislodging of case-worms, using rat traps, allowing snakes to control rats, planting of 'T' stick, natural enemy conservation, release of parasitoids, maintaining predator: pest ratio, usage of PPC based on the economic threshold level (ETL) and neem based chemicals.

REFERENCES

Aigner, D.J.; C.A. K. Lovell and P. Schmidt (1977), "Formulation and Estimation of Stochastic Frontier Production Function Models", *Journal of Econometrics,* Vol.6, No.1, pp. 21-37.

Ameta O.P., B.S. Rana and O.M. Bombawale (2004), "Validation of IPM Technology in Cotton in Southern Rajasthan" *Pestology*, Vol.28, No.11, pp. 27-30.

Antle, J.M. and Prabhu L. Pingali (1994), "Pesticides, Productivity, and Farmer Health-A Philippine Case Study", *American Journal of Agricultural Economics*, Vol.76, No. 3, pp. 418-430.

Bashir, G.A Yasir; Elamin M. Elamin and Eltigani M.Elamin (2003), "Development and Implementation of Intergrated Pest Management in the Sudan", in K.M. Maredia, D. Dakouo and D. Mota-sanchez (Eds.) (2003), *Intergrated Pest Management in the Global Arena*, CAB International, U.K., pp. 131-141.

Battese, G.E. and T.J. Coelli (1988), "Prediction of Firm-level Technical Efficiencies with a Generalized Frontier Production Function and Panel Data", *Journal of Econometrics,* Vol.38, No.3, pp. 387-399.

Battese, G.E. (1992), "Frontier Production Functions and Technical Efficiency; A Survey of Empirical Applications in Agricultural Economics", *Agricultural Economics*, Vol.7, pp.185-208.

Birthal Prathap, S.; O.P. Sharma and Sant Kumar (2000), "Economics of Integrated Pest Management: Evidences and Issues", *Indian Journal of Agricultural Economics,* Vol.55, No.4, October-December, pp. 644-659.

Bisaliah, S. (1977), "Decomposition Analysis of Output Change Under New production Technology in Wheat Farming: Some implication to Returns on Research Investment", *Indian Journal of Agricultural Economics*, Vol.32, No.3, July-September, pp. 193-207.

Dasgupta, Susmita; Meisner Craig and Wheeler David (2004), *"Is Environment Friendly Agriculture Less Profitable for Farmers? - Evidence on Integrated Pest Management in Bangladesh"* World Bank Policy Research Working paper No.3417, September, The World Bank, Washington, D.C. U.S.A.

Devarassou, K. (2002), "Arthropod biodiversity in IPM and Non-IPM Fields of Irrigated Rice Ecosystem", M. Sc (Ag) thesis, Tamil Nadu Agricultural University, Coimbatore.

Fernandez-Cornejo, Jorge (1998), "Environmental and Economic Consequences of Technology Adoption: IPM in Viticulture", *Agricultural Economics*, Vol.18, pp. 145-155.

Gandhi, Vasant P. and N.T. Patel (1997), "Pesticides and the Environment: A comparative Study of Farmer Awareness and Behaviour in Andra Pradhesh, Punjab and Gujarat" *Indian Journal of Agricultural Economics,* Vol 52, No.3, July-September, pp. 519-529.

Hall, D.C. and G.M. Dunean (1984), "Econometric Evaluation of New Technology with an Application to Integrated Pest Management", *American Journal of Agricultural Economics*, Vol. 66, pp. 624-633.

Heong, K.L.; M.M. Escalada, N.H. Huan and V. Mai (1998), "Use of Communication media in Changing Pest Management in the Mekong Delta, Vietnam" *Crop Protection*, Vol.17, No.5, pp. 413-425.

Hillocks R.J (2002), "IPM and Organic Agriculture for Small Holders in Africa", *Integrated Pest Management Reviews*, Vol.7, No.1, pp. 17-27.

Javier, A Pio; Maria Lourdes, Q. Sison and Reynaldo V. Ebora (2003)"Integrated Pest Management in Philippines", in K.M. Maredia, D. Dakouo and D.Mota Sanchez (Eds.) (2003), *Integrated Pest Management in the Global Arena*, CAB International, U.K., pp. 239-248.

Jondrow, J., C.A.K.Lovell, I.S.Materov and P.Schmidt (1982), "On the Estimation of Technical Inefficiencies in the Stochastic Frontier Production Function Model", *Journal of Econometrics,* Vol.19, No.2, pp.233-238.

Kenmore Peter (1997), "A Perspective on IPM", *LEISA*, Vol.13, No.4, pp. 8-9.

Khan,Z.R.; W.A. Overholt and A.Ngeny Mengech (2003), "Integrated Pest Management –Case studies from ICIPE", in K.M. Maredia, D. Dakouo and D. Mota Sanchez (Eds.) (2003), *IntergratedPpest Management in the Global Arena,* CAB International, U.K., pp.441-452.

Leake. A (2000) "The Development of Intergrated Crop Management in Agricultural Crops: Comparisons with Conventional Methods, *Pest Management science*, Vol.56, No.11, pp.950-953.

Magnan Margaret, S. (1997), "Chinese Rice Farmers-The New IPM Experts" *LEISA,* Vol.13, No.4, pp. 14-15.

Meeusen, N. and J. Van Den Broeck (1977), "Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error", *International Economic Review,* Vol.18, No.2, pp. 435-444.

Mohan ,S.; B.Usharani and T.S. Raveendran (2004), "Cotton IPM Success Story" *IPM Mitr* Vol.1, No.3, pp: 48-55.

Moorthy, P.N.K.; N.K.K. Kumar; S. Prabhukumar; R. Ragunatha and G.T.P Kumar (2002), Validation of the IPM of Tomata Fruit Bores by using NPV Sprays and Marigold as Trap Crops, Proceedings of Symposium on Biological Control of Lepidopteran pests, July-17-18, Bangalore, India.

Ogilvy S.E.; V.W. Jorder; A.R. Leake and S. Higginbotham (2000), "Crop Protection Strategies for Intergrated Farming Systems" in S.K Cook; W.F. Comack; A.R. Leake and J.P. Welsh (Eds.) (2000), *Farming System for New Millennium*, Cambridge University Press, U.K.

Page, Sam L.J (1997), "Natural Pest Management in Zimbabwe", *LEISA*, Vol.13, No.4, pp. 12-13.

Pedanda, Ida and Nyrman Jelantik Oka (2003) "Integrated Pest Management in Indonesia:IPM by Farmers", in K.M.Maredia, D .Dakouo and D.Mota-sanchez (Eds.) (2003), *Intergrated pest Management in the Global Arena,* CAB International, U.K., pp.223-237.

Peshin, Rajinder and Rajinder Kalra (1997), "Integrated Pest Management: Adoption and Economic Impact at Farmers' Level", Ecological Agriculture and Sustainable Development, Vol.2. Proceedings of International Conference on Ecological Agriculture Towards Sustainable Development, Chandigarh, India, November 15-17.

Pingali, Prabhu L. and A.C. Rola (Eds.) (1995). "Impact of Pesticides on Farmer Health and the Rice Environment," Kluwer Academic Publisher, Mars Norwall; International Rice Research Institute, Los Banos, Philippines.

Pretty, N. Jules (1998), "Supportive Policies and Practice for Scaling up Sustainable Agriculture", in N.G. Roling and M.A.E. Wagemakers (Eds.) (1998), *Facilitating Sustainable Agriculture*, Cambridge University Press, Cambridge, U.K.

Puri S.N., U.N. Mote and A.R. Walunji (2004), "A Case Study on Large Scale Testing/Verification of IPM module on Rainfed cotton in Tribal areas of Maharastra" *IPM Mitr,* Vol.1, No.3, pp. 123-132.

Razack Abdul (2000), "*Economics Evaluation of Integrated Pest Management (IPM) Programme in West Tamil Nadu*", M.Sc (Ag) Thesis, Tamil Nadu Agricultural University, Coimbatore.

Schmidt, P. and C.A.K. Lovell (1979), "Estimating Technical and Allocative Efficiency Relative to Stochastic Production and Cost-Frontiers", *Journal of Econometrics,* Vol.9, No.3, pp. 343-366.

Shanmugam,T.R and K. Palanisami (1993), "Measurement of Economic Efficiency-Frontier Function Approach", *Journal of Indian Society of Agricultural Statistics*, Vol.45, No.2, pp. 235-242.

Shetty .P.K. (2004), "Socio Ecological Implications of Pesticide use in India", *Economic and Political Weekly*, Vol.39, No.49, December 4, pp. 5261-5267.

Shivaraya Balappa, L.B. Hugar and K.C. Gummaglomath, "Economic Analysis of Integrated Pest Management Technology in Red Gram" *Artha Vikas*, Vol.35, No.2, July-December, pp.35-41, 1999.

Staver, Charles and Falguni Guharay (2003), "Building IPM Programs in Central America: Experiences of CATIE", CAB International, U.K., pp. 477-492.

Stoll Gaby (1997), "Crop Protection in the 1990s", *LEISA*, Vol.13, No.4, pp. 10-11.

Tamizheniyan .S (2001*), Integrated Pest Management in Paddy Production – A Resource Economic Study in Tiruvavur District, Tamil Nadu*, M.Sc (Ag) Thesis, Tamil Nadu Agricultural University, Coimbatore.

Tripp, R. and A. Ali (2001), *Farmer Access to Natural Pest Control Products: Experience from an IPM Project in India*, Overseas Development Institute, Network Paper –Agricultural Research and Extension Network, No.113, London, U.K.

Vanden, H. Berg and A.S. Lestari (2001), "Improving Local Cultivation of Soyabean in Indonesia through Farmers Experiments", *Experimental Agriculture*, Vol.37, No.20, pp. 183-193.

Singhal, Vikas (1999), "Pesticides", *Indian Agriculture, Indian Economic Data Research Centre,* Shivam Offset Press, Naraina, New Delhi, pp. 35-40.

White, Fred, C. and Michel E. Wetzstein (1995), "Market Effects of Cotton Integrated Pest Management" *American Journal of Agricultural Economics*, Vol. 77, pp. 602-612.

APPENDIX

DETAILED COST AND RETURNS FOR ADOPTERS AND NON-ADOPTERS OF IPM

(*Rs.*)

Inputs (1)	Adopters (2)	Non-adopters (3)
Seed	252.9 (4.06)	251.7 (4.16)
Organic manure	620.4 (9.96)	530.0 (8.76)
Fertiliser	763.7 (12.26)	1103.5 (18.24)
Human labour	3422.8 (54.95)	3112.3 (51.44)
Animal/tractor power	786.7 (12.63)	645.0 (10.66)
Pesticides	366.3 (5.88)	402.2 (6.65)
Other pest control inputs	16.2 (0.26)	5.3 (0.09)
Total cost	6229.0 (100.00)	6050.0 (100.00)
Gross return	11436.00	10197.00
Net return	5208.00	4147.00

Figures in parentheses are per cent to the total cost.