ECONOMIC IMPACT ASSESSMENT OF INTEGRATED PEST MANAGEMENT (IPM) ON ONION IN TAMIL NADU

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CENTRE FOR AGRICULTURAL AND RURAL DEVELOPMENT STUDIES

TAMIL NADU AGRICULTURAL UNIVERSITY

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Thesis submitted in partial fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE) IN AGRICULTURAL ECONOMICS** to the Tamil Nadu Agricultural University, Coimbatore.

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CERTIFICATE

This is to certify that the thesis entitled "**ECONOMIC IMPACT ASSESSMENT OF INTEGRATED PEST MANAGEMENT (IPM) ON ONION IN TAMIL NADU"** submitted in partial fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE) IN AGRICULTURAL ECONOMICS** to the Tamil Nadu Agricultural University, Coimbatore is a record of bonafide research work carried out by **Ms. N. KIRUTHIKA** under my supervision and guidance and that no part of the thesis has been submitted for the award of any degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.

Place: Coimbatore **Dr. K. CHANDRAN**
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Date:

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(N. Kiruthika)

ABSTRACT

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By

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Degree	:	**Doctor of Philosophy (Agriculture) in Agricultural Economics**
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India has varying climatic conditions and provides an opportunity for growing a large number of horticulture crops including vegetables. Though India is the second largest producer of vegetables next to China, insect pests, diseases and weeds limit the agricultural productivity growth. India loses about 30 percent of its crops due to pests and diseases each year. The insect pests inflict crop losses to the tune of 40 percent in vegetable production. To combat these pests, farmers largely depend on the pesticides. Vegetables and fruits receive a large quantity of pesticides, and with a cropped area of three per cent, they consume 13 per cent of the total pesticides in the country. To combat the insecticide resistant insects, IPM techniques were being devised. The onion is an important vegetable and has been grown in almost all the parts of India for thousands of years. Indiscriminate use of insecticides in onion cultivation with intensive agronomic practices affected both profitability of farming and the nature of farm. To combat the pests with eco-friendly practices, the scientists developed six components of an IPM package for onion.

The study aims at analyzing the economic impact of onion integrated pest management (IPM) in Tamil Nadu. The specific objectives were to assess the nature and

the extent of adoption of IPM technologies among the onion growers, to identify the determinants of adoption of IPM technologies, to assess the tangible and intangible benefits of adopting IPM technologies and to assess the joint economic benefits of IPM technologies to producers and consumers. Multi-stage sampling design was employed in the present study for selection of sample respondents. Based on the concentration of area, Perambalur and Trichy districts were purposively selected to study the impact of IPM in Onion. The farmers were post-stratified as IPM and non-IPM farmers depending upon whether they followed the IPM practices or not. Economic evaluation was carried out among the 53 IPM farmers and 211 non-IPM farmers. Regarding the planting material, on an average the onion cultivators used 1500kg of onion bulbs per hectare. On an average 60-64 male labourers and 125-143 female labourers were required to cultivate per hectare of onion. A huge difference existed between the IPM and non-IPM farmers in the usage of plant protection chemicals. The IPM farmers used only 4.1 litres of chemicals but non IPM farmers used 5.6 litres of chemicals to cultivate one hectare of onion. Overall the onion cultivators used 5.3 litres of plant protection chemicals for a hectare of onion production.

The economics of onion production indicated that there was large difference in terms of yield and net income and the benefit cost ratios (BCR) also differ. The BCR was higher for the IPM cultivators ranging from 2.10 to 2.27 and it was much lower (1.66) for the non-IPM farmers. The results of partial budgeting indicated that adoption of integrated pest management (IPM) for pest control would bring an additional benefit to the farmers of about Rs. 41,179 per hectare compared to non adoption of IPM by decreasing the cost by Rs. 6824.

Probit regression results showed that education and advice of extension agent positively and significantly influence the adoption of IPM as well as the significant negative coefficient of choosing a pesticide with the advice of pesticide dealers indicates that farmers getting more advice from pesticide dealers were less inclined to adopt IPM.

The results on propensity score matching (PSM) indicated that IPM adopters had a significantly higher yield than the non-adopters. The various matching procedures showed that the onion IPM farmers got 2.47 to 2.63 tonnes of higher yield than non IPM farmers from a hectare. The net revenue of the IPM farmers also higher than the non-IPM farmers. The onion IPM farmers got Rs 40,549 to Rs 41,521 higher profit than non IPM farmers from a hectare. The amount spent by the onion IPM growers for pesticides was significantly lower than that spent by the non-IPM cultivators. The matching results indicated that due to the adoption of integrated pest management (IPM) in onion the cost for pesticide expenditure was reduced by Rs. 6828/ha to Rs 6847/ha.

The results on multiple simultaneous treatments indicated that the relative effect of IPM in onion on yield, net returns and pesticide expenditure with different matching procedures indicate that the yield and net returns for the different groups of IPM farmers were significantly higher than the non-IPM farmers.

The results on economic surplus analysis indicated that the net present value of the potential research for the study area was Rs. 6.23 crores and the internal rate of return (IRR) was 250% for an adoption rate of 8%. The potential research benefits from 2008-2022 for the surveyed area generated by IPM in onion were projected to be about Rs. 41.11 crores for an adoption rate of 20% and increase proportionally with the adoption rate. The maximum benefits expected can reach Rs. 94 crores with an adoption rate of 60%. The internal rate of return (IRR) was also increased proportionally with the adoption rate. It varied from 256% for an adoption rate of 20% to 303% when the adoption rate reached 60%. The potential research benefits generated by IPM from 2008-2022 for Tamil Nadu in onion were projected to be about Rs. 182.39 crores for an adoption rate of 40% and increased proportionally with the adoption rate. The maximum benefits expected can reach Rs. 260 crores with an adoption rate of 60%. The internal rate of return (IRR) varied from 677% for an adoption rate of 40% to 746% when the adoption rate reaches 60%. The results of economic surplus also indicated that the size of economic surplus for adopting the IPM strategy in onion was quite large and the consumers gained a larger share (77%) than producers (23%).

CHAPTER I

INTRODUCTION

1.1 Agriculture in India

Agriculture has been a way of life and continues to be the single most important livelihood of the masses in India. Agriculture has been the backbone of the Indian economy and it will continue to remain so for a long time. It has to support almost 17 per cent of the world population from just 2.3 per cent of world geographical area and 4.2 per cent of world's water resources. Agricultural policy focus across decades has been on self-sufficiency and self-reliance in foodgrains production. Considerable progress has been made on this front. Indian agriculture has become highly diversified after the green revolution era. Agricultural production and productivity have shown significant growth over the last more than three decades. Food grains production rose from 52 million tonnes in 1951-52 to 244.78 million tonnes in 2010-11 (Economic survey, 2011-12, GOI). However, problems are numerous in different marketing systems especially marketing infrastructure, information system and policies.

Over the years, the central and state governments have taken number of efforts to improve both input and output production. The share of agriculture in real GDP has fallen because of its lower growth rate relative to industry and services. During the period 1960-61 to 2010-11, foodgrains production grew at a compounded annual growth rate (CAGR) of around two per cent. In fact, the Ninth and Tenth Five Year Plans witnessed agricultural sectoral growth rate of 2.44 per cent and 2.30 per cent respectively compared to 4.72 per cent during the Eighth Five Year Plan. During the current Five Year Plan, agriculture growth is estimated at 3.28 per cent against a target of four per cent.

The growth of the horticulture sector significantly improved within agriculture and been recognized as potential field for diversification in the last decade to sustain agriculture based economy. This sector was given emphasis by policy makers and budget outlay enhanced significantly in the eleventh plan proposal. The area and production of vegetables have expanded continuously. Although in recent decades, India has achieved self-sufficiency in food grain production, concerns about food security remain, as the scope to bring additional land under cultivation is limited and agricultural production technology has started showing signs of fatigue, and has been accompanied by degradation of the natural production resource base. Notwithstanding these facts, the incremental production has to come from productivity increases without damaging the ecological foundations of agriculture. This combination of the need for food and ecological concern emphasis the need for generation and diffusion of new technologies that produce sufficient food and protect the environment and human health. According to the noted agricultural scientist, M.S. Swaminathan (1999), agriculture production systems in the 21st century need to be based on the appropriate use of biotechnology, information technology, and eco-technology. Integrated Pest Management (IPM) is one such technology.

1.2 Vegetable Production in India and Tamil Nadu

India has varying climatic conditions and provides an opportunity for growing a large number of horticulture crops including vegetables. Approximately 250 million farmers in Asia growing vegetables, which is generally quite labour intensive and undertaken mostly by small farmers. Due to its labour intensive nature and association with higher value added agricultural products, vegetable cultivation would appear to have made a significant contribution to farmers' incomes and poverty alleviation.

Vegetable cultivation is one of the most economically important and dynamic branches of agriculture. It has become an important source of income for both farmers and field laborers, serving as a vehicle for reducing poverty in rural areas. The cumulative growth rate of vegetable productivity in India is more than the world productivity of 15.1 percent during 1992-2008. The country has witnessed a cumulative growth of 31.8 percent in onion production and 22.8 percent growth in tomato production during post WTO regime. India contributes about 13 percent of the total world production of vegetables. Of the total vegetable production in India, potato accounts for 27.6 percent, onion 10.6 percent and tomato 8.9 percent share. The impressive growth rate of vegetable export from India at 9.8 percent per annum is recorded in last decade. In global market export of onion stands tall as compared to trade share for potato and tomato which are negligible. In domestic market trade share and consumers preference are more for potato followed by onion.

The area under vegetable cultivation at world level has witnessed 52 percent increase with 70 percent increase in corresponding production level during 1992 to 2002. The growth trend in area and production in vegetable cultivation further increased to 13.3 percent and 16.1 percent, respectively during 2002-08. This has facilitated an overall 15.1 percent improvement in vegetable productivity at world level. The Indian situation has changed with 39.5 percent increase in area of cultivation and 115 percent increase in production during 1992-2008. However, the productivity has achieved 54 percent increase, which is more than the world productivity increase of 15.1 percent during 1992-2008 (Chhabi, 2012).

India is the second largest producer of vegetables next only to China and accounts for 13.4 per cent of world production. It has an annual production of 81 million tonnes from 5.12 million ha of land (Karnath, 2000). India contributes about 12 percent of the world output of vegetables from about two percent of cropped area in the country. Among the major vegetables, country has made highest contribution for okra production with share of 70.8 percent in the world production pool followed by green peas and cauliflower (29.5%). The contributions of the other vegetables are onion (11.7%) and tomatoes (6.5%). Tomato and green pea have maintained continuous increasing trend in area as well as in production share. Total cultivated area under okra crop in India has been increased with decreasing share in production (Chhabi, 2012).

Onion has reached plateau in cultivated area, however the production is declined. At the same time, vegetable cultivation is becoming more costly due to the increased use of purchased inputs, such as pesticides and fertilizers, to sustain production levels. If used improperly, many of these purchased inputs have deleterious effects on human health and the environment. The proportion of area under vegetables in Tamil Nadu is 3.59 percent of the vegetable area in India, accounting for 6.74 percent of production (National Horticultural Board, 2012).

In Tamil Nadu among the selected vegetables, in terms of area chilly (22.63%) has the largest proportion of the total vegetable area followed by onion (10.47%). Tomato, brinjal and okra have shares of 7.87%, 2.52% and 1.75% respectively. But in terms of production, tomato has the largest proportion (5.06%) and it is followed by onion (4.88%).

The shares of chilly, brinjal, and okra are insignificant. The data are presented in Appendix I. The share of total vegetable area to total cultivated area in Tamil Nadu is increasing since vegetable cultivation has become more economically profitable.

1.3 Losses due to Pests

Insect pests, diseases, and weeds are the major factors limiting agricultural productivity growth. It is estimated that herbivorous insects eat about 26 percent of the potential food production. Emerging problems of insecticide resistance, secondary pest outbreak and resurgence further add to the cost of plant protection. Annual crop losses due to insect pests and diseases in India are estimated to be 18 percent of the agricultural output. Losses caused by specific pests may be higher. For instance, *Helicoverpa* spp. in cotton causes losses up to 50 percent. According to Raheja and Tewari (1996), *H. armigera* (American bollworm) alone causes an annual loss of about Rs1000 crores. The production losses have shown an increasing trend over the years. In 1983, the losses due to insect pests were estimated worth Rs 6,000 crores (Rao and Murthy, 1983), which increased to Rs 20,000 crores in 1993 (Jayaraj, 1993) and to 29,000 crores in 1996 (Dhaliwal and Arora, 1996). Pest problem is one of the major deterants for achieving higher production in agriculture crops. India loses about 30% of its crops every year due to pests and diseases (Sharma, 2012). The insect pests inflict crop losses to the tune of 40 percent in vegetable production (Gaurav, 2011).

1.4 Intensive Agriculture and Pesticide Use in India

In India, pesticide use has increased at an annual rate of 2.5 percent since early 1970s. Pesticide use in India increased from a mere 15 g/ha of gross cropped in 1955-56 to 90 g/ha in 1965-66. Introduction of green revolution technologies in mid-1960s gave a fillip to pesticide use, and in 1975-76, it had increased to 266 g/ha, and reached a peak of 404 g/ha in 1990-91 (Birthal, 2003). About 96,000 tonnes of technical grade pesticides are currently produced in the country, of which two-thirds are used in agriculture (Khan, 1996). The adoption of high yielding cereal varieties led to a manifold increase in crop yields. Maintaining higher yields also led to a dramatic increase in pesticide use; from 5,700 tonnes in 1960 to 46,195 tonnes in 2000. Although per hectare pesticide use in India is about 250g, pesticides are used indiscriminately (Dhaliwal and Arora, 1996).

However, after 1995-96 there is substantial reduction in pesticide consumption both in India and Tamil Nadu. In India, the pesticide consumption has declined from 71894 MT (1989-90) to 43860 MT (2008-09). Similarly in Tamil Nadu, the pesticide consumption has declined from 10,000 MT (1989-90) to 2317 MT (2008-09).

1.5 Pest Menace in Vegetables

Despite the importance of vegetable cultivation, there are several problems in the production of vegetables, the most important being insect pests. As a result of insect pest attacks, farmers use the pesticides throughout the period of growth and sometimes even at the fruiting stage. Vegetables and fruits with a cropped area of three per cent, consume huge quantum of pesticides accounting 13 per cent of the total pesticides in the country (Nigam & Murthy, 2000).

The study of Arora (2009) indicated that 13-14 % of total pesticides used in the country are applied in vegetable crops. Average pesticide usage has been estimated at 5.13, 2.77, 4.64 and 3.71 kg a.i/ha (active ingredient/ha) on chillies, cauliflower, brinjal and okra crops respectively. Chemical pesticides have harmful effect on vegetables. Indiscriminate use of pesticides particularly at fruiting stage and non-adoption of safe waiting periods leads to accumulation of pesticide residues in consumable vegetables.

1.6 Role of IPM in Vegetables

Tomato, brinjal, cabbage, cauliflower, onion, okra, beans and cucurbits are important vegetables cultivated in India. There has been a change in the vegetable pest scenario. Many pests have adapted to new hosts, developed resistance to pesticides and often there are secondary outbreaks. Cultivation of hybrids or improved varieties of vegetables during off-season, intensive agronomic practices and indiscriminate use of insecticides have disrupted the delicate balance between the insect pests and their natural enemies. The development of insecticide resistance in tomato fruit borer (*Helicoverpa armigera*), brinjal fruit borer (*Leucinodes orbonalis*), serpentine leaf miner (*Liriomyza trifollii*), and diamond back moth (*Plutella xylostella*) in cabbage are a few examples. As the vegetables are harvested at shorter intervals, chemical methods of plant protection have become risky and hazardous. To combat these insecticide resistant insects, IPM techniques are being devised. Integrated Pest management (IPM) would provide an acceptable and affordable basis for pest control in vegetables. According to Norton and Mullen (1994), IPM is an approach which uses increased information to make pest control decisions, and also uses multiple tactics to manage pest populations in a way that is both economically efficient and ecologically sound.

Some quantum of pesticides appear as residues in the crop products when they are used at the time of harvest and at the point of consumption. The amount of such residues varies across crops, for different pesticides and locations. Examination of the residue data on pesticides in samples of fruits, vegetables, cereals, pulses, grains, wheat flour, oils, eggs, meat, fish, poultry, bovine milk, butter and cheese in India indicates their presence in sizable amounts.

Singh (2002) compared pesticide residues in food products during 1976-1996 with 1996-2001 and data indicated that contamination of vegetable samples with persistent organic chemicals have increased to 71 percent during 1996-2001 as against 43.7 percent during 1976-1996, indicating their higher use in perishable, ready to eat market food products. Recent survey conducted from November 2007 to October 2008 across the country by the Union Agriculture and Cooperation Ministry, revealed that 18 percent vegetables, both home grown and imported contains pesticides. About 18 per cent of the samples of brinjal, okra, tomato, cabbage and cauliflower contained residues. Between 1965 and 1998, pesticides in India has been estimated at only 41% of food being free from residues, as compared to 63% being free from residues in the European Union in 1996 (Bhushan, 2006). In India, it is also estimated that 20% of the contamination is above fixed Maximum Residue Limits [MRLs].

1.7 Problem Statement

There is an urgent need to find viable alternatives to pesticides so as to minimize the pesticide residues. There should be promotion of IPM practice which is an eco-friendly approach which employs available alternate pest control methods such as mechanical, biological control with greater emphasis on use of crop rotation, biopesticides and plant origin pesticides like neem formulations to keep pest population low. Pesticides should be used only when pest population crosses economic threshold level. Thus, for reducing the pesticide load, IPM strategies involving need based application of pesticides should be developed for vegetable crops.

The onion is an important vegetable and has been grown in almost all the parts of India for thousands of years. Onions are regarded as a highly export-oriented crop and earn valuable foreign exchange for the country. Though India produces a significant quantity of onions it is not regular and sufficient enough to meet the demands for both domestic requirement and exports.

Amongst the onion producing countries in the world, India ranks second in area and production, the first being China. The highest productivity of onion in the world is in Korea Rep (67.25 MT/ha) followed by USA (53.91 MT/ha), Spain (52.06 MT/ha) and Japan (47.55 MT/ha). India being a second major onion producing country in the world has a productivity of 10.16 MT/ha only (FAO 2008). Maharashtra is the leading onion producing state in India. The other major states producing onions are Gujarat, Uttar Pradesh, Orissa and Karnataka. In India per hectare yield is highest in Maharashtra (21.55 MT/ha) followed by Gujarat (21.24 MT/ha), Haryana (20.37 MT/ha) and Rajasthan (15.24 MT/ha). But in Tamil Nadu the average per hectare yield of Onion is only 9.63 MT. Productivity of onion shows variable trends as the crop is susceptible to various weather variations. Yield obtained in India with those obtained in developed countries show that there is a wide gap between the optimum yield of the onion crop in the country and the yields actually obtained by the farmers. Two to three crops of onions are now harvested in various parts of the country. The estimated requirement of quality seed of onion is 3120 tonnes (assuming seed rate 6 kg/ha) during 2002 and out of that only 9.6 % of the demand is met by public sectors organizations viz; NHRDF, NSC, ICAR institutes (IARI & IIHR and SAU's). Quite often due to unfavourable weather conditions, diseases like purple blotch, stemphylium blight, colletotrichum blight and thrips, insect pest attack the standing onion crop, causing a major damage in production and quality.

Indiscriminate use of insecticides in onion cultivation with intensive agronomic practices affected both farm profitability and the farm. To combat the pests with eco-friendly practices, the scientists developed six components of an IPM package for onion. Adoption of integrated pest management (IPM) may provide an acceptable and affordable basis for pest control in vegetables.

To study the impact of IPM technologies in onion, it is essential to know about the economic success of the IPM packages and to provide reasonable recommendations to the farmers.

1.8 Objectives of the study

i. To assess the nature and the extent of adoption of IPM technologies among the onion growers
ii. To identify the determinants of adoption of IPM technologies
iii. To assess the tangible and intangible benefits of adopting IPM technologies
iv. To assess the joint economic benefits of IPM technologies to producers and consumers

1.9 Hypothesis

- Producers' gender, level of education, farm size, previous farmers' field school (FFS) training for IPM, and contact with extension agents are key factors influencing positively the adoption of IPM strategies.
- IPM practices result in a positive Net Present Value (NPV) of benefits.
- Adoption of IPM strategies improves farm household income by generating significantly higher profits for producers.

1.10 Scope of the Study

The adverse effect of pesticides on agriculture is increasing. The public concern about the adverse effects of chemical pesticides on the environment and human health and also the amount spent towards the pesticide have been the principal triggers of the development of integrated pest management (IPM). The present research aims at analyzing the impact of IPM in terms of yield, net returns and expenditure on pesticide use and also the joint economic benefits of integrated pest management (IPM) to producers and consumers. The outcome of the study will be highly useful for producers since they can know the impact of onion IPM on yield and net returns. The outcome of the study would also be useful for the scientists to develop strategies for low input produce such as IPM produce.

1.11 Limitations of the Study

The study being area specific involving the collection of both primary and secondary data from farmers and various government departments has its own limitations. The study is conducted through survey method by personal interview using pretested interview schedule. Farmers furnished the required information from their memory and experience and hence the collected data were subject to recall bias. However, efforts were taken to minimize the bias by including in the interview schedule, the questions that would facilitate cross checking. Moreover, existing problems and farm decisions may vary from region to region depending upon the socio-economic and institutional environments. Hence, many such separate studies of this nature have to be taken for different regions to generalise the conclusions of the study.

1.12 Organization of the Thesis

The thesis is organized in six following chapters.

Chapter I	**Introduction:** Highlights the problem focus, objectives, hypothesis, scope and limitations of the study.
Chapter II	**Concepts and Review:** It presents a review of various concepts, methods and empirical findings of past studies.
Chapter III	**Design of the study:** It specifies the sampling design, method of investigation and tools of analysis used in the conduct of research and analyzing the data.
Chapter IV	**Description of the study area**: It describes the geographical features, climate and rainfall, demographic details, land use pattern, cropping pattern, irrigation details and infrastructural facilities of the study area
Chapter V	**Results and Discussion:** The results obtained in the study are presented and discussed to draw meaningful conclusions.
Chapter VI	**Summary and Conclusion:** It summarizes the findings and implications drawn from the findings.

CHAPTER II

CONCEPTS AND REVIEW

To develop clarity and comprehension in any study, it is necessary to review the various concepts, research methodologies and analytical tools used by researchers in their studies. Such an attempt would help the researcher to have better and precise understanding of the perspectives of the research problem and also facilitate the researcher to modify and to improve the present analytical framework in the proper direction to suit the problem situation. This chapter briefly reviews the concepts, analytical tools and findings of the past studies, which are relevant for the present study.

2.1 Review of Concepts

In this section, various concepts used in this study are reviewed and presented under the following heads.

2.1.1 Integrated Pest Management (IPM)

2.1.2 Impact Evaluation

2.1.3 Awareness and Adoption

2.1.4 Average Treatment Effect

2.1.5 Propensity Score Matching (PSM)

2.2 Review of Past Studies

2.2.1 Awareness and Adoption of IPM

2.2.2 Factors affecting adoption of technology

2.2.3 Impact of pesticide use

2.2.4 Impact of IPM

2.2.5 Studies on Propensity Score Matching (PSM)

2.2.6 Studies on Economic surplus method

2.1.1 Integrated Pest Management (IPM)

IPM has been defined by the panel of experts on integrated pest control at the Food and Agricultural Organization (FAO) Rome as a pest management system that, in the content of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintaining the pest population at levels below those causing economic injury (FAO, 1967).

Indulkar (1989) refers to integrated pest management (IPM) as a farming system that considers a combination of various techniques for the management of pest problems, such as those caused by weeds, insects, diseases and rodents within the context of the farming systems.

Bird *et al.* (1990) defined, IPM as a systems approach to the design, use, and continued evaluation of pest management procedures that result in favorable socio-economic and environmental consequences.

World bank, (1994) indicated that IPM is gaining increased attention as a potential means of reducing food and fiber losses to pests, reducing reliance on chemical pest control and therefore paving way for the long-term sustainability of agricultural systems.

Blessing and Richard (1998) stated that IPM was a strategy for reducing the level of economic damage to crops by relying on numerous user and environmentally friendly technologies including host plant resistance, pheromones, natural enemies, crop rotation, trap crops, synchronized planting, sanitation measures and vegetable barriers.

Swinton and Williams (1998) indicated that IPM can be understood from two angles. The input oriented approach which looks at different IPM technology components and the output oriented approach which looks at IPM in terms of desired outcome, including attainment of a certain level of profitability, human health and environmental qualities.

By definition, IPM is a comprehensive approach to pest control, utilizing compatible control tactics in one unified program combining cultural control, host plant resistance, biological control, pheromone disruption, mechanical and chemical controls to maintain pest population below economic threshold level. In essence, it is an ecological approach to pest control. But, in practice social, religious, and cultural practices must be taken into account when planning and executing the program (Singh *et al.* 2001).

Ehler *et al.* (2006) state that for the IPM practitioner, IPM encompasses the simultaneous management of multiple pests, regular monitoring of pests and their natural enemies and antagonists, use of economic or treatment thresholds when applying pesticides and integrated use of multiple suppressive tactics.

In the present study, IPM was defined as a farming system that combines cultural control, host plant resistance, biological control, pheromone disruption, mechanical and cultural control to reduce the pest infestation and to maintain the human health and the environment.

2.1.2 Impact Evaluation

Impact evaluations are a particular type of evaluation that seeks to answer cause-and-effect questions. Unlike general evaluations, which can answer many types of questions, impact evaluations are structured around one particular type of question: *What is the impact (or causal effect) of a program on an outcome of interest?* This basic question incorporates an important causal dimension: i.e. to identify the *impact* of the program alone, that is, the effect on outcomes that the program directly causes. An impact evaluation looks for the changes in outcome that are *directly attributable to the program* (Gertler *et al.* 2000).

OECD-DAC (2002) defined impacts as the positive and negative, primary and secondary long-term effects produced by a development intervention, directly or indirectly, intended or unintended.

Nguyen *et al.* (2006) stated that impact evaluation studies evaluate the effect of an intervention on final welfare outcomes, rather than the project outputs or the project implementation process. More generally, project impact evaluation establishes whether the intervention had a welfare effect on individuals, households, and communities, and whether this effect can be attributed to the concerned intervention.

White (2006) stated that impact evaluation has been defined differently over the past few decades. It includes:

- An evaluation which looks at the impact of an intervention on final welfare outcomes, rather than only at project outputs, or a process evaluation which focuses on implementation;
- An evaluation carried out some time (five to ten years) after the intervention has been completed so as to allow time for impact to appear; and
- An evaluation considering all interventions within a given sector or geographical area.

Impact evaluation refers to the immediate effect of a program or process and the term outcome refers to the distant or the ultimate effect or following definition: impact refers to the extent to which the program has changed the behavior of the participants. An impact evaluation will often certainly seek "changes in the desired direction". Impact evaluation measures the short term effects of the health promotion program and is concerned with whether the objectives were achieved. It means any changes in behavior, environment, health, knowledge, social lifestyle or risk factors that were identified in the objectives (Kirch, 2008).

The International Initiative for Impact Evaluation (3ie) defines rigorous impact evaluations as analyses that measure the net change in outcomes for a particular group of people that can be attributed to a specific program using the best methodology available, feasible and appropriate to the evaluation question that is being investigated and to the specific context (2008).

According to the World Bank's DIME (The Development Impact Evaluation) impact evaluations compare the outcomes of a program against a counterfactual that shows what would have happened to beneficiaries without the program. Unlike other forms of evaluation, they permit the attribution of observed changes in outcomes to the program being evaluated by following experimental and quasi-experimental designs.

Similarly, according to the US Environmental Protection Agency impact evaluation is a form of evaluation that assesses the net effect of a program by comparing program outcomes with an estimate of what would have happened in the absence of a program (2008).

According to the World Bank's Independent Evaluation Group (IEG), impact evaluation is the systematic identification of the effects positive or negative, intended or not on individual households, institutions, and the environment caused by a given development activity such as a program or project (2008).

Evaluation is the periodic assessment of overall achievements. It examines what has been achieved or what impact has been made. Impact evaluation is done to determine whether the program had the desired effects on individuals, households, and institutions, and whether those effects are attributable to the program intervention (Jha *et al.* 2010).

Impact evaluation studies whether the changes in well-being are indeed due to the program intervention and not to other factors (Khandker *et al.* 2010).

White (2010) stated that the definition given by the Evaluation Network of the donor organization, the Development Assistance Committee (DAC) is ‘positive and negative, primary and secondary long-term effects produced by a development intervention, directly or indirectly, intended or unintended’.

In the present study, impact evaluation is defined as an analysis that study the changes in outcome that the program directly causes.

2.1.3 Adoption and Awareness

Rogers (1962) defines adoption process as the mental process an individual passes from first hearing about an innovation to final adoption. Final adoption at the level of individual farmer is defined as the use of a new technology in long-run equilibrium when the farmer has full information about the new technology and it’s potential.

Roger and Shoemaker (1971) defined awareness as a function or stage of decision process when the individual is exposed to an innovative existence and gains some understanding of how it functions.

Reddy (1988) defined adoption as a decision to use the practices on a continued basis.

Venugopal and Perumal, (1991) defined awareness as the things known to an individual presented as cognitive domain. It is a prerequiste for adoption of innovation, as this would enable the farmers to completely understand the aspects behind a technology and also its relative advantage.

According to Supe (1994) awareness is the first stage of the innovation decision process wherein the individual is exposed to an idea but lacks detailed information about it.

According to Sujatha (1995) adoption is the acceptance and application of some or all the recommendation practices by the respondents in crop husbandry.

Giriram and Sawarkar (1996) defined awareness as the type of social component which increases the consciousness among the people and generate confidence in the individual to face the problems contemplatively.

Priya (2006) defined awareness as the things known to an individual presented as cognitive domain. It is a pre-requisite for adoption of innovation, as this would enable the farmers to completely understand the aspects behind IPM technology for vegetable crops and also its relative advantage. She also defined adoption as a decision to use the practices on continued basis.

Thanulingam (1996) defined awareness as the ability of consumer to recall more or less currently the various aspects of consumer movement and consumer rights and the respondents' clarity of understanding of the selected aspects.

Sri Ram (1997) in his study meant adoption as following the eco-friendly agricultural practices in cotton cultivation as recommended by the extension agency.

According to Arul Murugan (2000) awareness is the pre - requisite for how to do knowledge and adoption.

In the present study awareness is defined as the things known to the individual and adoption is defined as a decision to use the practices.

2.1.4 Average Treatment Effect

Wooldridge (2002) mentioned that the average treatment effect (ATE) measures the effect or impact of a treatment on a person randomly selected in the population.

Imbens (2004) defined that the average treatment effect (ATE) is the average effect at the population level of moving an entire population from untreated to treated. A relative measure of treatment effect is the average treatment for the treated. The ATT is defined as the average effect of treatment on those subjects who ultimately received the treatment.

Imbens and Wooldridge (2009) mentioned that in terms of policy implications, average treatment effect (ATE) examines the effect of moving the entire population from one universal policy to a different policy. In contrast, the average treatment effect on the treated (ATT) examines program effects in a well-defined population exposed to the treatment or effects of a voluntary program where individuals are not obligated to participate.

Average treatment effect is the average gain in outcomes of participation relative to nonparticipants, as if nonparticipating households were also treated (Khandker *et al.*, 2010).

Grilli and Rampichini (2011) stated that, Average treatment effect is the expected gain for a randomly selected unit from the population.

$\tau_{ate} = E[Y(1) – Y(0)]$

Average treatment effect on the treated (ATT) is the average gain from treatment for those who actually were treated.

$\tau_{att} = E[Y(1) – Y(0) / W=1]$

In the present study, average treatment effect (ATE) is defined as a methodology that measures the effect or impact of a treatment on a person randomly selected in the population.

2.1.5 Propensity Score

Rosenbaum and Rubin (1983) defined propensity score as the conditional probability of receiving a treatment given a vector of observed covariates.

Heckman (1990) defined propensity-score matching is a non-experimental method for estimating the average effect of social programs. The method compares average outcomes of participants and nonparticipants, conditioning on the propensity-score value.

Imbens (2000) defined that the generalized propensity score is the conditional probability of receiving particular level of the treatment given the pre-treatment variables.

Propensity score matching is defined as the conditional probability (0 to 1) of receiving a given exposure (treatment) given a vector of measured or observed covariates. (Sukyeong Pi, 2006)

Grilli and Rampichini (2011) defined propensity scores are the probability to be treated given observed characteristics.

Capogrossi (2012) defined propensity score matching is a method to reduce the bias in treatment effect analysis using observational data. It matches treated and untreated observations that are as similar as possible in an attempt to control for potential confounding factors.

In the present study, propensity score is defined as the conditional probability of receiving particular level of the treatment given the pre-treatment variables.

2.2 Review of past studies

2.2.1 Awareness and Adoption of IPM

Van den Bosch (1978) considered the rising cost of pesticides was an important incentive for IPM adoption. Research and extension services were seen as helping IPM adoption by reducing producers' risks, providing timely advice and helping farmers understand the basics of IPM.

Shanmugasundaram (1987) found that only 16.66 per cent of contact farmers and non-contact farmers were aware of integrated pest management (IPM) for paddy.

James *et al.* (1988) found that 70 per cent of the growers interviewed heard of IPM and 23 per cent answered no and seven per cent answered not sure.

Nikhade *et al*. (1988) observed that more than 55 per cent of the cotton growers adopted the recommended plant protection measures for various pests.

Alexander *et al.* (1989) found that level of knowledge among farmers about pest control was low. Only 41 percent of the respondents knew the common pest of soybean and none of them knew the name of a pesticide or the dosage required to control them.

Saxena *et al.* (1989) reported that 32 per cent of farmers adopted crop rotation as a pest control measure. Only 39 per cent reported using insecticides to control insect pests of various crops. Nine per cent adopted hand picking/killing of insect pests. Only four per cent of farmers used both mechanical and physical methods.

Ramachandran and Sripal (1990) reported that higher adoption level was found for the plant protection (89 per cent) followed by seed treatment (75 per cent) in cotton.

According to Palanisamy (1992) greater adoption was found among cotton growing farmers and only cotton and rice growers used neem seed kernel extract.

The findings of Santha (1992) revealed that a majority of farmers (48 per cent) was under high awareness category on cultural methods of IPM, while 22.5 and 20 per cent belonged to low and medium level categories respectively. In general, most of the IPM respondents belonged to high awareness category, while only one-fourth of the non-IPM farmers were in the high awareness category.

According to Sorensen (1993) most farmers were using some IPM tactics, but were not incorporating a total systems approach in their farming operations. IPM producers were the one who used two or more IPM tactics. Based on this definition, anywhere between 15 and 25 percent of farmers today are practicing IPM.

Crissman *et al.* (1994) suggested that, methods for safe storage, handling and application of pesticides may reduce the health and environmental hazards that had been propagated in many developed countries. However, use of these safety precautions is not widely observed in most developing countries for the reasons such as lack of awareness about the possible risks, lack of information on product use.

The study by Sankari and Ramasamy (1994) on the adoption of IPM in cotton revealed that crop rotation and avoiding the cultivation of host plants were the dominant practices.

Sri Sankari and Punitha (1994) observed that majority of the farmers were not aware of the concept of Economic Threshold Level (ETL) of pesticide use and 23 percent were aware but had not adopted. Most of the farmers had knowledge on how much to spray (90 percent) and compatibility of chemicals (68 percent) and less than half of the farmers knew how to spray (48 percent) and when to spray (42 percent).

Iqbal *et al.* (1995) stated that more than half of the respondents were only medium in their adoption of recommended IPM practices.

The study by Velusamy (1997) revealed that, among the three bio-control methods for cotton pests, NPV spray was well known to 92.50 per cent of cotton growers followed by *Tricogramma chilonis* with 90 per cent awareness.

Sudhahar (1998) reported that 100 per cent of the farmers were aware of the practices viz., crop rotation, inter cropping and use of light traps. In general, 50 per cent of the respondents belonged to high level of awareness followed by 41.66 per cent with medium level awareness and 8.3 per cent under low level category.

Venkatachalam (1999) reported that 42.50 per cent of the cotton growers had low level of adoption followed by medium (35.00 per cent) and high (22.50 per cent) levels of adoption towards bio-control agents.

Sheety (2000) concluded that it is important to educate the farmers on need based and judicious use of plant protection chemicals and encourage the integrated pest management practices.

Velusamy (2000) concluded that in IPM practices, the adoption level of bio-control methods was low when compared to level of awareness because of the notion that this had not been effective when compared to chemical pesticides. Manual collection of larva by hiring labor was found to be most suitable and effective. Among the bio-control methods NPV spray was adopted by most of the farmers.

The survey conducted by Yadav (2000) on the knowledge level of cotton growing farmers about plant protection in Gujarat revealed that 90 percent of farmers relied on chemical pesticides. About 20 percent of farmers showed awareness about the importance of parasites, while others killed them using insecticides, considering them to be pests, and only one percent of the farmers used commercially available bio-agents.

According to Rajendran (2003) pesticides were not viable in the long run and hence a concerted effort needs to be made by all concerned for promoting sustainable agriculture development in the broader framework of environment and living beings.

Qaim and Janvry (2005) concluded that awareness and education had a positive effect on application rate of pesticides. The farmers who attended Farmers Field School

(FFS) on IPM reduced the level of pesticide use per hectare from 0.2 kg to 0.1 kg in Argentina.

The groundnut farmers in Anantapur district of Andhra Pradesh, India followed a wide range of pest management practices (Apart from application of chemical insecticides, other practices such as deep ploughing, intercropping, growing border crops, seed treatment, early sowing and spraying of neem based preparations were among the more frequently adopted IPM practices) in groundnut. A logistic regression analysis showed that the decision to adopt IPM was strongly influenced by education, participation of the farmers in community based organizations, labour endowment and ability to recognize the insect pests. Adoption of IPM practices lead to reduction in the use of insecticides, decrease in cost of plant protection and cost of cultivation and increase in net returns (Rama Rao *et al.,* 2008).

The study was conducted on 120 sugarcane growers from four randomly selected villages of Jagadhari and Radaur blocks from Yamunagar district in Haryana state. The overall high knowledge score was read in cultural and chemical control of insect-pests in sugarcane crop. However, the majority of farmers had no knowledge about biological control of insect-pests. Among the ten personal characteristics studied education, land holding, socio-economic status, extension contact, mass media exposure, risk orientation and economic motivation were found to have positive and significant correlation with knowledge level of overall IPM practices of sugarcane growers (Vijay singh *et al.,* 2009).

Chowdhury and Roy (2010), in their study on identifying the factors that affect the knowledge level as well as the level of adoption of the IPM techniques by the selected vegetable growers, found that a majority of the respondents had a low knowledge index and low level of adoption of IPM techniques. They also found that age, caste, educational status, total monthly income of the family of the respondent, material possession, type of farm power used in vegetable cultivation, experience of respondent in vegetable cultivation, social participation, respondent's family contact with extension agencies and exposure of the respondent to the mass media sources were significantly and positively correlated with knowledge index of the vegetable growers. The knowledge index and adoption level of the respondents regarding the IPM techniques in the selected vegetable cultivation were highly and positively correlated.

The previous studies on adoption of IPM indicated that majority of the cotton growing farmers were aware about the IPM practices and some of them adopted it.

2.2.2 Factors Affecting Adoption of Technology

Caswell and Zilberman (1985) examined the determinant factors in the adoption of new IPM technologies in California through a logit model and concluded that an increase in a yield would encourage vegetable growers to adopt IPM technologies.

Srivastava and Patel (1988) reported that farmers get substandard quality of pesticide product from local formulation. Non-availability of credit, shorter credit period and illiteracy of farmers, which led to cheating by dealers were other problems in pesticide usage.

Wearing (1988) listed the constraints in IPM implementation as technical, financial, educational, organizational and social/marketing obstacles. Marketing obstacles were ranked higher than all other obstacles with 50 percent response. Among technical obstacles, lack of economic thresholds (50 percent) and among financial obstacles, complex monitoring and staffs supervision were major constraints. Grower satisfaction with existing chemical control, lack of confidence with IPM and general resistance to change were the major constraints with 65 percent of response. Poor education and low level of co-operation among growers were the educational and organizational constraints.

EI-Osta and Morehart (1999) suggested a significant role of educational attainment, farm operator’s age, ownership of land and farm size in the choice and adoption of technology. The authors estimated a logit model to illustrate the economic benefits from farm expansion and IPM technology.

According to Birthal *et al.* (2000), adoption of integrated pest management (IPM) practices was likely to be influenced by labor market conditions. In labor surplus and low wage areas, the adoption rate of IPM was expected to be higher, while in labor scarce and high wage areas IPM might not be a preferred option.

Bonabana (2002) analyzed adoption of eight integrated pest management (IPM) technologies on cowpea, sorghum and groundnuts in Kumki district of eastern Uganda. The study found low levels of adoption (<25%) with five IPM technologies and high levels of adoption levels (>75%) with three IPM technologies. The study also found that farmers' participation in on-farm trial demonstrations, accessing agricultural knowledge through researchers and prior participation in pest training were associated with increased adoption of most IPM practices. The study found that farmers' perception on harmful effects of chemicals did not influence farmers' decisions in regard to IPM technology adoption despite their high knowledge of this issue, suggesting that these farmers did not consider environmental and health impacts as important factors when choosing farming practices.

Dasgupta *et al.* (2004) concluded that the farmers' adoption of IPM may depend on a variety of factors, including personal characteristics such as education, experience and farm characteristics such as production scale etc. some personnel and farm characteristics that influence IPM adoption could also affect productivity.

Mauceri (2004) studying IPM adoption for potato farmers in Ecuador, concluded that Farmer field school (FFS) participation is the most significant extension factor in influencing adoption of IPM, followed by field days and then pamphlets. Additional research is needed to investigate with formal IPM training methods, which influence the adoption of various practices and technologies.

Nouhoheflin *et al.* (2007) assessed farmers' perceptions on tomato pests and analyzed the factors affecting pest management decision-making in West Africa. Data were collected a sample of 343 farmers. Farmer decision-making in pest management was modeled using an econometric Logit probability model. From the results, the authors found that gender, share of tomato income from household income and the level of farm income are the key factors that affecting farmers' pest management decision-making.

The past studies revealed that farmers' education, experience, ownership of land, contact with extension service, level of farm income are all the major factors that influence the adoption of IPM technology. By considering these factors in the present study, probit model was used to study the factors that affect the adoption of onion IPM.

2.2.3 Impact of Pesticide Use

Burrows (1983) reported that the private decisions of farmers about using pesticides, fertilizers and some other inputs have resulted in significant off-site externalities, the pesticides caused a variety of wild life, production and human health externalities, such as fish and bird skills, the destruction of beneficial insects, worker exposure to toxic chemicals and the accumulation of chemical residues in the food chain.

Conway (1984) observed that chemical pesticides contaminating the environment have long-term implications on society. Farmers are addicted to using agro-chemicals indiscriminately and excessively to make the situation go from bad to worse not only in India but also in other parts of world.

Goodwell (1984) reported that, over use, misuse and improper use of pesticides endangers health of farm workers and consumers of agricultural products worldwide.

Ghodake (1984) reported that, over use, misuse and improper use of pesticides endangers health of farm workers and consumers of agricultural products worldwide.

Pingali and Carlson *et al.* (1985) indicated that pesticide application in high value crops was related to consumer demand for aesthetically appealing agricultural products. Since these high value agricultural products enjoy a substantial premium for unblemished physical appearance, risk-adverse farmers tend to apply pesticides, beyond the technical optimum, in order to capture that price differential.

According to Dasgupta (1989), the incidence of pesticide damage resulted in illness, death and contamination of livestock and food. Farmers and pesticide factory workers were exposed to the danger of pesticides through lack of protective clothing and equipment.

Sharma and Paliwal (1989) identified the environment pollution and residues in air, water, soil, wild-life and foodstuff as a result of the application of pesticides on agricultural crops.

According to Lichtenberg *et al.* (1990), benefits of pesticide use include a reduction in costs to farmers and processors as well as lower relative prices and increased food quality for consumers.

Pandurangadu and Raju (1990) in their studies on economics of pesticide use on cotton farmers in Guntur district found that negative and significant co-efficient of synthetic pyrithroids in all categories of farms represented the indiscriminate or excessive use of it. A one percent increase in expenditure on synthetic pyrithroids was found to deflate gross income by 0.24 percent. The empirical finding corroborated the general observation that farmers were in the habit of going in for 6-8 sprays of synthetic pyrithroids as against 2-3 sprays advocated recommended by researchers. Farmers were found to use roughly 732 gms of a.i synthetic pyrithroids recommended in cotton spraying schedules evolved by Andhra Pradesh agricultural university.

Sweet *et al.* (1990) observed to obtain desired effect and to avoid risks due to pesticide appropriate, pesticide should be applied in correct amounts at the right time, and with appropriate precautions in terms of storage, preparation, application and the cleaning of equipment.

Hayes and Laws (1991) observed that the effects of an inappropriate use of pesticides can seriously affect human health and the environment.

Pimental *et al.* (1992) conducted an assessment of costs and benefits associated with pesticide use in the United States. They estimates pesticide impacts such as human health effects; domestic animal poisonings; increased control expenses resulting from pesticide related destruction of natural enemies and from the development of pesticide resistance; crop pollination problems and honey bee losses; crop and crop product losses; groundwater and surface water contamination; fish, wildlife and microorganism losses; and governmental expenditures to reduce the environmental and social costs of pesticide use.

Clark *et al.* (1993) revealed that there was significant negative effect of agrochemicals on aquatic organisms and ecosystems resulting from non point source agricultural runoff.

Rola and Pingali (1993) observed that farmers make very short-term assessments of pesticide use and they invest more money on crop protection chemicals in order to get maximum returns and they fail to take into the health risk and medical expenditure with the pesticide use.

Antle and Pingali (1994) studied the impacts of pesticide use on farmer health and productivity in two rice producing regions of the Philippines. They found that the pesticide use has a negative effect on farmer’s health and hence there are likely to be social gains from reduction in insecticide use. Simulation analyses showed that reducing the use of the insecticide had a small effect on productivity. The policies that reduce insecticide use likely to improve social welfare by increasing farmer’s health. Research finding implied that if health effects are not considered in the economic assessment of the modern rice technology the rate of return to general rice research would be overestimated and the rate of return to technology that reduces pesticide use, such as pest resistant crop varieties would be underestimated. They concluded that the implication of such pesticide policy in developing countries would facilitate reallocation of resources in agricultural research accordingly.

Nagaraja *et al.* (1994) reported that HYV of brinjal production required intensive application of fertilizer and plant protection chemicals and their share in HYV brinjal was high compared to local variety of brinjal. The output elasticity of plant protection of HYV was 0.13 compared to 0.11 in local variety.

Rahman *et al.* (1995) studied the trend of pesticide usage in Bangladesh and concluded that total pesticide consumption had doubled over the past six years. Of the total pesticide consumption, organophosphorous compounds comprised 60.40 percent, carbamates 29.00 percent, organochlorines 8.00 percent and other 3.40 percent.

Oka (1997) found that all pesticide formulations that are broad spectrum and applied excessively would cause various environmental problems. They not only killed pests but also beneficial organisms such as parasitoids, predators, bees, earthworms, birds and fish in irrigated rice-fish ecosystems. Chemical insecticides polluted irrigation water, eventually reaching the rivers and village people who used water for bathing, cooking and other needs were exposed to health hazards.

Bryan *et al.* (1998) used a Random utility model to examine the pesticide efficacy, environmental safety, user safety and regulatory attributes as well as IPM practices. Results showed that the product and rate choices are most influenced by efficacy and user safety attributes. Impacts of IPM practices are mainly on the choice of insecticide products but effects differ by practice and by product.

Fernandez – Corneio *et al.* (1998) concluded that in US agriculture the marginal cost of reducing pesticide use for health and environmental considerations is relatively high. The value of the marginal product of pesticide use is declining, suggesting that marginal costs of reducing pesticide use might be declining as well.

Thakur and Pawar (1990) concluded that IPM training cum demonstrations in vegetables such as tomato, cabbage and cauliflower had significant positive impact on crop production and pesticide usage. They observed that the percentage increase varied from 28 to 32.1 quintals per hectare. Cost benefit ratios varied from 1.3.81 in IPM fields to 1.2.97 in non-IPM fields. Reduction in input costs in IPM fields was mainly due to no use or reduced use of safer pesticides at optimum dose at appropriate time. Reduction in pesticide sprays varied from 32.33 percent to 50 percent.

Dasgupta *et al.* (2001) examined the trend in pesticide use in Brazil in the 1990's in the context of agro industrialization and globalization. Results indicated that agricultural trade liberalization had led to increased pesticide use in Brazil's agricultural growth in the era of trade liberalization which caused serious human health problems and environmental damage.

Pingali (2001) revealed that due to agro industrialization, the use of insecticides and fungicides increased and the use of these agricultural chemicals would lead to higher environmental and human costs.

Tamizheniyan (2001) found that total cost per acre on IPM farms was Rs. 10,452 compared to Rs. 10,032 on non-IPM paddy farms. The gross return was Rs. 16,213 compared to Rs. 14,900. The Benefit cost ratio was 1.62 for IPM compared to 1.43 for non-IPM farms.

According to Dasgupta *et al.* (2004) IPM is intended to reduce ecological and health damage from chemical pesticide by using natural parasites and predator to control pest population. IPM offers prospect of lower product cost and higher profitability. Compared outcomes of farming with IPM and conventional techniques using input use accounting, conventional production function and frontier production estimation.

Gururaj *et al.* (2004) showed that in west Godawari district of Andrapradesh, the farmers spent on average Rs 2175 per hectare, which included Rs 1,197 for insecticides and Rs 976 for fungicides. The average yield obtained was 7.5 t/ha. According to their estimate the farmers felt that they would have incurred a loss up to Rs 9,728 per ha (resulting from an average of 32.50 percent loss due to pests as mentioned by them) if no pesticides were applied to control them.

Jeyanthi *et al.* (2005) examined pest management practices in four important vegetable crops viz, chillies, cauliflower, brinjal and bhendi in the Oddanchatram block of Dindigul district of Tamil Nadu, using farm level cross-sectional data. The authors found that on average the farmers use 5.13, 2.77, 4.64 and 3.71 kg active ingredient of pesticide per hectare on chillies, cauliflower, brinjal and bhendi crops respectively. On an average, cauliflower and brinjal were each given 15 applications, chillies was 13 and bhendi was given 12 applications. The study suggested that for reducing pesticide use, farmers need to be educated about different non-chemical control methods and should be encouraged to adopt integrated pest management (IPM) practices.

Chitra *et al.* (2006) analysed the impact of pesticide use in agriculture and its impact on environment and human health. The study found that above 75 farmers use a wide range of pesticides, mostly of "moderately hazardous" to "highly hazardous". They also found that the farmers were not aware of the health hazards caused by the inappropriate handling of pesticides.

Indira Devi (2009) analyzed the awareness of pesticide use and handling, behavioural responses and perceptions of health impacts among farm workers in the state of Kerala. The author reported that the workers have not been adequate training to understand the toxicity level by looking at the colour code on the packet, though they have been found aware about the different options available in the market. She also reported that often their perceptions of toxicity level of chemicals they handle are not in conformity with the actual situation; they have been found handling toxic chemicals considering them to be safe one. She found that despite a high literacy level, most of them do not care to read the instructions and follow them. The study found that a majority of respondents are of satisfactory health status by the body mass index values.

The past studies on pesticide use revealed that the use of pesticide will create harmful effect on human health and environment. In the present study, to know the impact of pesticide use, the pesticides used in the study area, the farmers awareness about the harmful effect of pesticide use, safety measures followed during and after pesticide application were studied.

2.2.4 Impact of IPM

Fernandez – Cornejo *et al.* (1998) studied the impact of IPM on pesticide use, toxicity and other environmental characteristics, yields and farm profit among the grape growers. They concluded that among grape growers, IPM adopters applied significantly less insecticides and fungicides than non-adopters. The average toxicity decreased slightly with adoption of insect IPM, but remained about the same for adopters and non-adopters of IPM for diseases. The effect of IPM adoption on yields and variable profits was positive but only significant in the case of IPM for diseases i.e. the adoption of IPM for diseases increased yields and profits significantly.

The impact of IPM in Basmati rice was analysed both in terms of socio-economic and productivity at Uttarpradesh, Haryana and Jharkand. The implementation of IPM resulted in 21.65, 21.37 and 19.7 percent increase in mean yield over farmers practice in 'Pusa Basmati1', 'Tarori Basmati' and 'Type 3' Basmati respectively across the three locations. The study also found that there was an increased benefit cost ratio due to reduced cost of cultivation in IPM and increase in yield. The pest outbreaks have substantially decreased, whereas natural enemy fauna increased to great extent. Adoption of IPM empowered the farmers in the way of decision making for release of parasitoids/pesticide application and also they are able to distinguish between harmful and beneficiary insects etc., (Garg *et al.* 1999).

Latha (1999) in her study on production and marketing of hybrid cotton in Coimbatore district worked out the influence of integrated pest management practice on cotton cultivation. She found that though the IPM involved additional cost, it helped in better and effective control of pests thereby improving the productivity per hectare in terms of yield. She also found that IPM practice avoided resurgence of pests and also other environmental problems.

Birthal *et al.* (2000) observed that integrated pest management (IPM) could reduce pesticide use substantially. The mean pesticide usage was 14 grams active ingredient per hectare in cotton IPM farms compared to 3.2 kg active ingredient per hectare in non IPM situations. The expenditure on plant protection inputs was 13 percent less on IPM farms compared to non-IPM farms.

Alastir Orr (2003) revealed that the IPM has proven more relevant for cash crops and for high value vegetables, where farmers use pesticides. IPM is more likely to be adopted by resource poor farmers if it focuses on host plant resistance and biological control, high value commodities and help to meet farmers' wide objectives of household food security and earning cash income.

Ariyadasa *et al.* (2003) evaluated the effectiveness of an IPM approach, where Farmer Field Schools (FFS) approach, a widely adopted participatory learning process to promote rice IPM, was followed to introduce the IPM principles and practices to develop farmer skills and decision making on pest management.

Beckmann *et al.* (2003) investigated the link between farm labour organization and adoption of integrated pest management (IPM) in Thailand and the authors found that labour organization has a highly significant impact on the adoption rate of IPM.

Chowdhury and Shively (2004) studied how IPM technologies affect the crop land technology choices of low-income rice farmers. The results show that access to IPM can play an important role in shifting production towards vegetables; the study also reflect the IPM practices tend to generate higher yields and higher net returns per hectare as to increase vegetable production.

Godtland *et al.* (2004) evaluated the impact of a pilot farmer field school (FFS) program on farmers' knowledge of integrated pest management (IPM) practices related to potato cultivation by using the survey-data from Peru. The authors used both regression analysis controlling for participation and a propensity score matching approach to create a comparison group similar to the FFS participants in observable characteristics. They found that the results are robust across the two approaches as well as with different matching methods. The study found that farmers who participate in the program have significantly more knowledge about IPM practices than those in the non-participant comparison group. The study also found suggestive evidence that improved knowledge about IPM practices has the potential to significantly improve productivity in potato production.

Pasalu and Katti (2004) concluded that the use of biological methods to manage crop pest was the key component of IPM as an alternate to ecologically disruptive chemical control. Native natural enemies can also be used profitably in pest management under IPM.

Santhakumar (2004) reported that the seed cotton yield in IPM adopted village was about 1200 kg /ha compared to non-IPM village where it was about 600kg/ha with little extra expenditure in cultivation cost for IPM village.

A socio-economic study, undertaken in Birbhum district of West Bengal state of India analyzed the farmers' pest management practices, patterns of input use and economic returns in production of brinjal. The study also evaluated the extent of adoption of IPM practices and the initial economic and social impacts of such adoption. The study found that pesticide misuse decreased as farming experience and level of education increased. Greater awareness about IPM technologies as also reduced pesticide misuse. The authors found that the farmers' awareness about IPM, availability of IPM inputs, perceived economic and health benefits and degree of crop damage are the significant factors promoting adoption of IPM. Significant factors hindering adoption of IPM include size of landholding, age of decision maker and easy access to pesticides. The study also found that the impact of the project is significant both in terms of reducing the cost of growing eggplant as well as increasing returns. Growers who adopted IPM practices experienced increases in yield, a higher proportion of pest-free fruit and higher profits compared to non-practitioners. (Baral *et al*., 2006).

Dhaliwal *et al.* (2006) reported that in rice, the adoption of an integrated pest management (IPM) strategy resulted in 50-100% reduction in pesticide use and 6.2-421% increase in yield in IPM fields as compared to non-IPM fields during 1994-95 in major rice growing areas of India.

Gajanana *et al.* (2006) analysed the impact of integrated pest and disease management in tomato in Karnataka. The study found that the yield was higher on IPM (65.35 t/ha) than non-IPM (44.72 t/ha) farms. The cost of cultivation was lower on IPM

(Rs 86641/ha) than non-IPM (Rs 110,008/ha) farms. The study also found that the benefit cost ratio (BCR) was higher at 3.66 for IPM than non-IPM farmers at 1.95. The study reported that the technical grade equivalent (active ingredient) of the chemical pesticides used was much less on IPM farms (0.43 litre of insecticides and 0.79 kg of fungicides as against 3.09 litre and 6.86 kg respectively) than non-IPM farms and the difference in the cost of insecticides and fungicides between IPM and non-IPM farms was found to be statistically significant at 5 percent level of probability. The authors found that the labour used on IPM farms was less than that on non-IPM farms. The study also reported that about 53 percent of the non-IPM adopters reported health hazards like headache, eye irritation, stomach upsets etc in the labourers due to spraying of chemical pesticides and none of the IPM adopters expressed the incidence of such health hazards.

Mancini *et al.* (2007) evaluated the impact of cotton integrated pest management (IPM) farmer field school outcomes on cotton production systems in southern India. The study examined the additional benefits of FFSs in the social and economic arena, using the sustainable livelihoods (SL) concept to frame the evaluation. The study found that farmers who had participated in integrated pest management (IPM) FFSs perceived a range of impacts much beyond the adoption of IPM practices. It also found that reduced cost of cultivation allowed for financial recovery from debt and building of physical assets. IPM FFS households and production systems were perceived by the participants to have become more economically resilent than Non-IPM FFS control groups when faced with adversity. In the participants view, IPMFFSs also led to enhanced individual and community social well-being, a benefit valued in particular by the women participants.

Mandal *et al.* (2008) examined the impact of IPM strategy for the controlling of brinjal fruit and shoot borer (Leucinodes orbonalis) in Karnataka. The authors found that due to adoption of integrated pest management (IPM) technology there were about 4.7, 34.0 and 53.8 % change in yield, fresh fruit and profit amongst brinjal growers. They also found that the impact of IPM practice have its positive effects on brinjal area increasing to 21.6% for adopters while decreasing to 8.7% for non-adopters. They also reported that all the farmers adopting IPM technology agreed that high cost of pesticides, convenience of IPM practices, potential health hazards of pesticides and profitability of IPM were responded by 91, 75 and 71% farmers respectively. The internal rate of return as well as benefit-cost ratio were also very high indicating thereby, large potential economic impact of the IPM technology to control EFSB in the study area.

Mariyono *et al.* (2008) estimated the demand for insecticides in soybean farms in Java, Indonesia and also analyzed the impact of the integrated pest management (IPM) technology on insecticide use. The study conducted with the aggregate cross-section time series data during the period 1990-1998, when the IPM technology disseminated in Indonesia. By using recursive and simultaneous equation models, the author estimated the IPM technology on the demand for insecticides. The study found that the IPM technology has reduced significantly the use of insecticides in soybean farming.

Peshin *et al.* (2009) evaluated an Insecticide Resistance Management based Integrated Pest Management (IRM-IPM) programme in cotton and compared it with non-IRM production for a range of IPM and economic measures. The IRM-IPM programme resulted in a reduction in insecticide consumption (technical grade material) by 30% and it reduced the number of sprays by 15%, however it did not result in a significant change in productivity. On average, the IRM-IPM programme resulted in a return of US$24.05/ha (at 2005 rates: US $1=45 Indian rupees) by saving on insecticide costs. While the farmers gained significantly in knowledge of IPM practices, the level of adoption of IPM techniques were low.

Groote *et al.* (2010) analysed the impact of different options in integrated pest and soil fertility management in maize system of Western Kenya. The study found that these technologies are highly profitable.

Samiayyan *et al.* (2010) evaluated the economic and ecological benefit of rice integrated pest management (IPM) module confirmed the higher yield, natural enemies and lesser pests than farmers practices. The main incremental yield obtained in IPM adopted farm was significantly higher by 366 kg/ha with an additional return of Rs 2190/ha. The study says that the mean usage of pesticides on IPM farms was 73g a.i./ha which accounts 65.56 percent less than the non IPM farms.

Barakade *et al.* (2011) studied about the economic onion cultivation, price spread, marketing channels and marketing efficiency onion in Satara district of Maharashtra.

They found that total cost of onion production was found much higher in rabbi season compared to that during Kharif season. The cost benefit ration came to about 1:1.48.

George *et al.* (2011) analysed the impact of IPM in terms of reduction in pest and disease levels, effects on the level of usage of chemicals and reduction in the cost of cultivation compared to farmers' practices. The study found that there was marked reduction in the frequency of application of insecticides and fungicides. The frequency of insecticide spray came down to 2.5 (IPM plots) from 8.5 times per crop in farmers practice. Frequency of fungicides came down to 3 compared to 4.5 in farmers practice. The author also conducted pre and post knowledge test evaluation to measure the impact of FFS. The study found that overall score showed that farmers level of knowledge increased significantly from 35.7% before the FFS to 82.2% after the FFS. Partial budget analysis revealed that by following IPM practices in tomato farmers could increase their net income to the level of Rs 26,032/ha.

Mukherjee *et al.* (2011) estimated the impacts of IPM programs in Basmati rice by estimating the pesticide residues. The authors collected the sample of Basmati rice grain, soil and water from IPM and non-IPM field trials conducted at four regions of Haryana, Uttar Pradesh and Uttarkhand in India for pesticide residue analysis. The study found that the residues of the pesticides in soil and water samples and rice grains of IPM trials were below the detectable limit while that of non-IPM trials showed traces of pesticides.

Yorobe *et al.* (2011) examined the impact of farmer field schools (FFSs) on insecticide use by onion farmers in the Philippines. The data used in the study are from a 2009 face-to-face farm level-survey of 200 onion growers in Nueva Ecija province. Using instrumental variable (IV) procedures to control for endogeneity and selection problems in the data, the authors found that FFS-trained onion farmers in the Philippines have significantly lower insecticide expenditures than non-FFS trained control farmers. The authors also mentioned that the results of the study provided important evidence about the effectiveness of the FFS approach in affecting insecticide use behaviour. The reduction in insecticide expenditures for FFS trained farmers also imply that there can be potential environmental and health benefits from FFS training as well.

Environmental Impact of IPM

Mullen *et al.* (1997) assessed the effect of integrated pest management (IPM) on risks posed by pesticides to the environment and human health and also estimated the society's willingness to pay to reduce the risks. The study was concerned with the peanut IPM program in Virginia. The study found that society values the non-target resources that are adversely affected by pesticide use. The authors found that the annual environmental benefits of the IPM program are estimated at $844,000.

Cuyno *et al.* (2001) examined the economic evaluation of the environmental benefits of the onion IPM program in the Philippines. The assessment was made with two primary components. The first is an assessment of the effects of IPM on the health and environmental risks posed by pesticides. The second is a determination of society's willingness to pay to reduce those risks. The study found that IPM practices on onions reduced the use of specific pesticides from 25 to 65% depending on the practice and the projected adoption of IPM practices varied from 36 to 94%. Estimated economic benefits varied from 231 to 305 pesos per person per cropping season (40 pesos = 1US $).

The past studies indicate that the farmers who are following one or more IPM tactics were considered as IPM farmers and the studies also revealed that the adoption of IPM practices reduced the cost of cultivation and increased the yield.

2.2.5 Studies on Propensity Score Matching

The impact of wheat transfers and cash incomes on wheat consumption and wheat markets were examined by using the data from a 1998/99 survey of rural household in Bangladesh. The empirical calculation of the marginal propensity to consume wheat out of wheat transfers has been estimated using two alternative methodologies. First, the propensity score matching (PSM) was used in which the set of program participant households that "look like" program participants. As an alternative the authors employed the parameters of an econometrically estimated Engel function to calculate the MPC for wheat out of income and wheat transfers (Carlo *et al.,* 2002).

Jalan *et al.* (2003) employed recent advances in propensity score matching (PSM) to the problem of estimating distribution of net income gains from an Argentinean workforce program. The authors mentioned that propensity score matching (PSM) has a number of attractive features in this context, including the need to allow for heterogeneous impact while optimally weighting observed characteristics when forming a comparison group. The propensity score matching estimator employed in the study is reasonably robust to a number of changes in methodology.

The effect on malnutrition rate of different durations of exposure to the Seecaline program and the heterogeneity of the program impacts with respect to some key socio-economic characteristics of the sites in Madagascar were examined. The authors employed propensity score matching (PSM) to estimate the marginal effect of being exposed to the program for different durations. The marginal impact was examined by comparing "comparable" participating communities that enter the Seecaline program at different points in time. The authors found that the returns to exposure are positive. The results also show higher differential returns to the program in poorer areas and areas more vulnerable to diseases (Galasso and Yau 2006).

Mendola *et al.* (2007) adopted a non-experimental evaluation strategy in order to assess the direct contribution of modern-seed technology adoption to rural poverty in Bangladesh. They isolated the causal effect of adopting high yielding varieties (HYVs) of rice on poverty alleviation by using the propensity score matching (PSM) method. They also perceived that the adoption of high yielding varieties of rice has a positive impact on farm household wellbeing through the propensity score matching results.

Faltermeier *et al.* (2008) analyzed the impact of the adoption decision of bund construction and seed dibbling on net returns, input demand and output supply by using the cross-sectional data of 342 small-scale lowland rice farmers in northern region of Ghana. The study did the impact assessment through propensity score matching controlled for selection bias. Matching was conducted based on Mahalanobis distance combined with propensity score. The authors also did the balancing tests by checking the mean standard absolute bias in the matched sample and also did the sensitivity analysis to check for hidden bias due to unobservable selection.

Gibson *et al.* (2009) studied whether joining a gang Leeds to future violent victimization or not. Guided by selection, facilitation and enhancement perspective the study applied propensity score matching (PSM) on data from the Gang Resistance Education and Training longitudinal study to investigate the nature of the gang-violent victimization relationship. Results indicated antecedent differences between those who did and did not join gangs, particularly violent victimization and delinquency.

Pufahl and Weiss (2009) evaluated the effects of agri-environment (AE) programmes on input use and farm output of individual farms in Germany by applying a semi-parametric propensity score matching approach. The study found that a positive and significant treatment effect of AE programmes on the area under cultivation, in particular grassland, resulting in a decrease of cattle livestock densities. Furthermore, participation significantly reduced the purchase of farm chemicals (fertiliser, pesticide). The author also found differences in the treatment effect among individual farms (heterogeneous treatment effects). Farms that can generate the largest benefit from the programme are most likely to participate.

Akhther Ali and Awudu Abdulai (2010) employed a propensity score-matching approach to examine the direct effect of Bacillus thuringiensis (Bt) cotton on yield, pesticide demand, household income and poverty using cross-sectional data from a survey of farmers in the Punjab province of Pakistan. The authors employed nearest neighbor matching (NNM) and kernel-based matching (KBM). The findings revealed that adoption of new technology exerts a positive and significant impact on cotton yield, household income and poverty reduction and a negative effect on the use of pesticides.

Huang *et al.* (2010) examined the impact of privatization on firm employment using a panel dataset of 386 firms in china in the period 1995-2001. In addition to the fixed-effect model, the authors also estimated the impact of privatization on employment by the difference-in-difference propensity score matching (DID PSM) method and the kernel-weights were used in the matching. To test whether the estimation satisfies the conditional independence assumption (CIA) and common support conditions balancing tests were used. The authors did the balance test by comparing the pseudo-R^2s before and after matching. The estimates of the total effects are all statistically significant except for the fourth and fifth year before privatization.

Wu *et al.* (2010) assessed the impact of improved upland rice technology on farmers' well-being. The study used the propensity-score matching to address the problem of 'self-selection,' because technology adoption is not randomly assigned. It applied this procedure to household survey data collected in Yunnan, China in 2000, 2002 and 2004. The study found that improved upland rice technology had a robust and positive effect on farmers' well-being, as measured by income levels and the incidence of poverty and also they found that the effect of technology on well-being implied a diminishing impact on producers' incomes.

Kassie *et al.* (2010) examined the contribution of sustainable land management (SLM) practices to net value of agricultural production in areas with low versus high agricultural potential. A combination of parametric and non-parametric estimation techniques were used to check the robustness. The parametric analysis was based on matched samples of adopters and non-adopters obtained from the propensity score matching (PSM) process. The results indicated that technology adoption and performance vary by agricultural potential.

Abebaw *et al.* (2010) examined the impact of integrated food security program (IFSP) in Ethiopia through average treatment effect on treated (ATT). Using a propensity score matching method to control for pre-intervention differences, the impact on household food calorie intake of an integrated food security program, which had been implemented in Northwestern Ethiopia by two non-governmental organizations was examined. The estimated results provide evidence that integrated food security program has a positive and statistically significant effect on food calorie intake.

Becerril *et al.* (2010) examined the adoption of improved maize germplasm in Oaxaca and Chiapas in Mexico. The authors employed the propensity score-matching approach to analyze the impact of the adoption of improved maize varieties on household income and poverty reduction, using cross-sectional data of 325 farmers from the two regions. The findings revealed a robust positive and significant impact of improved maize variety adoption on farm household welfare measured by per capita expenditure and poverty reduction. Specifically, the empirical results suggest that adoption of improved maize varieties helped raise household per capita expenditure by an average of 136–173 Mexican pesos, thereby reducing their probability of falling below the poverty line by roughly 19–31%.

Kassie *et al.* (2011) evaluated the ex post impact of adopting improved groundnut varieties on crop income and poverty in rural Uganda. The study utilized cross-sectional data of 927 households, collected in 2006, from seven districts in Uganda. Using propensity score matching methods, the study found that adopting improved groundnut varieties (technology) significantly increases crop income and reduces poverty. The positive and significant impact on crop income is consistent with the perceived role of new agricultural technologies in reducing rural poverty through increased farm household income.

Bradely *et al.* (2011) evaluated the multiple overlapping treatment effect of secondary educational policies on pupil test scores in UK. They did through propensity score matching methodologies in a multisite analysis.

Owusu *et al.* (2011) examined the impact of non-farm work on household income and food security among farm households in the Northern region of Ghana. They analyzed the impact by employing propensity score matching method that accounts for selection-bias. The study found that participation in non-farm work exerts a positive and statistically significant effect on household income and food security status through the matching results.

Rejesus *et al.* (2011) evaluated the impact of a controlled irrigation technique (alternate wetting and drying – AWD) on rice production in the Philippines. They studied the impact through propensity score matching (PSM) and regression based approaches. The authors mentioned that the propensity score matching and regression-based approach accounts for the potential bias due to selection problems from observable variables.

Khundi *et al.* (2011) measured the relationships among income, poverty and charcoal production in three charcoal – producing districts of Western Uganda. Using household survey data and propensity score matching techniques the authors found positive and statistically significant correlations between participation in charcoal – related activities and subsequent household income and poverty levels.

Kiiza *et al.* (2012) studied the factors that affect access to ICT-based market information by smallholder farmers and assessed the impact of access to this market information on the intensity of adoption of seed technologies and the impact of these agricultural technologies on farmer yields and incomes. A binary probit model was used to determine the factors that influence the likelihood of a farm household adopting ICT-based or formal market information and they employed propensity score matching (PSM) methods to assess the impact to effectively control for hidden selection bias.

Nazli (2012) analyzed the economic impact of existing unapproved Bt varieties on farmers' wellbeing and also examined the potential impact of the adoption of commercialized Bt cotton varieties. The treatment effect model was used to examine the economic impact of Bt cotton on farmers wellbeing. The results of treatment effect models indicate a positive impact of Bt cotton on the wellbeing of cotton farmers in Pakistan, even after controlling for selection bias.

The past studies indicated that propensity score matching (PSM) was used to study the impact of technologies since this technique is found a best methodology that will remove the "selection bias'. In the present study, propensity score matching (PSM) was used to study the impact of IPM in onion.

2.2.6 Studies on Economic Surplus Method

Hareau *et al.* (2002) analyzed the economic impact of Genetically Modified Organisms (GMOs) in Urugay's agriculture. Transgenic varieties were simulated for two crops rice and potatoes and modeled as small open and small closed economies respectively in a partial equilibrium framework. The study found that the change in economic surplus generated after the adoption of the new technologies was positive, although the seed markup charged by the monopolists reduces its magnitude compared to expected benefits in perfectly competitive markets.

Mamaril (2002) indicated that the total welfare gain from adopting *Bt* rice in the Philippines and Vietnam would be $618.8 million ($269.6 million for the Philippines, $329.1 million for Vietnam, and, $201 million for the rest of the world) by using the economic surplus method. The distribution of the benefits showed that producers would capture 66.5% of the total welfare effect in both countries whereas 25.9% could go to consumers, and the remaining 3% to the rest of the world.

Economic surplus approach was used to project the welfare benefits of adopting *Bt* eggplant in India, Bangladesh, and the Philippines (Mishra, 2003). The welfare benefits were estimated at $411 million, $37 million, and $28 million for India, Bangladesh and the Philippines, respectively. The distribution of the benefits for consumers and producers was about 57% and 43% of the total surplus respectively.

Wander *et al.* (2004) assessed the economic impacts of new technologies generated and adopted by the Brazilian Agricultural Research Corporation (EMBRAPA). The authors mentioned that in agricultural research the economic surplus method represents one of the suitable frameworks to measure the aggregated social benefits of a research project. They also mentioned that with this method it is possible to estimate the return of investments by calculating a variation of consumer and producer surplus through a technological change originated by research results.

The economic surplus method was also used by Hareau *et al.* (2005) to estimate the benefits resulting from adopting transgenic rice in Asia. The author found that the Net Present Value resulting from the adoption of transgenic rice could increase with perfectly competitive markets from $1.82 million to $5.38 million in Asia.

Krishna and Qaim (2007) examined the potential impacts of Bt eggplant on economic surplus and farmers' health in India. They used the economic surplus model to project the welfare and distribution effects among eggplant farmers, consumers and the innovating company. Additionally to the economic surplus effects, the authors also estimated the potential impact of Bt eggplant technology on farmers' health through reduced insecticide exposure. The authors employed econometric model to estimate the impact of insecticide sprays on pesticide poisonings. Simulations showed that the aggregate economic surplus gains of Bt hybrids could be around US $108 million year. The study found that consumers will capture a larger share of the gains, but farmers and the innovating company benefit too.

Feng Song and Swinton (2009) estimated the economic benefits of U.S. research and outreach for the IPM of soybean aphid with the help of economic surplus approach. The authors calculated the ex-ante net benefits from the adoption of an economic threshold (ET). They found that gradual adoption of an ET for soybean aphid management will generate a projected net benefit $1.3 billion, for an internal rate of return 124%, over the 15 years (2003-17). Lower and upper bound sensitivity analysis brackets the estimated net benefit to

U.S. consumers and soybean growers in the range of $0.6 to $2.6 billion dollars in 2005. They also found that if a 10% rate of return is attributed to IPM applied research and outreach on soybean aphid, that would leave nearly $800 million dollars to compensate prior activities that contribute to the development and adoption of IPM.

Kostandini *et al.* (2009) assessed the *ex-ante* benefits of transgenic drought tolerance research for maize, rice, and wheat across Asia and Africa, in particular in Bangladesh, India, Philippines, Indonesia, Kenya, Nigeria, Ethiopia, and South Africa. The authors showed that benefits from yield variance reductions were an important component of aggregate drought research benefits. The yield variance reductions accounted for 40% of total benefits across the countries. The annual private sector benefits were estimated at $178 million. These benefits were a significant incentive for private sector participation in transgenic drought-tolerance research. The authors also examined the *ex-ante* 18 economic impact of transgenic drought- resistant maize breeding and conventional maize, millet and sorghum drought-resistant breeding in Kenya, Uganda, and Ethiopia.

Napasintuwong *et al.* (2009) estimated the economic benefits of adoption of Genetically Modified (GM) papaya in Thailand. The aggregate economic surplus impact of GM papaya was measured. The authors found that the total economic surplus would be generated in the range of $650 million to $1.5 million USD within the first 10 years of adoption. The study found that these benefits would accrue primarily to small-scale papaya farm and would accrue even with the loss of export markets.

Rakshit *et al.* (2011) assessed the economic benefits of managing fruit flies infecting sweet gourd using pheromones. They assessed the total benefits to producers and consumers if farmers widely adopt the pheromone technology when producing sweet gourd. Economic analysis to assess the total or market level benefits of pheromones was conducted using an economic surplus model in which shifts in supply and demand curves were projected based on changes in yield due to reduced pest damage, changes in input costs and projected adoption of the technology. Changes in economic surplus that were calculated in the model were discounted and totaled over 15 years to provide estimates of economic benefits of the technology to producers and consumers. A closed economy specification of the economic surplus model was used.

Kumar *et al.* (2011) examined the potential economic benefits of Bt brinjal hybrids in terms of yield gain, rduction in insecticide use and increase in net returns per hectare. The potential economic benefits of Bt brinjal and its distribution between producers and consumers have been estimated using the economic surplus method. The estimated showed that adoption of Bt brinjal could raise consumer surplus by Rs 381 crore and producer surplus by Rs 196 crore annually with adoption rate of 15 percent. The gains in economic surplus have been distributed between consumer and producer in the ratio of 66:34.

The past studies revealed that economic surplus methodology was used to study the net economic benefit of a particular technology for the whole study area. In the present study, economic surplus methodology is used to study the net economic benefit for the selected districts and for the whole state.

CHAPTER III

DESIGN OF THE STUDY

This chapter presents a brief description about the methodology followed and analytical tools used in the study as given follow:

3.1 Selection of the study area

3.2 Period of the study

3.3 Sampling design and data sources

3.4 Collection of data

3.5 Measurement of variables

3.6 Tools of analysis

3.7 Econometric analysis

3.1 Selection of the Study Area

Onion is cultivated in almost all the districts of Tamil Nadu with an area ranging from 1000 hectares to 3000 hectares. For the present study, multi stage sampling design was used to select the study area. Based on the concentration of area under onion districts, blocks and villages were purposively selected. In the first stage, the top two onion growing districts viz., Perambalur and Trichy were selected. The details are furnished in Table 3.1 and 3.2. In the second stage, based on proportion of area under onion in these two districts, top two blocks in Perambalur district (Alathur and Perambalur) and top block (Thuraiyur) in Trichy districts were selected. In the third stage, in each block one village was selected which is having highest area under onion. The selected villages are Irur village of Alathur block, Chattiramani village of Perambalur block and Sengatupatti village of Thuraiyur block. Figure 3.1, 3.2 and 3.3 show the study area.

Table 3.1 Area distribution across the districts - onion

Area in ha	Number of Districts	Name of the districts
Less than 1000	9	Madurai, Theni, Salem, Dharmapuri, Vizhupuram, Ramanathapuram, Vellore, Thiruvannamalai, Karur
1000 to 2000	3	Thoothukudi , Thirunelveli, Virudhunagar
2000 to 3000	4	Coimbatore, Erode, Dindigul, Namakkal
More than 3000	2	Trichy, Perambalur

Table 3.2 Growth performance of area and productivity of onion- (1996-97 to 2010-11)

Name of the Districts	Area	Productivity
Trichy	**6.02**	**-0.19**
Perambalur	**7.41**	**-0.81**
Coimbatore	2.29	-1.65
Erode	1.04	-1.66
Dindigul	-4.63	2.22
Namakkal	-4.78	4.91

3.2 Period of the study

The field survey was conducted during the months of March to December, 2011 and the procedures used in collecting the data are detailed below.

3.3 Sampling Design and Data Sources

Sample size can be determined by using various methods. To determine the sample size, the purpose of the study, the population size, the level of precision, the level of confidence or risk and the degree of variability in the attributes being measured were considered (Miaoulis & Michener, 1976). The level of precision, sometimes called sampling error, is the range in which the true value of the population is estimated to fall.

The confidence or risk level is based on the Central Limit Theorem which says that when a population is repeatedly sampled, the average value of the attribute obtained by those samples is equal to the true population value.

There are several approaches to determine sample size. These include using a census for small populations, repeating a sample size of similar studies, using published tables, and applying formulas to calculate the sample size.

Yamane (1967: 886) provides a simple formula to calculate sample sizes. The necessary sample size can be calculated for various combinations of levels of precision, confidence and variability by using following formula:

$$n = \frac{N}{1+N(e)^2}$$

n – Sample size

N – Population size

e – Level of precision

The sample size was derived based on the confidence interval method. Sample size was fixed with 10% precision levels and a 95% confidence level with a 0.5 probability. The details of sample size for the targeted villages are presented in Table 3.3.

Table 3.3 Sample size for the surveyed villages **(No)**

S. No	District	Village	IPM	Non-IPM	Total
1.	Perambalur	Irur	17	65	82
2.	Perambalur	Chattiramanai	16	71	87
3.	Trichy	Saengattupatti	20	75	95
		Total	**53**	**211**	**264**

Sample size of 264 farmers as shown in the above Table 3.3, were selected randomly. The farmers were post stratified as IPM and non IPM farmers depending upon whether they followed the IPM practices or not. From the survey, it was observed that farmers follow six components of IPM practices with different combinations. A farmer was considered to be adopting IPM in onion if he or she followed at least two different pest control technologies (Gajanana *et al.* 2006; Rama Rao *et al.* 2008; Hristovska, 2009) and he farmers who were largely dependent on chemical insecticides were considered as non-adopters. Discussion with the scientists in the Divisions of Entomology and Pathology of TNAU, Coimbatore indicated that all the components were equally important in controlling the pests and diseases. The IPM practices suggested for onion and the usage of the IPM components are provided in the Table 3.4.

Table 3.4 Details of IPM practices suggested for onion

IPM component	Quantity	Use
Trichoderma viride	Bulb treatment (5g/kg) + Soil application (1.25kg/ha)	Suppression for various diseases by various pathogens
Pseudomonas fluorescens	Bulb treatment (5g/kg) + Soil application (1.25kg/ha)	To induce systemic resistance against various insect pests and diseases
VAM (Vesicular Arbuscular Mycorrhiza)	12.5kg/ha	• Improve uptake of phosphorous and zinc and immobile nutrients • Imparts diseases and pest resistant to plant
Yellow sticky trap	12/ha	Used to control onion thrips
Pheromone trap	12/ha	Used to control cutworm
Foliar application of Azadirachtin 1%	2ml/lit	To reduce damaging pest populations

3.3 Collection of Data

Both primary and secondary data were collected for the study. The required primary data were collected through personal interviews with the help of a comprehensive interview schedule. Data related to farm and household characteristics include age, education, experience in farming, adoption of pest management technologies, inputs use, productivity and prices were obtained using a pre-tested interview schedule. Information about cost incurred and profit realized by the onion producers were also collected.

Secondary information on Pesticide consumption in Tamil Nadu were collected and analyzed to study the extent of pesticide use over 20 years (1990-2009). Secondary information on area, production and productivity of onion cultivation (1996-97 to 2010-11) were collected in order to study trends and to identify the major cultivated areas.

3.4 Measurement of variables

Onion production

a) Planting material

Onion can be propagated through both seeds and bulbs. The data on quantity of seed material were obtained directly from the farmers. The cost of seed material was arrived at by multiplying the quantity of seed material used by the sample farmer and the price of the seed materials.

b) Human labour

Human labour was measured in terms of number of working days separately for men and women. The amounts of permanent and hired labour were treated alike and converted to a common physical unit (man days of eight hours). Family labour was considered separately and added to hired labour to calculate the total labour requirement.

c) Machine power

Machine power was valued using the prevailing rates of custom-hiring in the selected villages.

d) Manures, fertilizers and plant protection chemicals

The data on chemical fertilizers, manures and plant protection chemicals were collected from individual onion farmers. Fertilizers and plant protection chemicals were valued at their actual prices paid, and farm produced manure was valued at the prevailing market rate.

e) Irrigation

The irrigation variable was quantified in terms of the number of irrigations because the depth of irrigation does not show much variation across farms. Irrigation cost included labour cost for irrigating the field (mostly family labour) as well as other costs pertaining to operation and maintenance of pumpsets and other irrigation structures used by the sample farmers for irrigating onion field.

3.5 Tools of Analysis

Keeping in view the objectives of the study, appropriate methods were employed to analyze the collected data. The analytical techniques used in the study are presented below:

3.5.1 Descriptive analysis

Averages and percentages were used to examine the characteristics of sample farm households such as age, educational status, size of operational holdings, production and cost and returns in onion production.

3.5.2 Cost analysis

The cost concepts followed are given below:

i. Cost of cultivation

It included operational and material costs in cultivation of onion in a season.

ii. Output and Returns

It included output and returns obtained in onion cultivation.

An analysis of cost would enable the farmers to examine the efficiency of allocations of farm resources and reallocate them efficiently.

The cost of cultivation refers to the total expenses incurred by the onion growers in cultivating onion expressed on a per hectare basis. In order to determine the returns, the average market price of Rs 15/kg of onion bulb was considered.

iii. Cost of cultivation of Onion

The details of cost of cultivation of onion are presented and discussed in the following paragraphs.

a. Cultivation Costs

It included operational and material costs in cultivating onion in a season. The various costs included were costs of labour, manures, chemicals, depreciation, land revenue and interest on working capital.

b. Cost of labour

It included both hired labour and family labour for the operations like manuring, application of chemicals, cultural operations like forming of ridges and furrows, trimming of ridges and furrows, planting of bulbs, manuring, weeding, earthing up, irrigation and spraying of chemicals. It also included the labour required for harvesting of onion bulbs. The labour costs were calculated based on the wage rates prevailed in the study area during the reference year for the data collection, i.e., Rs 250 for male and Rs 120 for female per day of eight hours.

c. Cost of seed material

It included the cost of seed material at the rate of Rs 15/kg. In the study area all the farmers use Co4 variety of onion for the cultivation.

d. Cost of fertilizers and plant protection chemicals

It included the cost of different forms of fertilizers and plant protection chemicals used. All the fertilizers and plant protection chemicals used by the farmers were valued at their respective market prices to calculate the total cost.

e. Depreciation

Depreciation for fixed capital items such as farm machinery and irrigation structures used in onion cultivation was calculated at the rate of five percent for buildings and ten percent for implements.

f. Interest on working capital

The interest rate for agricultural loans was calculated at the rate of seven percent.

3.5.2 Budget Analysis of Production Costs and Returns

Partial budgeting is a planning and decision-making framework used to compare the costs and benefits of alternatives faced by a farm business. It focuses only on the changes in income and expenses that would result from implementing a specific alternative. Thus, all aspects of farm profits that are unchanged by the decision can be safely ignored. In a nutshell, partial budgeting provides a better handle on how a decision will affect the profitability of the enterprise, and ultimately the profitability of the farm itself. However, the value of a partial budget analysis is highly dependent upon the quality of the information used in the analysis.

A partial budget consists of two columns, a subtotal for each column and a grand total. The left hand column has the items that increase returns while the right hand column notes those that reduce returns for a farm business. The budget can be divided into four parts.

1. Added Returns

This area estimates the added returns of the new enterprise or new technology. The realistic yields, product quality and prices are used to estimate the higher benefits. Over estimation may lead to incorrect decisions and possibly reduced financial performance when the change is meant to improve it. Average prices from the markets where production is most likely to be sold are used.

2. Reduced Costs

The costs that reduced the cost of production were listed out in this area. Obvious items for inclusion in the section would be crop or livestock expenses no longer incurred. These costs could be reductions or total elimination of certain expenses.

3. Added Costs

All increased expenses were listed out due to the change being considered. Most of these were costs of production for the new enterprise or new technology. This list included non-cash costs such as labour and depreciation.

4. Reduced Returns

The revenues that are decreased or eliminated as a result of choosing a particular alternative were included in this area. If the new technology decreased the yield, the amount of reduction was estimated and multiplied it by an expected price to approximate the reduced returns.

Partial Budget format

Increased returns		**Reduced returns**	
Higher benefits:		**Reduced benefits:**	
1. ___________	Rs______	1. ___________	Rs ______
2. ___________	Rs ______	2. ___________	Rs ______
3. ___________	Rs ______	3. ___________	Rs ______
Total $______ (A)		Total $______ (B)	
Lower costs:		**Higher costs:**	
1. ___________	Rs ______	1. ___________	Rs ______
2. ___________	Rs ______	2. ___________	Rs ______
3. ___________	Rs ______	3. ___________	Rs ______
Total Rs ______ (C)		Total Rs ______ (D)	
A+C = Rs______ (E)		B+D = Rs ______ (F)	

Change in net returns = E - F = Rs________

3.6 Econometric analysis

3.6.1 Awareness and Adoption Indices

Adoption is an outcome of a decision to accept a given innovation. Feder, Just and Zilberman (1985) define adoption as "a mental process an individual passes from first hearing about an innovation to final utilization." Much scholarly interest on adoption falls in two categories: rate of adoption, and intensity of adoption. It is usually necessary to distinguish between these two concepts as they often have different policy implications. Rate of adoption refers to the relative speed with which farmers adopt an innovation. On the other hand, intensity of adoption refers to the level of use of a given technology in any time period. The rate of adoption is usually measured by the length of time required for a certain percentage of members of a system to adopt an innovation. Extent of adoption on the other hand is measured from the number of technologies being adopted and the number of producers adopting them. The current study focuses on the extent of adoption and the factors affecting it. Several stages precede adoption. Awareness of a need is generally perceived as a first step in adoption process (Rogers, 1983). Hence to know the extent of awareness and the adoption rate of onion IPM practices awareness index and adoption index were constructed.

An awareness index (AWI) and an adoption index (ADI) will give an overall picture about the awareness and adoption of IPM measures in the onion. These indices were constructed from the per cent of awareness and adoption of various recommended IPM measures (i^{th} number of measures) as follows.

$$AWI = \left(\sum_{i=1}^{n} AW_i\right) / n$$

where,

AWI – Awareness Index

AW_i - Per cent of awareness of i^{th} IPM measure, i = 1,2,………………….,n

n – Total number of IPM practices

$$ADI = \left(\sum_{i=1}^{n} AD_i\right) / n$$

where,

ADI – Adoption Index

AD_i - Per cent of adoption of i^{th} IPM measure, i = 1,2,………………….,n

n – Total number of IPM practices

3.6.2 Impact Evaluation with Propensity Score Matching

The purpose of the estimation that follows is to measure the impact of IPM adoption on several outcome variables of interest. Ex post evaluations, measure actual impacts accrued by the beneficiaries that are attributable to program intervention. Ex post evaluations have immediate benefits and reflect reality. These evaluations, however, sometimes miss the mechanisms underlying the program's impact on the population, which structural models aim to capture and which can be very important in understanding program effectiveness particularly in future settings. One form of this type of evaluation is the treatment effects model (Heckman and Vytlacil, 2005).

Issue of self-selection

The basic evaluation problem comparing outcomes *(Y)* across treated and non-treated individuals *(i)* can be represented as:

$$Y_i = \alpha X_i + \beta T_i + \varepsilon_i \tag{1}$$

Here, *T* is a dummy equal to 1 for those who participate and 0 for those who do not participate. *X* is set of other observed characteristics of the individual household and local environment. And, ε is an error term reflecting unobserved characteristics that also affect *Y*. Equation (1) reflects an approach commonly used in impact evaluations, which is to measure the direct effect of the program *T* on outcomes *Y*. The problem with estimating equation (1) is that treatment assignment is not often random because of the following factors: (a) purposive program placement and (b) self-selection into the program. That is, programs are placed according to the need of the communities and individuals, who in turn self-select given program design and placement. Self-selection could be based on observed characteristics, unobserved factors, or both. In the case of unobserved factors, the error term in the estimating equation will contain variables that are also correlated with the treatment dummy *T*. Unobserved characteristics in equation (1) cannot be measured, which leads to *unobserved selection bias* i.e., cov (*T*, ε) ≠ 0 implies the violation of one of the key assumptions of ordinary least squares in obtaining unbiased estimates: independence of regressors from the disturbance term ε. The correlation between *T* and ε naturally biases the other estimates in the equation, including the estimate of the program effect β.

It can be illustrated as: Let Y_i represent the outcome for household *i*. For participants, $T_i = 1$, the value of Y_i under treatment is represented as Y_i (1). For nonparticipants, $T_i = 0$, Yi can be represented as Y_i (0). If Y_i (0) is used across nonparticipating households as a comparison outcome for participant outcomes Y_i (1), the average effect of the program might be represented as follows:

$$D = E(Y_i(1)/\ T_i = 1) - E(Y_i(0)/\ T_i = 0) \tag{2}$$

The problem is that the treated and nontreated groups may not be the same prior to the intervention, so the expected difference between those groups may not be due entirely to program intervention. Equation (2) can be extended as,

$$D = E(Y_i(1)/\ T_i = 1) - E(Y_i(0)/\ T_i = 0) + E(Y_i(0)/\ T_i = 1) - E(Y_i(0)/\ T_i = 1)$$

***[E* (*Yi*(0) / *Ti* = 1)** represents the expected outcome for nonparticipants had they participated in the program (or) it is the another way to specify the counterfactual.]

$$\Rightarrow \quad D = ATE + E(Y_i(0)/\ T_i = 1) - E(Y_i(0)/\ T_i = 0) \quad (3)$$

$$\Rightarrow \quad D = ATE + B \quad (4)$$

In these equations, *ATE* is the average treatment effect [*E* (*Yi* (1) | *Ti* = 1) – *E* (*Yi*(0) | *Ti* = 1)], namely, the average gain in outcomes of participants relative to nonparticipants, as if nonparticipating households were also treated. The *ATE* corresponds to a situation in which a randomly chosen household from the population is assigned to participate in the program, so participating and nonparticipating households have an equal probability of receiving the treatment *T*. The term *B*, [$E\ (Y_i\ (0) \mid T_i = 1) - E\ (Y_i\ (0) \mid T_i = 0)$], is the extent of selection bias that crops up in using *D* as an estimate of the *ATE*. Because if we do not know $E\ (Y_i\ (0) \mid T_i = 1)$, the magnitude of selection bias cannot be calculated. As a result, if we do not know the extent to which selection bias makes up *D*, the exact difference in outcomes between the treated and the control groups cannot be measured. The basic objective of a sound impact assessment is then to find ways to get rid of selection bias (*B* = 0) or to find ways to account for it.

An impact evaluation is essentially a problem of missing data, because the outcomes of program participants had they not been beneficiaries cannot be observed. Without information on the counterfactual, the next best alternative is to compare outcomes of treated individuals or households with those of a comparison group that has not been treated. In doing so, a comparison group that is very similar to the treated group has to be picked up, such that those who received treatment would have had outcomes similar to those in the comparison group in absence of treatment. Successful impact evaluations depend on finding a good comparison group. There are two broad approaches that researchers resort to in order to mimic the counterfactual of a treated group: (a) create a comparator group through a statistical design, or (b) modify the targeting strategy of the program itself to remove differences that would have existed between the treated and non-treated groups before comparing outcomes across the two groups. A number of different methods can be used in impact evaluation theory to address the fundamental question of the missing counterfactual. Each of these methods carries its own assumptions about the nature of potential selection bias in program targeting and participation, and the assumptions are crucial to developing the appropriate model to determine program impacts.

In cases where experimental data are gathered through randomization, information on the counterfactual situation would normally be provided, and as such the problem of causal inference can be resolved. However, when the data available are from a cross sectional survey, as the one employed in the present study, no information on the counterfactual situation can be obtained. An effective way of addressing the problem is to resort to an investigation of the direct effect of technology adoption by looking at the differences in outcomes among farm households (Blundell and Costa Dias, 2000).

Some authors have employed the Heckman two-step method or similar approaches to address selection bias. However, the two-step procedures are completely dependent on the strong assumption that unobserved variables are normally distributed. Another way of controlling for selection bias is to employ an instrumental variable approach (IV). A major limitation of that approach is that it normally requires at least one variable in the treatment equation to serve as an instrument in specifying the outcome equation. Finding such instruments remains a difficult task in empirical analyses. Moreover, both OLS and IV procedures tend to impose a linear functional form assumption, implying that the coefficients on the control variables are similar for adopters and non-adopters. As indicated by Jalan and Ravallion (2003) and Mendola (2007), this assumption is not likely to hold.

When panel data are available, selection bias can be addressed by the difference-in differences matching estimator. Difference-in-differences matching differs from cross-sectional matching in that it allows for temporally invariant differences in out-comes between adopters and non-adopters (Smith and Todd, 2005). In the absence of panel data, this study employs statistical matching to address the problem of selection bias. This involves pairing adopters and non-adopters that are similar in terms of their observable characteristics (Dehejia and Wahba, 2002). When outcomes are independent of assignment to treatment, conditional on pretreatment covariates, matching methods can yield an unbiased estimate of the treatment impact.

IPM Impact Assessment

To obtain an accurate assessment of the IPM impact, the difference between the outcomes of farmers who use IPM and the outcomes from the same farmers had they not adopted the IPM technique has to be examined. The empirical challenge is the typical one of filling in missing data on the counterfactual – what would have been the outcome if the IPM adopters had not used the Integrated Pest Management (IPM) method. In the present context, and given the cross-sectional nature of our data, a suitable comparison group of non- IPM farmers whose outcomes on average provide an unbiased estimate of the missing counterfactual has to be identified. Given the non-random adoption of IPM among farmers, simple comparison of mean outcomes between IPM and non-IPM farmers would yield biased estimates of impact.

As discussed earlier, there are two main sources of bias in simple comparison of mean outcomes in the context of IPM adoption: (1) selection on observables and (2) selection on unobservables. First, IPM adopters are likely to differ from non-adopters in the distribution of their observed characteristics leading to a bias from ‘‘selection on observables’’. Propensity Score Matching (PSM) techniques can control selection on observables and provide an unbiased measure of impact on the IPM adopters (i.e., the ATT) under the assumption of conditional mean independence. Conditional mean independence is that pre-adoption outcomes are independent of IPM adoption given the observable characteristics used in the matching procedure. The second source of potential bias in the simple comparison of mean outcomes is from the difference in the distribution of unobservable characteristics between the IPM and non-IPM adopters, where the unobservable characteristics affects both the decision to adopt IPM and the outcomes of interest. That is, the measured effect of IPM on the outcomes may just be due to the difference in the unobservable variables, rather than being due to IPM itself.

Propensity Score Matching

The Propensity Score Matching (PSM) technique introduced by Rosenbaum and Rubin (1983) is the primary approach used in this study to control for selection bias based on observable characteristics. The basic idea behind the PSM method is to find control observations (i.e., non-IPM farmers) having observable characteristics as similar as possible to the treatment group, to serve as valid surrogates for the missing counterfactuals. The PSM approach tries to capture the effects of different observed covariates *X* on participation in a single propensity score or index. Then, outcomes of participating and non-participating households with similar propensity scores are compared to obtain the program effect. Households for which no match is found are dropped because no basis exists for comparison. PSM constructs a statistical comparison group that is based on a model of the probability of participating in the treatment *T* conditional on observed characteristics *X*, or the propensity score: $P(X) = \Pr(T = 1|X)$. It follows that the expected treatment effect for the treated population is of primary significance.

To create the conditions of a randomized experiment, the PSM employs the unconfoundedness assumption also known as conditional independence assumption (CIA), which implies that once Z is controlled for, technology adoption is random and uncorrelated with the outcome variables. *Conditional independence* states that given a set of observable covariates *X* that are not affected by treatment, potential outcomes *Y* are independent of treatment assignment *T*. If Y_i^T represent outcomes for participants and Y_i^C outcomes for nonparticipants, conditional independence implies,

$$(Y_i^T, Y_i^C) \perp T_i \,|\, X_i$$

This assumption is also called *unconfoundedness* (Rosenbaum and Rubin 1983), and it implies that uptake of the program is based entirely on observed characteristics. A second assumption is the *common support* or *overlap condition*: $0 < P(T_i = 1|\, X_i) < 1$. This condition ensures that treatment observations have comparison observations “nearby” in the propensity score distribution (Heckman, LaLonde, and Smith 1999). Specifically, the effectiveness of PSM also depends on having a large and roughly equal number of participant and nonparticipant observations so that a substantial region of common support can be found. For estimating the TOT, this assumption can be relaxed to $P(T_i = 1|\, X_i) < 1$. Treatment units will therefore have to be similar to non-treatment units in terms of observed characteristics unaffected by participation; thus, some non-treatment units may have to be dropped to ensure comparability. However, sometimes a non-random subset of the treatment sample may have to be dropped if similar comparison units do not exist (Ravallion 2008). This situation is more problematic because it creates a possible sampling bias in the treatment effect. Examining the characteristics of dropped units may be useful in interpreting potential bias in the estimated treatment effects. Heckman, Ichimura, and Todd (1997) encourage dropping treatment observations with weak common support.

The PSM can be expressed as,

$$p(Z) = \Pr\{I = 1/Z\} = E\{1/Z\} \quad (5)$$

where $I = \{0,1\}$ is the indicator for adoption and Z is the vector of pre-adoption characteristics. The conditional distribution of Z, given p (Z) is similar in both groups of adopters and non-adopters. Unlike the parametric methods mentioned above, propensity score matching requires no assumption about the functional form in specifying the relationship between outcomes and predictors of outcome. The drawback of the approach is the strong assumption of unconfoundness. As argued by Smith and Todd (2005), there may be systematic differences between adopters and non-adopters outcomes even after conditioning because selection is based on unmeasured characteristics. However, Jalan and Ravallion (2003) pointed out that the assumption is no more restrictive than those of the IV approach employed in cross-sectional data analysis. In a study by Michalopoulos *et al*. (2004) to assess which non-experimental method provides the most accurate estimates in the absence of random assignment, they conclude that propensity score methods provided a specification check that tended to eliminate biases that were larger than average. On the other hand, fixed effects model did not consistently improve the results.

In this study both single binary treatment and multiple simultaneous treatments were followed. We follow common practice in the matching literature by using a parametric binary response model (a probit model in our case) for the single binary treatment and multinomial logit model for the multiple simultaneous treatment to estimate the propensity score for each observation in the treatment (IPM adopters) and control (non- IPM adopters) groups.

A rich set of observable covariates are used to estimate the propensity scores, with special focus on the observable variables used as the criteria for the initial dissemination of the IPM technology in the area and the factors used in previous literature that studied IPM technology adoption. The ‘‘balancing property’’ of the observables used in the probit specification is then tested to ensure that observations with similar propensity scores have the same distribution of observable characteristics independently of whether or not IPM is adopted. In other words, for a given propensity score, satisfying the balancing property indicates that IPM adoption is random and, thus, the IPM adopters and non-adopters should be on average observationally identical. Using the estimated propensity score from the probit model and the multinomial logit model for the single binary treatment and multiple simultaneous treatments respectively the IPM adopters in the sample are then matched to non-adopters with sufficiently similar propensity scores.

3.6.2.1. Single Binary Treatment

Probit model

A probit model was used to identify the factors that influence the probability of adoption of Integrated Pest Management (IPM) practices among farmers since its asymptotic characteristic constrains the predicted probabilities to a range of zero to one. The decision to adopt the new strategy is a discrete choice which is assumed to follow a normal distribution. Probit analysis is based on the concept of cumulative normal distribution. The estimated model that emerges from cumulative normal distribution function is popularly known as probit model, sometimes it is also known as the normit model. The probit model is based on utility theory or rational choice perspective on behaviour (Gujarathi, 2008).

Let the adoption of IPM be a dichotomous choice, where the new technology is adopted when the net benefits from choosing the technology are greater than not adopting the technology. The difference between the net benefits from adoption and non-adoption may be denoted as I^*, such that $I^* > 0$ indicates that the net benefits from adoption exceeds that of non-adoption. Although I^* is not observable, it can be expressed as a function of observable elements in the following latent variable model.

$$I_i^* = \beta Z_i + \mu_i, \qquad I_i = 1\ (I_i^* > 0)$$

where I_i is a binary indicator variable that equals 1 for household i in case of adoption and 0 otherwise, β is a vector of parameters to be estimated, Z_i is a vector of household and plot-level characteristics and μ_i is an error term assumed to be normally distributed.

The probability of adoption of the new technology can be represented as

$$Pr\,(I_i = 1) = Pr\,(I_i^* > 0) = Pr\,(\mu_i > -\beta Z_i) = 1 - F\,(-\beta Z_i) \qquad (6)$$

where F is the cumulative distribution function for I_i.

The probability of adoption is estimated using a probit model expressed as follows (Greene, 2008):

$$\Pr\,(Y = 1) = \int_{-\infty}^{x'\beta} \emptyset(t)dt = \Phi(x'\beta) = \Phi(Zi^*)$$

Where

- Φi (x' β) is the cumulative density function evaluated at Xi β.
- ø (.) is the standard normal distribution
- x' is a vector of independent variables, some of which may be interaction terms
- β is a vector of coefficients to be estimated
- Zi* is the expected value of the latent variable Zi^*

It is assumed that Zi is a function of the vector of household characteristics (HHC), farms characteristics (FARM), and of institution characteristics (INST). The latent variable can be written as follows:

$$Zi = \propto + \nu\text{HHC} + \theta\text{FARM} + \gamma\text{INST} + \text{e}$$

and the expected value of Zi* as:

$$\text{Zi}^* = E(Z_i/X) = \propto + \nu\text{HHC} + \theta\text{FARM} + \gamma\text{INST}$$

The maximum likelihood function is given by

$$\ln \text{L}(\beta) = \sum_{i-1}^{n} \{yi \ln \Phi(x'\beta) + (1 - \text{yi}) \ln[1 - \Phi(x'\emptyset)]\}$$

The estimator β^ maximizes the likelihood function and is consistent, asymptotically normal, and efficient. Rubin and Thomas (1996) suggest using all the covariates included in the model to predict the propensity score, even if they are not statistically significant.

The expected treatment effect for the treated population may be given as,

$$T/I = 1 = E\,(T/I = 1) = E(R_1/I = 1) - E(Ro/I = 1) \qquad (7)$$

where 'T' is the average treatment effect for the treated (ATT), R_1 denotes the value of the outcome for adopters of the new technology and R_0 is the value of the same variable for non-adopters.

The onion IPM package consists of six components such as, *Trichoderma viride*, *Pseudomonas fluorescens*, VAM, Yellow/blue sticky traps, Pheromone trap and Neem products. The quantity and price were discussed in the results. As discussed earlier, from the data, we identified that out of 264 sample onion cultivars 53 farmers use some of the IPM components and they are considered as IPM adopters. Impact evaluation with single binary treatment was analyzed by considering these IPM adopters as the participants in the treatment and remaining 211 farmers were considered as non-participants.

Diagnostics

Before running the probit model all the hypothesized explanatory variables were checked for the existence of multi-collinearity problem.

There are two measures are often suggested to test the existence of multi-collinearity. These are Variance Inflation Factor (VIF) and Tolerance Factor (TF) used to test for association among the explanatory variables. In this study, tolerance factor was used to test multi-collinearity problem. According to Gujarati (2008) TF is defined as

$$TF = (1-Rj^2)$$

Where Rj^2 is the squared multiple correlation coefficient between Xi and other explanatory variables. If TF is closer to one then there is no problem of multi-collinearity but if it is closer to zero then it indicates the problem of multi-collinearity (Gujarati, 2007).

The choice of explanatory variables (i.e., conditioning variables) in predicting propensity scores is crucial in propensity score matching analysis. The selection of covariates should fulfill the assumption of unconfoundedness. Therefore, there is a need to select variables that influence both treatment and outcomes, but are not affected by the treatment (Caliendo and Kopeinig, 2008).

The empirical model used in the present study is,

$$Y = a + \beta 1\ Age + \beta 2\ Age^2 + \beta 3\ Education + \beta 4\ HS1\ (0\text{-}10) + \beta 5\ HS2\ (11\text{-}16) + \beta 6\ HS3(17\text{-}60) + \beta 7\ HS\ 4\ (61\text{-}80) + \beta 8\ Total\ land + \beta 9\ Pesticide\ cost + \beta 10\ Pesticide\ dealer\ adv + \beta 11 Relative\ adv + \beta 12\ Village1 + \beta 13\ Village2 + \beta 14\ Village3 + e_i$$

Table 3.5 presents definitions and descriptive statistics for the variables used in the empirical analysis.

Table 3.5 Description of the variables used in the Probit model

Variables	Type	Description
Dependent variable		
IPM onion adoption	Binary	1 if the farmer adopt the IPM technology
Independent variable		
Age	Continuous	Household Head : Age in years
Age^2	Continuous	Household Head : Age in squared
Education	Binary	1 if the household head attended more than primary school
HS1(0-10)	Continuous	Household size: Age between 0 to 10
HS2 (11-16)	Continuous	Household size: Age between 11 to 16
HS 3 (17-60)	Continuous	Household size: Age between 17 to 60

Variables	Type	Description
HS 4 (61-80)	Continuous	Household size: Age between 61 to 80
Total land	Continuous	Total land area owned (in ha)
Pesticide cost	Binary	1 if the choice of pesticide based on the pesticide cost
Extensionage	Binary	1 if the choice of pesticide based on the advice of the extension agent
Pesticide dealer adv	Binary	1 if the choice of pesticide based on the advice of the pesticide dealers
Relative adv	Binary	1 if the choice of pesticide based on the advice of the relatives
Village1	Binary	1 if the household belongs to Irur village
Village2	Binary	1 if the household belongs to Sengattupatti village
Village3	Binary	1 if the household belongs to Chatiramanai village

Age

Farmer age is often used as a variable in adoption studies. Age is expected to negatively affect adoption. In a study by Adesina and Zinnah (1993), age was found to be negatively correlated with adoption. This relationship is explained by the assumption that as farmers grow older, there is an increase in risk aversion and a decreased interest in long-term investment in the farm. Hence older and more experienced farmers may be less likely to experiment with new technologies while younger farmers are less risk averse and more likely to adopt new techniques.

Education

Education is often considered as a factor in technology adoption studies. It is an indication of the ability to communicate, read pesticide containers and other applicable publications, and synthesize information for optimal decision making. The variable 'Education' is binary, it takes 1 if the household head attended more than primary school.

Household size

Household size is a continuous variable which represents the number of members in the family. Affects on adoption may vary depending on the ages of household members. Since it is expected that the family having younger children are more likely to adopt the technology, household size is disintegrated into four groups such as HS1(0-10) [Number of people who are in age between 0 to 10], HS2(11-16) [Number of people who are in age between 11 to 16], HS1(17-60) [Number of people who are in age between 17 to 60], HS4(>60) [Number of people who are in age more than 60]. Number of members in the household who are in age between 17 to 60 is of particular interest because of the likelihood that these individuals will participate in on-farm labour activities. Therefore, this variable is used as a measure of labour availability. These individuals may also participate in off-farm work as a supplement for on-farm income. Availability of labour is a potential factor for adoption of sustainable agriculture technologies. Household size has been found to have a positive effect on adoption (Bonabana, 2002). It may also negatively affect adoption, since the farmers belong to the larger size of the family will less likely to aware about the new technologies.

Total land

Total land is a continuous variable which represents the total cultivable land of the family. This variable is a per capita measure of the amount of land held by the farmer's household and is one indicator of wealth. It is expected that larger farms are expected to adopt more capital intensive technologies while smaller farms are expected to adopt more labour intensive technologies.

Pesticide cost

Pesticide cost is a dummy variable that indicates whether the choice of pesticide is based on the pesticide cost. It is expected that the farmers who choose the pesticide based on the cost of the pesticide are less likely to adopt.

Extensionage

Extension agent is a dummy variable that indicates whether the choice of pesticide is based on the advice of the extension agent. It is expected that the farmers who choose the pesticide based on the advice of the extension agent are more likely to adopt.

Pesticideadv

Pesticideadv is a dummy variable that indicates whether the choice of pesticide is based on the advice of the pesticide dealers. It is expected that the farmers who choose the pesticide based on the advice of the pesticide dealers are less likely to adopt.

Relativeadv

Relativeadv is a dummy variable that indicates whether the choice of pesticide is based on the advice of the relatives. It is expected that the farmers who choose the pesticide based on the advice of the relatives are less likely to adopt.

Village dummy

Villagedummy is a dummy variable. Each of the three different villages: Irur, Sengatupatti, Chatiramanai by one variable: Village1, Village2 and Village3 respectively. These distinguished the village to which each farmer belongs. The coefficients on this variable (Village1, Village2 and Village3) indicated the variation between villages.

3.6.2.2 Multiple Simultaneous Treatments

We utilize the multinomial logistic model (MNL) which estimates the probability of the farmer using one or more IPM components. There are several reasons for using MNL as our selection equation:

1. The model assumes that program participation cannot be perfectly predicted from the provided independent variables (Dow and Endersby 2004);
2. We estimate the probability of program participation based on a fixed, stable group of options;
3. MNL almost always converges to a global optimum without requiring numerical integration; and
4. Multinomial probit models (MNP) are often weakly identified in application and may produce arbitrary parameter estimates (Dow and Endersby 2004).

One of the criticisms of MNL is the independence of irrelevant alternatives (IIA) assumption (Dow and Endersby 2004); however, this should not be a problem for our model.

From the MNL, we obtain the marginal probabilities of program participation:

$$P(MP_i = k/x_i) = \frac{\exp(X'^{\beta_k})}{\sum_{k=0}^{K} \exp(X'^{\beta_k})} \qquad i = 1.....N,\ k = 0........K \qquad (8)$$

MP represents the treatment status of IPM adoption with k options of program choices (in our case k = Group I, Group II, Group III, Group IV, Group V, Group VI (Non-adoption).

For multiple simultaneous treatment ATT, we must also take into consideration the conditional probability of joining program *g* rather than program *j* (or joining program *j* rather than *g* or joining both programs) where the conditional probability of choosing to participate in program *g* rather than program *j* is as follows:

$$P^{gj,g} = P^{gj,g}(MP = g|X = x, MP\epsilon\{j, g\} = \frac{P^{g}(x)}{P^{j}(x)+P^{g}(x)} \qquad (9)$$

where $P^{gj,g}$ is the estimated propensity score. In addition, $P^{g}(x) = P(MP = g/X = x$ and $P^{j}(x) = P(MP = j/X = x$. We obtain each of the conditional probabilities from the MNL model where only pre-treatment variables are used. Cuong (2009) finds that controlling for simultaneous participation in multiple treatments (e.g., using MNL rather than a series of binary models) makes PSM more efficient with regard to the mean square error.

Using the notation of Bradley and Migali (2011), the multiple treatment version of the ATT is

$$ATT^{j,g} = E(Y_{ij} - Y_{ig} \mid MP = j) = E(Y_{ij} \mid MP = j) - E(Y_{ig} \mid MP = g) \quad (10)$$

where is the expected average treatment effect of group *j* relative to treatment *g* for farmers participating in group *j*. *MP* is the treatment status. Because both outcomes cannot be observed for the same student, we utilize the Conditional Independence Assumption (CIA) for identification (Imbens 2000; Lechner 2001). The CIA requires observation of the major variables jointly influencing selection into the program and outcomes for a given treatment. Although we assume CIA, ATT is often identifiable with much weaker assumptions than ATE (Geneletti and Dawid 2011). With this assumption, we actually estimate:

$$ATT^{j,g} = E(Y_{ij} \mid MP = j) + E_{P^{gj,g}}[E(Y_{ig} \mid P^{gj,g}(X), MP = g) \mid MP = j] \quad (11)$$

The conditional probability of group g is taken from the PSM (equation 9). We then match the propensity scores for the treated and untreated groups for estimation using several matching methods.

Among the 53 IPM adopters, based on the IPM components used the farmers were categorized into five groups and the remaining 211 non-IPM farmers were considered as the sixth group and the details were furnished in Table 3.6. The impact evaluation was done with multiple simultaneous treatments.

Table 3.6 Classification of IPM farmers

Group	IPM components	No of Farmers
I	*Trichoderma Viride, Pseudomonas fluorescens,* Neem products	24
II	*T. Viride, P. fluorescens,* Neem products, Yellow sticky trap (4)	7
	Trichoderma Viride, Pseudomonas fluorescens, Neem products, VAM (3)	
III	*Trichoderma Viride, Pseudomonas fluorescens*	6
IV	*Trichoderma Viride,* VAM, Neem products (3)	9
	Trichoderma Viride, Neem products (6)	
V	*Without Trichoderma Viride*	7
VI	*Non-IPM Farmers*	211

Matching Methods

Several techniques have been developed to match adopters with non-adopters of similar propensity scores. The most commonly used techniques include nearest neighbour matching (NNM), kernel-based matching (KBM), stratified matching, radius matching and Mahalanobis matching methods. The nearest neighbour matching (NNM), kernel-based matching (KBM) and radius matching methods (RDM) methods were employed for the study.

Stratification or interval matching procedure partitions the common support into different strata (or intervals) and calculates the program's impact within each interval. Specifically, within each interval, the program effect is the mean difference in outcomes between treated and control observations. A weighted average of these interval impact estimates yields the overall program impact, taking the share of participants in each interval as the weights. One risk with the method above is that only a small subset of nonparticipants will ultimately satisfy the criteria to fall within the common support and thus construct the counterfactual outcome. Nonparametric matching estimators such as kernel matching use a weighted average of all nonparticipants to construct the counterfactual match for each participant.

The NNM involves choosing individuals from the adopters and non-adopters that are closest in terms of propensity scores as matching partners. Several variants of the NNM have been proposed in the literature, including NNM matching 'with replacement' and 'without replacement'. In the former case, an untreated individual can be used more than once as a match, whereas in the latter case it is considered only once. Matching with replacement involves a trade-off between bias and variance (Smith and Todd, 2005). Allowing for replacement increases the average quality of matches but tends to reduce the number of distinct non-adopter observations used to construct the counterfactual mean, thus increasing the variance.

The KBM method is also a non-parametric matching method that uses the weighted average of the outcome variable for all individuals in the group of non-adopters to construct the counterfactual outcome, giving more importance to those observations that provide a better match. This weighted average is then compared with the outcome for the group of adopters. The difference between the two terms provides an estimate of the treatment effect for the treated case.

A sample average over all adopters is then the estimate of the sample average treatment effect for the treated group. As pointed out by DiNardo and Tobias (2001), the choice of the kernel function for the KBM does not appear to be important. However, Hujer et al. (2004) pointed out that a proper imposition of the common support condition is quite crucial in employing the KBM, as this helps in avoiding bad matches.

Caliper or Radius matching procedure involves matching with replacement, among propensity scores within a certain range. Caliper and radius matching uses a predefined tolerance level on the maximum propensity score distance (caliper/radius) between matches. Treated observations are matched with nearest neighbour control observations within that caliper to avoid poor matches. If the radius is set very small, then it is possible that some treated units are not matched because the neighbourhood does not have any control units with a close enough propensity score (Becker and Ichino 2002). For our ATT analysis, we use caliper/radius matching with a radius of 0.01 with replacement. Replacement is where a control unit can be a best match for more than one treated unit. Common support was also imposed by dropping 2% of the treatment observations that have the lowest match with its control. The analysis was done with the statistical package STATA by executing proper codes.

3.6.3 Economic Surplus Method

The economic surplus approach has been frequently used in recent years to assess the impact of agricultural research benefits in developing countries. This approach measures benefits that can be included in a benefit-cost analysis and also used to calculate the net economic benefits associated with research alternatives. An economic surplus approach is also a strong decision-making tool which captures both researchers' and policymakers' interests.

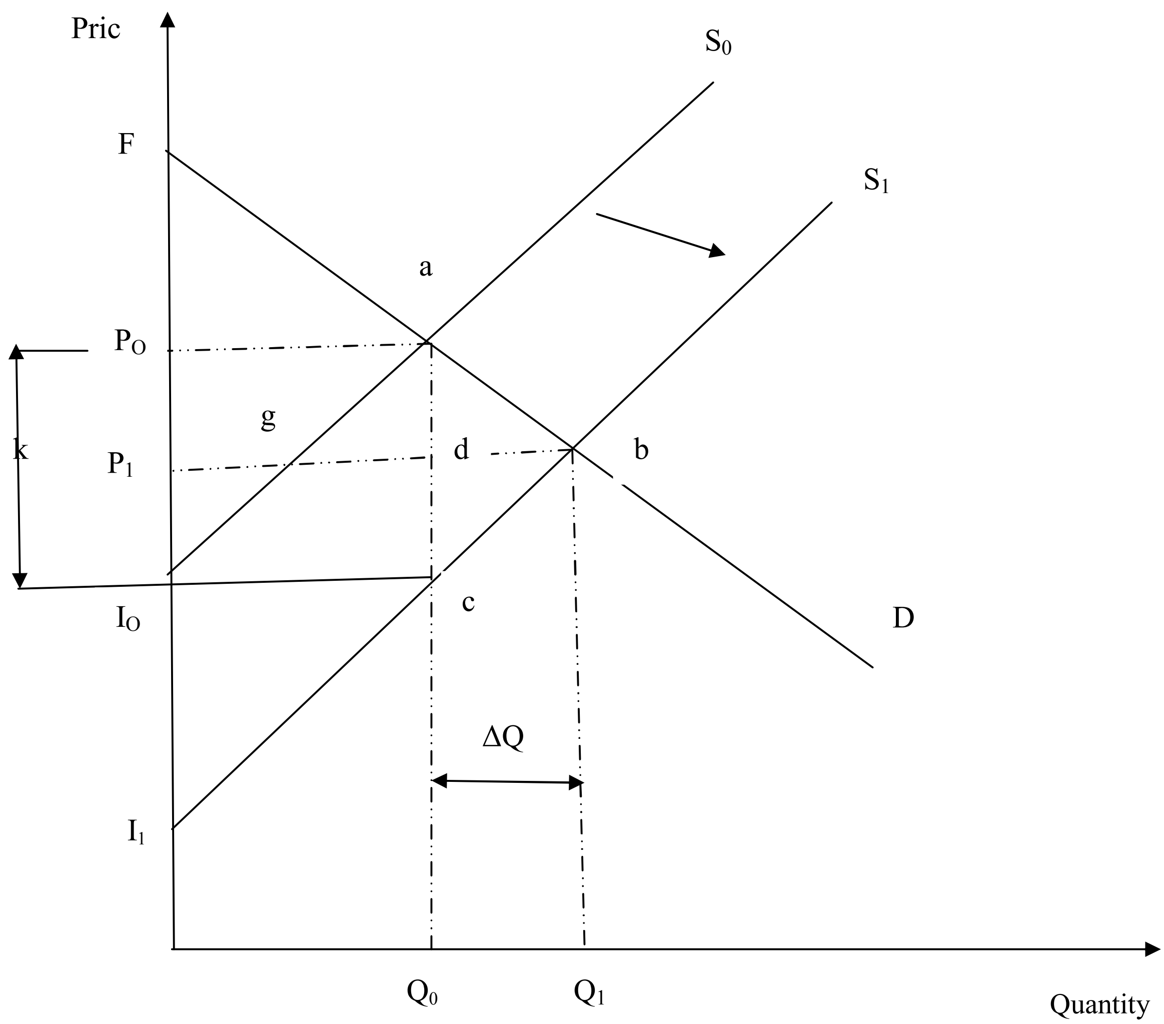
The economic surplus method is used to measure the net returns at the market level from a research project or program, which shifts the supply curve out to the right. It is a very flexible method that also allows consideration of technology and price spillover effects. Technology spillover is when other countries are able to adopt and utilize the research benefits of one country (Alston, Norton, and Pardey, 1998).

The economic surplus model can be used to measure the change in producer and consumer surplus as a result of a program (such as the IPM) and also the total or net welfare effect. Since one of the objectives of this thesis is to calculate the net present value of benefits resulting for the specific IPM programs using the economic surplus model is necessary. Using the economic surplus approach provides rupee values for the producer and consumer benefits resulting from the particular program that is being evaluated which is necessary and important for the decision making process.

When widespread adoption of IPM technologies across large areas occurs, changes in crop prices, cropping patterns, producer profits and overall societal welfare can occur and economic surplus analysis captures these changes. The changes arise because costs change and because supplies may increase, affecting prices for producers and consumers. These changes are illustrated for the closed economy model (Figure 3.4) which shows the research benefits resulting from adoption of an onion IPM. Figure 3.4 illustrates a change in supply after a technological change for a single homogeneous good (onion). In this figure, line D represents the demand curve for the good (onion), while line S_0 represents the supply curve of the onion before the adoption of an IPM strategy. The initial equilibrium price and quantity are P_0 and Q_0 (Figure 3.4) respectively.

In Figure (3.4), the area below the demand curve D above the price line P_0 is called consumer surplus (CS). It indicates how much some consumers are willing to pay above the current price to obtain the product. However, these consumers pay the current price and not what they would be willing to pay. The area P_0 a I_0, above the supply curve S_0, and below the price line is called producers surplus (PS). It indicates how much the producers are willing to accept below the current market price and represent the returns to fixed factors of production.

Figure 3.4 Shift of supply curve due to technological change – closed economy



The area of the region FaI_0 represents the total economic surplus before the adoption of IPM strategies. We assume that demand and supply curves are linear, demand for onion remains unchanged, and that the supply curve shifts parallel to its initial position, as a consequence of technological change. We assume an outward shift in the supply curve to S_1 because we expected that adoption of technologies diminishes the per-unit cost of onion production. This shift induces an increase in production and consumption of Q_1 (by $\Delta Q = Q_1 - Q_0$); the market price falls to P_1 (by $\Delta P = P_1 - P_0$). The new equilibrium price and quantity are P_1 and Q_1 respectively. The total economic surplus after the adoption of IPM technologies is represented by the area FbI_1 which consists of the sum of the corresponding consumer and producer surpluses, (FbP_1 and P_1bI_1 respectively). The gain in economic surplus is represented by area FbI_1 minus area FaI_0 which yields area I_0abI_1.

The change in total economic surplus (ΔTS) is also defined as the sum of a change in consumer surplus (ΔCS) and a change in producer surplus (ΔPS). These changes are expressed as follow:

$\Delta CS = FbP_1 - FaP_0 = P_0abP_1 = P_0agP_1 + abg$

$\Delta PS = P_1bI_1 - P_0aI_0 = (I_0gbI_1 + P_1gI_0) - (P_0agP_1 + P_1gI_0) = I_0gbI_1 - P_0agP_1$

$\Delta TS = (P_0agP_1 + abg) + (I_0gbI_1 - P_0agP_1) = abg + I_0gbI_1 = I_0abI_1$

Consumers are better off and producers may be better off after the adoption of IPM technologies. Consumers can buy more onions (Q_1) at a lower price (P_1) and benefit by an amount equal to their cost savings on the original quantity (Q_0*ΔP) plus their net benefits from the increment to consumption. Producers' per-unit production costs have fallen by the amount (k) and they gain additional income from that, although part (or even all) of their gains are offset by the lower price. Based on our assumptions, (linear demand and supply curves, and parallel shift in the supply curve), the changes in consumer surplus, producer surplus, and economic surplus can be computed as follows:

$$\Delta CS = PoQoZ\,(1 + 0.5Z\eta)$$

$$\Delta PS = PoQo\,(K - Z)\,(1 + 0.5Z\eta)$$

$$\Delta TS = \Delta CS + \Delta PS = PoQoZ\,(1 + 0.5Z\eta)$$

Where η is the absolute value of the elasticity of demand, E is elasticity of supply, Z = KE / (E + η), where Z is the price reduction from P_0 to P_1 due to the supply shift.

While, K represents the vertical shift of the supply function expressed as a portion of the initial price (Alston, Norton, and Pardey, 1998, pp210).

CHAPTER IV

DESCRIPTION OF THE STUDY AREA

A profile of the study region in terms of agro-climatic conditions, topography and other socio-economic characteristics are important for understanding the problems of agricultural development there. The basic information of the study area regarding location, climatic condition, soil type, irrigation facilities, cropping pattern, infrastructural facilities of the study area are reported in this section.

4.1 Perambalur

Perambalur district is located in the state of Tamil Nadu. It lies in the Southern plateau & hill zone of agro-climate regional planning with characteristics of semi-arid climate. Perambalur district came into existence after trifurcation of Tiruchirappllai district with effect from 30.09.1995.

4.1.1 Geography

Perambalur district lies between $10^0$54’ and $11^0$30’ of North latitude and $78^0$40’ and $79^0$30’ of east longitude. Fig.4.1 shows that the Perambalur district is bounded on the North and Northeast by Viluppuram and Cuddalore districts, Northwest by Salem district, Southeast by Ariyalur district and Southwest by Tiruchirappalli district and it is spread over in the area of 3,691.07 sq.kms. The district lies in the Southern plateau and hill zone of agro-climate regional planning with characteristics of semiarid climate and it is an inland district without any coastal line. The general physiography of this district is versatile with hilly ranges, series of plains, valley bottoms, undulating upland area and broken chains of Eastern ghats *viz.,* Pachamalai hills. A part of Pachamalai hill is the important hill in Perambalur taluk of this district. Perambalur taluk forms a gentle undulating upland having hilly areas, gullied lands and small hillocks.

4.1.2 Administrative System

The details of the administrative set up of Perambalur district is shown in Table 4.1. Perambalur district has only one revenue division *viz.,* Perambalur. The district for administrative purpose has been divided into three taluks (Perambalur, Kunnam, Veppanthattai) which is further sub-divided into four blocks viz. Perambalur, Veppanthattai, Veppur, Alathur. The district comprises 10 firka's, 152 revenue villages, 121 village panchayats, four town panchayats and one municipality viz., Perambalur.

Table 4.1 Administrative setup in Perambalur district

<table>
<tr><th>S. No.</th><th>Taluks</th><th>Blocks</th><th>Firkas</th><th>Revenue villages (Nos)</th></tr>
<tr><td>1.</td><td>Perambalur</td><td>Perambalur</td><td>1. Perambalur
2. Kurumbalur</td><td>27</td></tr>
<tr><td rowspan="2">2.</td><td rowspan="2">Kunnam</td><td>Veppur</td><td>3. Vadakalur
4. Kallapuliyur
5. Varakoor</td><td rowspan="2">86</td></tr>
<tr><td>Alathur</td><td>6. Chettikulam
7. Kolakkanatham</td></tr>
<tr><td>3.</td><td>Veppanthattai</td><td>Veppanthattai</td><td>8. Venkalam
9. Pasumbalur
10. Valaikandapuram</td><td>39</td></tr>
</table>

4.1.3 Economy

Currently, Perambalur district is the top maize and Onion (small) producer in Tamil Nadu, with 27% and 50% of the state's share respectively. Perambalur is planning to set up multi-product special economic zone (SEZ) over an area of 5000 acres (20 km^2) specializing in high-technology by SREI Infrastructure Finance Ltd through a Joint Venture with TIDCO (Tamil Nadu Industrial Development Corporation). The SEZ will have linkages to Cuddalore, Pondicherry & Chennai Ports, Railway line and Trichy Airport. This SEZ will bring in high-technology industries, MROs, biotechnology, pharmaceutical companies, textile & leather clusters. The project is being developed with world-class infrastructure to be able to compete with the best investment centres in the world. Perambalur SEZ has a large hinterland that offers huge labour force. The SEZ is well connected with all major cities/regions of the country with excellent road/rail network. The SEZ will focus on testing & certification facilities, warehouses, and infrastructure on demand etc. In addition, residential & recreational complexes are planned within the SEZ. Most of the leading Nationalised Banks including Axis Bank, HDFC, ICICI, SBI, Bank of Baroda, canara bank, IOB, Indian Bank has opened their branches at perambalur.

4.1.4 Demographic Pattern

According to the 2011 census Perambalur district has a population of 564,511. This gives it a ranking of 536th in India (out of a total of 640). The district has a population density of 323 inhabitants per square kilometre (840 /sq mi). Its population growth rate over the decade 2001-2011 was 14.36 percent. Perambalur has a sex ratio of 1006 females for every 1000 males and a literacy rate of 74.68 percent.

In 2011, Perambalur had population of 564,511 of which male and female were 281,436 and 283,075 respectively. There was change of 14.36 percent in the population compared to population as per 2001. In the previous census of India 2001, Perambalur District recorded increase of 9.45 percent to its population compared to 1991. The initial provisional data suggest a density of 323 in 2011 compared to 282 of 2001. Total area under Perambalur district is of about 1,750 sq.km.

The average literacy rate of Perambalur in 2011 was 74.68 percent compared to 66.07 percent in 2001. If things are looked out at gender wise, male and female literacy were 83.39 and 66.11 respectively. For 2001 census, the same figures stood at 77.89 and 54.43 in Perambalur District. The total literate population in Perambalur District was 379,797 of which 210,313 were male and 169,484 were female respectively. In 2001, Perambalur District had 286,197 people in its total region.

In Perambalur district, according to 2011 census there were 55,950 children under the age of 6 comapred to 60,478 in the 2001 census. Of the total, 55,950 29,245 were male and 26,705 were female respectively. The child Sex Ratio as per the census in 2011 was 913 compared to 937 in the census of 2001. In 2011, Children under 6 formed 9.91 percent of Perambalur District compared to 12.25 percent in 2001. There was a net change of -2.34 percent in this compared to the previous census of India. Perambalur District population constituted 0.78 percent of the total Tamil Nadu population. In 2001 census, this figure for Perambalur District was at 0.78 percent of the Tamil Nadu population. The demographic details of Perambalur district is furnished in Table 4.2.

Table 4.2. Demographic details of Perambalur district – 2011 census

S. No.	Block	Area (km^2)	Population			Literature		
			Male	Female	Total	Male	Female	Total
1.	Perambalur	336.84 (19.17)	76522 (27.19)	74420 (26.29)	150942 (26.74)	67356 (28.70)	57646 (30.55)	125002 (29.53)
2.	Veppanthattai	573.72 (32.65)	77670 (27.60)	78299 (27.66)	155969 (27.63)	63859 (27.21)	52023 (27.57)	115882 (27.37)
3.	Veppur	429.02 (24.41)	72421 (25.73)	74732 (26.40)	147153 (26.07)	58753 (25.03)	43758 (23.19)	102501 (24.21)
4.	Alathur	417.78 (23.77)	54823 (19.48)	55642 (19.65)	110447 (19.57)	44732 (19.06)	35248 (18.68)	79980 (18.89)
	Total	1757.36 (100.00)	281436 (100.00)	283075 (100.00)	564511 (100.00)	234690 (100.00)	188675 (100.00)	423365 (100.00)
	Tamil Nadu	130058	36158871	35980087	72138958	28314595	24098521	52413116

(Figures in parentheses indicate the percentage to total)

Source : Statistical Hand Book, Assistant Directorate of Economics and Statistics, Perambalur district, 2011)

4.1.5 Occupational Pattern

The details of the distribution of the working population in the study area were important to understand the economic status of the people in study area. The details of the occupational pattern of the Perambalur district are provided in Table 4.3, where the population is categorized by broad industrial workers' levels.

Table 4.3. Occupational pattern of Perambalur district (2010-11)

(in lakhs)

S. No	Industrial Category	Perambalur	Tamil Nadu
1.	Main workers	2.54 (45.04)	275.28 (38.16)
a.	Cultivators	1.36 (24.11)	55.35 (7.67)
b.	Agricultural labourers	0.69 (12.23)	70.24 (9.74)
c.	Household industry (HHI), Manufacturing – processing – servicing and Repairs	0.04 (0.71)	14.53 (2.01)
d.	Other workers	0.44 (7.80)	135.14 (18.73)
2.	Marginal workers	0.49 (8.69)	46.98 (6.51)
3.	Total workers (1 + 2)	3.03 (53.72)	322.26 (44.67)
4.	Non workers	2.61 (46.28)	399.12 (55.33)
	Total population (3 + 4)	5.64 (100.00)	721.38 (100.00)

(Figures in parentheses indicate the percentage to total)

Source : Statistical Hand Book, Assistant Directorate of Economics and Statistics, Perambalur district, 2011)

From the Table 4.3., it could be concluded that the total workers of main occupation were accounted as 45.04 percent to the total workers. The total workers of main occupation includes cultivators, agricultural labourers, household industry manufacturing – processing – servicing and repairs and other workers were accounted as 24.11 percent, 12.23 percent, 0.71 percent and 7.80 percent respectively. This implies that the cultivators and agricultural labourers were accounted as high in working population compared to state population of 7.67 percent and 9.74 percent respectively. This implied that most of the people in the study area depending on the agriculture for their livelihood. In the category of household industry, workers in manufacturing – processing – servicing and repairs were included which was lower i.e., 0.71 percent than the state population i.e., 2.01 percent which indicated that this district was not developed with industrial activities and the other workers were accounted as 7.80 percent to the total working population while for state was 18.73 percent.

The marginal workers population of the district was 8.69 percent to the total working population and the marginal worker of the state was 6.51 percent to the total working population. From the Table 4.3., it could be understand that on an average 53.72 percent of the total population were workers and 46.28 percent were non workers in the district indicated that more than 50 percent of the total population of the district are depending on workers for their livelihood.

4.1.6 Climate

a) Rainfall

Perambalur district comprises three major agro climatic sub zones. The major part (Perambalur and Alathur bocks) comes under Cauvery delta zone and the other two zones are Northeastern zone (Veppur block) and Northwestern zone (Veppanthattai block). It is a dry, sub humid coastal plain of Tamil Nadu. The total normal rainfall in the district is about 1019 mm, a little higher than the state average of 976.9 mm. Out of the total rainfall, 49 percent is received during the North East monsoon (October to December) and 32 percent during the South West monsoon (June to September). The remaining 19 percent comes during winter and summer months. Month wise normal rainfall in Perambalur district during the year 2010-11 is given in Table 4.4. It was noted that the actual rainfall received during the year 2010-2011 was similar to the normal rainfall.

Table 4.4 Month wise normal rainfall in Perambalur district (2010-11)

(in mm)

S. No.	Particulars	Normal rainfall		Actual Rainfall	
		Millimeters	Percentages	Millimeters	Percentages
1.	**South West monsoon**				
	a. June	107.00	10.50	33.00	4.05
	b. July	18.30	1.80	53.20	6.52
	c. August	115.00	11.28	84.90	10.41
	d. September	86.30	8.47	130.60	16.02
		326.60	**32.04**	**301.70**	**37.00**
2.	**North East monsoon**				
	e. October	153.80	15.09	174.90	21.45
	f. November	249.30	24.46	134.20	16.46
	g. December	95.70	9.39	74.30	9.11
		498.80	**48.93**	**383.40**	**47.02**
3.	**Winter**				
	h. January	1.30	0.13	13.10	1.61
	i. February	0.00	0.00	8.30	1.02
		1.30	**0.13**	**21.40**	**2.62**
4.	**Summer**				
	j. March	0.00	0.00	12.70	1.56
	k. April	176.30	17.29	30.80	3.78
	l. May	16.40	1.61	65.40	8.02
		192.70	**18.90**	**108.90**	**13.36**
	Total	**1019.40**	**100.00**	**815.40**	**100.00**

Source: Statistical Hand Book, Assistant Directorate of Economics and Statistics, Perambalur district, 2011.

b) Temperature

The mean annual temperature was above 28.5^{0}C and the difference between the mean summer (April to June) and mean winter temperature (November to February) was less than 5^{0}C. The hot months are April, May and June with the maximum temperature ranging between 36.8^{0}C to 38^{0}C and the cool months are January and February with the minimum temperature ranging between 19^{0}C to 20^{0}C.

4.1.7 Soil

The soil is predominantly red loamy and black soil. Among the four blocks of Perambalur district, part of Alathur block is covered by red loam soil and the remaining three bocks viz., Perambalur, Veppanthattai, Veppur and another part of Alathur is covered by black soil. Both black and red loam soils are categorized into fine textured soils, fine loamy soils, coarse loamy open textured soils and sandy soils with open texture, where fine textured soils (soils with high clay content) account for 130, 251 hectares followed by coarse loamy open textured soils which spread over an area of 108,351 hectares, sandy soils with open texture around 63,857 hectares and fine loamy soils with moderate clay content account for 27,187 hectares. The details of the soil type of Perambalur district is given in the Table 4.5.

Table 4.5 Soil type of Perambalur district (2010-11)

(in Hectare)

S. No.	Type of soil	Area covered
1.	Soils with high clay content	130,251
2.	Fine loamy soils	27,187
3.	Coarse loamy	108,351
4.	Sandy soils	63,857

Source: Statistical Hand Book, Assistant Directorate of Economics and Statistics, Perambalur district, 2011

4.1.8 Land Utilization Pattern

The land utilization pattern gives a picture of how the total area in the district is divided into forest, agricultural uses, non agricultural uses and the area under different classification of waste land. It could be seen from the Table 4.6, 14.63 percent and 7.51 percent of the total geographical area was covered by forests in Perambalur and Alathur block of Perambalur district respectively. About 13.94 percent and 16.48 percent of the total geographical area of both blocks were put into non agricultural uses respectively. It was observed that 43.62 percent and 53.93 percent of the total geographical area were under net sown area indicated that agricultural is the main activity of the district.

Table 4.6 Block-wise Land use pattern of Perambalur district (2010-11)

(in hectares)

S. No.	Particulars	Perambalur	Alathur	Total
1.	Forests	4926.72 (14.63)	3137.54 (7.51)	16281.85 (9.26)
2.	Barren and uncultivable lands	1267.24 (3.76)	831.06 (1.99)	2786.55 (1.59)
3.	Land put to non-agricultural uses	4696.50 (13.94)	6883.44 (16.48)	28493.29 (16.21)
4.	Cultivable wastes	1136.41 (3.37)	1379.83 (3.30)	5289.44 (3.01)
5.	Permanent pastures and other grazing lands	8.99 (0.03)	72.00 (0.17)	152.37 (0.09)
6.	Land under misc.tree crops not included in net sown area	241.62 (0.72)	488.47 (1.17)	1427.19 (0.81)
7.	Current fallows	1198.76 (3.56)	1266.52 (3.03)	3911.57 (2.23)
8.	Other fallows	5513.07 (16.37)	5187.17 (12.42)	20510.43 (11.67)
9.	Net sown area	14694.55 (43.62)	22531.48 (53.93)	96882.96 (55.13)
10.	Total geographical area	33683.85 (100.00)	41777.50 (100.00)	175735.62 (100.00)
11.	Gross cropped area	19080.27	23664.93	99545.73
12.	Area sown more than once	510.38	633.02	2662.77

Source: Statistical Hand Book, Assistant Directorate of Economics and Statistics, Perambalur district, 2011

Among the fallow land classification, the area under other fallow occupied a major portion (16.37 percent and 12.42 percent for two blocks respectively) followed by cultivable waste land (3.37 percent and 3.30 percent for two blocks respectively) and current fallow land (3.56 percent and 3.03 percent for two blocks respectively). Over a period of time the area kept as fallow has been increasing, which may signal the need to take corrective measures to bring that area under cultivation.

4.1.9 Operational Land Holding

The distribution of land holdings among various farmers in a country in general possesses much variation. It gives an idea about the possible adoption of various technologies including machinery. Perambalur district is not an exception to this case. It is common to see a large proportion of land area being owned by a few people and a small portion being owned by a large number of people. Table 4.7., provides information on different categories of farmers in the district and the extent of land area possessed by them.

Table 4.7 Operational land holdings in Perambalur district

(in hectares)

S. No.	Size of landholding (ha)	Type	Number	Area (ha)
1.	Below 1.0	Marginal	238,564 (77.28)	164,560 (51.35)
2.	1.0 – 2.0	Small	46,720 (15.13)	77,429 (24.16)
3.	2.1 – 4.0	Semi medium	18,645 (6.04)	50,238 (15.68)
4.	4.1 – 10.0	Medium	4,582 (1.48)	24,982 (7.80)
5.	Above 10.0	large	203 (0.07)	3,266 (1.02)
	Total		**308,714 (100.00)**	**320,475 (100.00)**

(Figures in parentheses indicate the percentage to total)

Source: Statistical Hand Book, Assistant Directorate of Economics and Statistics, Perambalur district, 2011

From the Table 4.7., we can see that most of the farmers in the district are classified under the category of marginal farmers, followed by small farmers, semi medium farmers, medium farmers and large farmers. It can also be observed from the Table 4.7., that 92.41 percent of (marginal and small) farmers possessed 75.51 percent of total land holdings whereas the remaining 7.59 percent of farmers possessed 24.49 percent of the total land holdings. It is clear that a vast number of farmers owned a small land holding. . Hence this district was predominantly covered by small farmers.

4.1.10 Irrigation

Velar is the important river flowing in Perambalur district and substantially benefiting agricultural activities. Velar river is originated from Salem district and flows through Perambalur and Cuddalore districts. Apart from river irrigation, rainfed tanks are scattered all over Perambalur district benefiting a considerable extent of cultivable lands. Beside rivers and tanks, the other main source of irrigation is wells. The block wise area under irrigation through different sources is furnished in Table 4.8.

Table 4.8 Source wise area under irrigation in Perambalur district

(in hectares)

S.No	Sources of irrigation	Net area irrigated			
		Perambalur	Alathur	Total	Perambalur district
1.	Surface water	251.35 (2.28)	929.99 (13.02)	1181.34 (6.51)	3167 (10.13)
2.	Ground water	10751.86 (97.72)	6215.45 (86.98)	16967.31 (93.49)	28102 (89.87)
	Total	11003.21 (100.00)	7145.44 (100.00)	18148.65 (100.00)	31269 (100.00)

(Figures in parentheses indicate the percentage to total)

Source: Statistical Hand Book, Assistant Directorate of Economics and Statistics, Perambalur district, 2011

From the Table 4.8., we can see that the net area irrigated from ground water resources for cultivation of crops of the Perambalur and Alathur blocks were 97.72 percent and 86.98 percent of the total net area of the district where the groundwater resources were open wells and tube wells, followed by the surface water. The area irrigated by surface water like tanks, ponds and reservoir of the Perambalur and Alathur blocks, were 2.28 percent and 13.02 percent respectively.

4.1.11 Cropping Pattern

The cropping pattern of Perambaur district is furnished in the Table 4.9. The major crop in the study area is maize which was cultivated in both irrigated and rainfed situations. The percentage of maize to the total area was 33.80 percent followed by cotton covering 28.70 percent area to the total area under cultivation.

Table 4.9 Area under crops in Perambalur district during 2010-11

(in hectares)

S. No	Crops	Irrigated	Rainfed	Total
1.	Maize	138 (0.44)	31970 (49.98)	32108 (33.80)
2.	Cotton	5 (0.02)	27258 (42.61)	27263 (28.70)
3.	Paddy	14245 (45.92)	-	14245 (15.00)
4.	Onion	7795 (25.13)	-	7795 (8.21)
5.	Sugarcane	5317 (17.14)	-	5317 (5.60)
6.	Sorghum	2 (0.01)	3193 (4.99)	3195 (3.36)
7.	Groundnut	965 (3.11)	452 (0.71)	1417 (1.49)
8.	Turmeric	1248 (4.02)	-	1248 (1.31)
9.	Others	1306 (4.21)	1098 (1.72)	2404 (2.53)
	Total	31021 (100.00)	63971 (100.00)	94992 (100.00)

(Figures in parentheses indicate the percentage to total)

Source: Statistical Hand Book, Assistant Directorate of Economics and Statistics, Perambalur district, 2011

Paddy, onion and sugarcane were the next major crops cultivated in the study area which occupy 15.30, 8.21 and 5.60 percent of cultivated area and these crops were grown only under irrigation. Other crops like sorghum, groundnut and turmeric were occupying 3.36 percent, 1.49 percent and 1.31 percent area to the total cropped area both in irrigated and rainfed situations. Only a small portion of the area (2.53 percent) was occupied by other crops.

4.1.12 Infrastructure

4.1.12.a Transport facilities

Perambalur is an important road junction on the Chennai – Madurai National Highways (NH -45). The district has a well-connected road system connecting various important centres in the region. The important categories of roads in Perambalur district are given in Table 4.10.

Table 4.10 Category and Length of Roads in Perambalur districts

(in kms)

S. No.	Category	Total length
1.	National Highways (NH 45)	41.02 (1.08)
2.	State highways	133.20 (3.52)
3.	Major district roads	187.80 (4.96)
4.	Other district roads	1136.39 (30.03)
5.	Panchayat union roads	1508.90 (39.87)
6.	Village panchayat roads	777.40 (20.54)
	Total	**3784.71 (100.00)**

(Figures in parentheses indicate the percentage to total)

Source: www.perambalur.tn.nic.in

From Table 4.10, it can be observed that there is a well developed network of surface transportion. The roads are almost all surfaced roads which are constructed by cement and black top which facilitates the transportation of inputs and commodities on time.

4.1.12.b Agricultural institutions

Since agriculture occupies a major share for the livelihood of the population in Perambalur district in the mode of strengthening agricultural activities in this district, all institutions which are supporting for the agriculture development were institutionalized under NADP project. The details on agricultural institutions available for production and protection for crops are furnished in the Table 4.11.

Table 4.11 Agricultural institutions in Perambalur district

(in nos)

S. No	Particulars	Units	Place
1.	Soil testing lab	1	Perambalur
2.	Mibile testing lab	1	Perambalur
3.	Agri clinic centers	4	a. Kurumbalur b. Irur c. Puduvettakudi d. Poolambadi
4.	Automatic weather stations	4	a. Kalarampatti b. Padalur c. Kunnam d. Krishnapuram
5.	Seed processing unit	2	a. Poolampadi b. Vengalam
6.	Bio inputs production centers	4	a. Perambalur b. Veppanthattai c. Veppur d. Alathur
7.	Vermin-compost production unit	20	a. Perambalur – 5 e. Veppanthattai - 5 f. Veppur – 5 b. Alathur – 5
8.	Sugar factories	2	a. Eraiyur b. Udumblam

Source: www.perambalur.tn.nic.in

These facilities provide better opportunities to receive the timely support towards decision making in solving the problems of crop production activities.

4.1.12.c Cooperative societies

The **c**ooperative sector in the Perambalur district is well developed especially in the rural banking, public distribution system, handlooms, housing etc. There are 59 cooperative societies of different types functioning under the control of the regional joint registrar of cooperative societies in the district. The category wise details of the societies are given in the Table 4.12.

Table 4.12 Cooperative society particulars in Perambalur district

(in nos)

S. No	Type of the societies	Units
1.	Primary Agricultural Cooperative Bank	53
2.	Primary Agricultural and Rural Development Bank	1
3.	Cooperative Marketing Society	1
4.	Cooperative stores	2
5.	Cooperative union	1
6.	Cooperative wholesale store	1
	Total	59

Source: www.perambalur.tn.nic.in

4.1.12.d Storage facilities

The detail of the storage facilities are furnished in Table 4.13.

Table 4.13 Storage structures in Perambalur district

(in nos)

S. No	Storage structures	Units	Places
1.	Agricultural main godowns	4	a. Perambalur b. Veppanthattai c. Veppur d. Alathur
2.	Agricultural sub godowns	3	a. Perambalur b. Elambalur c. Alathur
3.	Panchayat union godowns	4	a. Perambalur b. Veppanthattai c. Veppur d. Alathur
4.	Civil supply godowns	3	a. Perambalur b. Kunnam c. Veppanthattai
5.	Regulated market	1	a. Perambalur
6.	Cold storage unit	2	a. Thuraimangalam b. Chettikulam

Source: www.perambalur.tn.nic.in

The cold storage unit of Chettikulam was constructed with a storage quantity of a 0.80 hectare area, and the beneficiaries are onion farmers from 33 villages around Chettikulam Panchayat in Alathur block of Perambalur district. The regulated market in Perambalur is also used for storage of commodities like cotton and groundnut.

4.1.12.e Financial institutions

In Perambalur district, the cooperative sector has a good network especially in the rural banking, dairying, handlooms, housing etc. There are 115 primary agricultural cooperative credit societies, 55 nationalized banks functioning in the district. The details of financial institutions of Perambalur district are furnished in Table 4.14.

Table 4.14 Financial institutions functioning in Perambalur district

(in nos)

S. No	Banks	Units
1.	Indian Overseas Bank branches	14
2.	Canara Bank branches	13
3.	State Bank of India branches	13
4.	Bank of India branches	5
5.	Indian Bank branches	5
6.	Union Bank of India	4
7.	Punjab National Bank branches	1
8.	Primary Agricultural Cooperative Credit Societies	115
	Total	**170**

Source: www.perambalur.tn.nic.in

4.2 Tiruchirappalli

Tiruchirappalli District is located along the Kaveri River in Tamil Nadu, India. The main town in Tiruchirappalli District is the city of Tiruchirappalli, also known as Trichy. During the British Raj, Tiruchirappalli was known as Trichinopoly, and was a district of the Madras Presidency; it was renamed upon India's declaration of independence in 1947. The city is known for its educational institutions, industries, and temples. It is shortly called as "Tiruchi" or "Trichy". Trichy is the district headquarters of the district of Tiruchirappalli and is known as a tourist attraction. The city is a thriving commercial centre in Tamil Nadu and is famous for artificial diamonds, cigars, handloom cloth, glass bangles and wooden and clay toys.

4.2.1 Geography

Tiruchirappalli district lies at the **heart of Tamil Nadu**. The district has an area of 4,404 square kilometers. It is bounded in the north by Salem district, in the northwest by Namakkal district, in the northeast by Perambalur district and Ariyalur district, in the east by Thanjavur District, in the southeast by Pudukkottai district, in the south by Madurai district and Sivagangai district, in the southwest by Dindigul district and, in the west by Karur district. It lies between $10^0$10’ and $11^0$20’ of the Northern latitudes and $77^0$45’ and $78^0$50’ of Eastern longitudes in the central part of Tamil Nadu. The general slope of the district is towards east. The average elevation is 88 metres (289 feet) above MSL (Mean Sea Level). Tiruchirappalli district comes under three agro climatic zones viz., Sub zone II North western zone, Sub zone IV Cauvery Delta zone and Sub zone V Southern zone. Tiruchirappalli District has a Geographical area of 4,40,383 hectares of which the net area cropped is 1,85,193 hectares. Out of which about 102799 Ha are irrigated and about 82394 hectares are rainfed. The River Cauvery irrigates about 51,000 Ha. It is one of the districts in Delta region known next to Thanjavur for its rice production.

4.2.2 Administrative System

The details of the administrative set up of Tiruchirappalli district are shown in Table 4.15. Tiruchirappalli district has three revenue divisions *viz.* ,Musiri, Lalgudi and Tiruchirappalli. The district for administrative purpose has been divided into eight taluks which is further sub-divided into 14 blocks. The district comprises 408 village panchayats and 1590 villages.

Table 4.15 Administrative setup in Tiruchirappalli district

S. No	Revenue Divisions	Taluks	Blocks
1.	Musiri	Thuraiyur	1. Thuraiyur 2. Uppilipuram
		Musiri	3. Musiri 4. Tattayyangarpettai
		Thottiyam	5. Thottiyam
2.	Lalgudi	Manachanallur	6. Manachanallur
		Lalgudi	7. Lalgudi 8. Pullambadi
3.	Tiruchirappalli	Tiruchirappalli	9. Thiruverumbur
		Srirangam	10. Manikandam 11. Andanallur
		Manapparai	12. Vaiyampatti 13. Manapparai 14. Marungapuri

4.2.3 Demographic Pattern

The Table 4.16 presents the demographic details and distribution of working population in the district. Tiruchirappalli had a population of 2,713,858 of which male and female were 1,347,863 and 1,365,995 respectively. The population had increased by 12.22 percent when compared to the population in the 2001 census, whereas the increase was 10.10 percent in 2001 when compared to 1991 census. The initial provisional data suggest a density of 602 in 2011 compared to 536 of 2001. The average decadal growth rate of population was 21.0 percent between 1951 and 1991. Among the taluks, the maximum population was concentrated in Tiruchirappalli taluk, which accounted for 45 percent to the total population of the district.

Table 4.16 Demographic details of Tiruchirappalli district during 2010-11

(in numbers)

S. No	Description	Tiruchirappalli	Literates
1.	Male	1,347,863 (49.67)	1,096,125 (53.32)
2.	Female	1,365,995 (50.33)	959,617 (46.68)
	Total	**2,713,858 (100.00)**	**2,055,742 (100.00)**

(Figures in parentheses indicate the percentage to total)

Source: www.census.tn.nic.in

4.2.4 Occupational pattern

The details of the distribution of working population in the study area are important to indicate the economic status of the people in the area.

Table 4.17 Occupational pattern of Tiruchirappalli district (2010-11)

(in lakhs)

S. No	Description	Tiruchirappalli	Tamil Nadu
1.	Cultivators	2.17 (8.01)	55.35 (7.67)
2.	Agricultural labourers	3.35 (12.36)	70.24 (9.74)
3.	Workers in household industry	0.41 (1.51)	14.53 (2.01)
4.	Other workers	13.97 (51.55)	135.14 (18.73)
5.	Marginal workers	1.36 (5.02)	46.98 (6.51)
6.	Non-workers	5.84 (21.55)	399.12 (55.33)
	Total	**27.10** **(100.00)**	**721.36** **(100.00)**

(Figures in parentheses indicate the percentage to total)

Source: Statistical Hand Book, Assistant Directorate of Economics and Statistics, Tiruchirappalli district, 2011

The details of the occupational pattern of the Tiruchirappalli district are provided in the Table 4.17. where the population is categorized by broad industrial workers levels.

4.2.5 Climate

a) Rainfall

Tiruchirappalli district has a long spell of hot climate with a short spell of rainy season and winter. Table 4.18 depicts the season-wise rainfall statistics during 2010-11 in Tiruchirappalli district. The district received the highest rainfall of 55 percent during North East monsoon followed by 34 percent during south West monsoon and least through winter precipitation.

Table 4.18 Season-wise Rainfall statistics during 2010-11

(in mm)

S. No	Particulars	Actual	Normal
1.	South West Monson	313.8 (33.93)	295.1 (36.28)
2.	North East Monsoon	508.2 (54.95)	385.6 (47.41)
3.	Hot weather season	97.7 (10.56)	109.9 (13.51)
4.	Winter	5.1 (0.55)	22.7 (2.79)
	Total (Annual rainfall)	**924.8 (100.00)**	**813.3 (100.00)**

(Figures in parentheses indicate the percentage to total)

Source: Statistical Hand Book, Assistant Directorate of Economics and Statistics, Tiruchirappalli district, 2011

b) Temperature

In Tiruchirappalli district, the variation of temperature throughout the year exhibits hot and dry climate with high temperature and low degree of humidity. Temperature is low during the month of January with average mean daily temperature of 28^0C. The maximum daily temperature recorded during the hot season in the month of May was 42^0C.

4.2.6 Soil

In Tiruchirappalli district, a majority of the area is under red sandy soil and this soil type covers 18 percent of the total area of the district. Black soil is distributed along the river Cauvery and ayacuts near big tanks. This soil type covers 14 percent of the total area in the district. The other soil types like clay, red ferruginous etc., occupy the remaining extent of the land cover of the district. Table 4.19 depicts the type of soils in Tiruchirappalli district during 2010-11.

Table 4.19 Soil type of Perambalur district (2010-11)

(In Hectares)

S. No	Type of soil	Area covered
1.	Deep black soil	141,945
2.	Deep red soil	74,154
3.	Moderately deep black soil	47,012
4.	Moderately deep red soil	110,216
5.	Shallow black soil	25,437
6.	Shallow red soil	96,608

Source: Statistical Hand Book, Assistant Directorate of Economics and Statistics, Tiruchirappalli district, 2011

4.2.7 Land Utilization Pattern

The land utilization pattern gives a picture on how the total area is in different categories of uses like area under forest, agricultural uses, non agricultural uses and the area under different classification of waste land. The block-wise land use pattern of Tiruchirappalli district is provided in Table 4.20.

Table 4.20 Block-wise Land use pattern of Perambalur district (2010-11)

(in hectares)

S. No.	Particulars	Trichy	Srirangam	Manapparai	Musiri	Thottiyam	Thuraiyur	Manachanallur	Lalgudi
1.	Forests	234 (0.69)	45 (0.13)	8312 (8.39)	1660 (2.50)	77 (0.28)	23309 (28.83)	1555 (4.19)	1054 (1.77)
2.	Barren and uncultivable lands	1134 (3.34)	673 (1.88)	1424 (1.44)	2468 (3.72)	193 (0.69)	7482 (9.26)	811 (2.18)	1547 (2.60)
3.	Land put to non-agricultural uses	13059 (38.42)	8841 (24.69)	14400 (14.54)	10168 (15.34)	6627 (23.84)	4762 (5.89)	5550 (14.94)	10902 (18.32)
4.	Cultivable wastes	1850 (5.44)	1571 (4.39)	1559 (1.57)	3295 (4.97)	295 (1.06)	1348 (1.67)	1377 (3.71)	1465 (2.46)
5.	Permanent pastures and other grazing lands	54 (0.16)	19 (0.05)	210 (0.21)	147 (0.22)	80 (0.29)	2285 (2.83)	1182 (3.18)	1263 (2.12)
6.	Land under misc.tree crops not included in net sown area	1174 (3.45)	230 (0.64)	385 (0.39)	248 (0.37)	106 (0.38)	3007 (3.72)	351 (0.94)	620 (1.04)
7.	Current fallows	926 (2.72)	2376 (6.63)	18773 (18.96)	7422 (11.20)	4430 (15.93)	2933 (3.63)	4639 (12.49)	430 (0.72)
8.	Other fallows	5997 (17.64)	7472 (20.86)	16572 (16.74)	13517 (20.40)	972 (3.50)	3990 (4.94)	5181 (13.95)	9152 (15.38)
9.	Net sown area	9560 (28.13)	14588 (40.73)	37385 (37.75)	27344 (41.26)	15022 (54.03)	31726 (39.24)	16503 (44.42)	33065 (55.57)
10.	Total geographical area	33988 (100.00)	35815 (100.00)	99020 (100.00)	66269 (100.00)	27802 (100.00)	80842 (100.00)	37149 (100.00)	59498 (100.00)

(Figures in parentheses indicate the percentage to total)

Source : Statistical Hand Book, Assistant Directorate of Economics and Statistics, Tiruchirappalli district, 2011

4.2.8 Operational Land Holding

The distribution of land holdings among various farmers in the district in general indicates much variation. It is common that a large proportion of land area is owned by a few people and a small portion is owned by a large number of people. Table 4.21 provides information on different categories of farmers in the district and the extent of land area possessed by them.

Table 4.21 Operational land holdings in Tiruchirappalli district

(in hectares)

S. No.	Size of landholding (ha)	Type	Number	Area (ha)
1.	Below 1.0	Marginal	210687 (73.23)	85664 (34.19)
2.	1.0 – 2.0	Small	49213 (17.11)	68096 (27.18)
3.	2.1 – 4.0	Semi medium	21780 (7.57)	58500 (23.35)
4.	4.1 – 10.0	Medium	5528 (1.92)	30374 (12.12)
5.	Above 10.0	large	484 (0.17)	7909 (3.16)
	Total		**287692 (100.00)**	**250543 (100.00)**

(Figures in parentheses indicate the percentage to total)

Source: Statistical Hand Book, Assistant Directorate of Economics and Statistics, Tiruchirappalli district, 2011

4.2.9 Irrigation

The major irrigation source in Tiruchirappalli district is canal irrigation that is mostly available in south west monsoon. The canal water stored in separate tanks is being used after the south west monsoon. Most of the small farmers rely upon canal irrigation alone. The details of sources of irrigation In Tiruchirappalli district during 2010-11 are presented in Table 4.22.

Table 4.22 Source wise area under irrigation in Tiruchirappalli district

(in hectares)

S. No	Sources of irrigation	Net area irrigated	Gross area irrigated
1.	Major rivers – Canals (Delta)	51012 (41.01)	60940 (42.50)
2.	Small rivers – Canals	3025 (2.43)	3883 (2.71)
3.	Lakes and tanks	20422 (16.42)	21144 (14.75)
4.	Open wells	45013 (36.19)	51668 (36.03)
5.	Tube wells	4295 (3.45)	4891 (3.41)
6.	Bore wells	102 (0.08)	117 (0.08)
7.	Filter points	511 (0.41)	746 (0.52)
	Total	**124380 (100.00)**	**143389 (100.00)**

(Figures in parentheses indicate the percentage to total)

Source: Statistical Hand Book, Assistant Directorate of Economics and Statistics, Tiruchirappalli district, 2011

4.2.10 Cropping Pattern

The cropping pattern of Tiruchirappalli district is furnished in Table 4.23. In the district, around 44 percent of the total area is under agricultural use. Paddy is the important staple crop among all the cereals and it is cultivated more during Samba season mainly due to the availability of canal irrigation in Samba season followed by millets and sugarcane. Around 41.52 percent area is under paddy cultivation. Tiruchirappalli is one of the major contributors to paddy production in the district. Millets occupied the second largest area leaving behind all other crops. The area of cotton is more or less equivalent to the area of pulses. Among the entire oilseed crop, groundnut is the main crop cultivated in 7.53 percent of the total area.

Table 4.23 Area under crops in Tiruchirappalli district during 2010-11

(in hectares)

S. No	Crops	Irrigated	Rainfed	Total
1.	Paddy	72530 (62.97)	-	72530 (41.52)
2.	Millets	3940 (3.42)	30412 (51.19)	34352 (19.66)
3.	Pulses	260 (0.23)	10520 (17.71)	10780 (6.17)
4.	Cotton	414 (0.36)	10562 (17.78)	10976 (6.28)
5.	Groundnut	6031 (5.24)	7031 (11.83)	13162 (7.53)
6.	Gingelly	457 (0.40)	135 (0.23)	592 (0.34)
7.	Sunflower	1801 (1.56)	609 (1.02)	2410 (1.38)
8.	Castor	11 (0.01)	146 (0.25)	157 (0.09)
9.	Onion	5589 (4.85)	-	5589 (3.20)
10.	Others	24141 (20.96)	-	24141 (13.82)
	Total	**115174 (100.00)**	**59415 (100.00)**	**174689 (100.00)**

(Figures in parentheses indicate the percentage to total)

Source: Statistical Hand Book, Assistant Directorate of Economics and Statistics, Tiruchirappalli district, 2011

4.2.11 Cooperative societies

The cooperative sector in the Tiruchirappalli district is well developed especially in the rural banking, public distribution system, daring handlooms, housing etc. There are 59 cooperative societies of different types functioning under the control of the regional joint registrar of cooperative societies in the district. The category wise details of the societies are given in the Table 4.24.

Table 4.24 Cooperative society particulars in Tiruchirappalli district

(In Numbers)

S. No	Particulars	Units
1.	Primary Land Development Banks	5
2.	District Central Cooperative Banks	30
3.	Urban Banks	5
4.	Primary Agricultural Credit Societies	141
5.	Housing Cooperative Societies	18
6.	Employees Cooperative Societies	99
7.	Lift Irrigation Societies	1
8.	Weavers Cooperative Societies	30
9.	Industrial Cooperative Societies	12
10.	Khadi and Village Industries Societies	69
11.	Primary Cooperative Stores	18
12.	Cooperative Sugar Mills	-
13.	Cooperative marketing societies	5
14.	Other Cooperative societies	135

Source: www.try.tn.nic.in

CHAPTER V

RESULTS AND DISCUSSION

The primary data collected with respect to the stated objectives of the study were analyzed and the results are presented and discussed under the following sections:

5.1 Pesticide consumption of India and Tamil Nadu

5.2 General characteristics of the sample households

5.3 Awareness and adoption level of Integrated Pest Management (IPM) in onion

5.4. Benefit cost analysis of onion cultivators

5.5. Determinants of adoption of Integrated Pest Management (IPM) in onion

5.6. Economic impact of Integrated Pest Management (IPM) in onion

5.7. Joint Economic benefits of IPM to producers and consumers

5.1 Pesticide Consumption of India and Tamil Nadu

According to the World Health Organisation, one million human pesticide poisoning cases are reported all over the world annually with one-third of them occurring in farm workers. This shows non-judicious use of pesticides, exposure to pesticides, and poor awareness among farmers. India is the second largest manufacturer of pesticides in Asia after China. In India, pesticide usage is high in Punjab, Haryana, Andhra Pradesh and Tamil Nadu where commercial crops are grown. The continuous use of pesticides has led to the development of resistance and resurgence in insect pests. Vegetables and fruits, occupy only three percent of total cropped area, but receive a high quantity of pesticides with 13 percent of the total amount applied in the country (Nigam and Murthy, 2000). The average amount of pesticides applied is estimated at 5.13, 2.77, 4.64 and 3.71 kg a.i/ha in chillies, cauliflower, brinjal and okra crops respectively. To know the intensity of the pesticide use the pesticide consumption of India and Tamil Nadu was analysed. The results indicated that the overall growth rate of pesticide consumption for the period from 1989-90 to 2008-09 in the state was -3.47 percent and - 5.43 percent respectively (Table 5.1.).

Table 5.1 Pesticide consumption in India and Tamil Nadu (MT)*

Year	India	Tamil Nadu
1989-90	71894	10000
1990-91	75033	7500
1991-92	72133	3500
1992-93	70794	5500
1993-94	63651	5177
1994-95	61357	3394
1995-96	61260	2080
CV (1989-1996)		43.33
1996-97	56114	1851
1997-98	52239	1809
1998-99	49157	1730
1999-00	46195	1685
2000-01	43584	1668
2001-02	47020	1576
2002-03	48350	3346
2003-04	41020	1434
2004-05	40672	2466
2005-06	39773	2211
2006-07	41515	2048
2007-08	43630	3940
2008-09	43860	2317
CV (1996-2009)		32.71
CGR (%)	-3.47	-5.43
CV (1989-2009)		68.824

* - Technical grade

Source: www. Indiastat.com

5.2 General Characteristics of the Sample Farmers

A brief description of the characteristics of the sample farmers provides the setting for discussion. Therefore, the demographic features, occupational status, land holding pattern and experience in farming as well as in onion cultivation of the respondents are discussed below.

5.2.1 Size and Distribution of Land Holdings of the Sample Farmers

Sample households were classified into two categories: IPM adopters and non-IPM farmers. The sample respondents were stratified into marginal (<1ha), small (1-2 ha), medium (2-4ha), semi-medium (4-10ha), and large (>10 ha) farms based on size of land holdings. The farm size distribution of the sample respondents in the study area is presented in Table 5.2. There was not much difference in land holdings among the two categories of farmers. The majority of sample respondents were small and medium size farmers. Average size of the land holding varied between 0.82 ha and 12.5 ha for IPM adopters and it was between 0.75 ha and 4.2 ha for non-IPM adopters.

Table 5.2 Size and distribution of land holdings of the sample farmers

Categories	IPM	Non-IPM	Total
Marginal (< 1 ha)	7 (13.21)	34 (16.11)	41 (15.53)
Average size of holding (ha)	0.82	0.75	0.76
Small (1-2 ha)	24 (45.28)	101 (47.87)	125 (47.35)
Average size of holding (ha)	1.2	1.4	1.25
Medium (2-4 ha)	19 (35.85)	72 (34.12)	91 (34.47)
Average size of holding (ha)	3.2	2.9	3.1
Semi-Medium (4-10 ha)	2 (3.77)	4 (1.90)	6 (2.27)
Average size of holding (ha)	4.3	4.2	4.2
Large farmer (>10 ha)	1 (1.89)	-	1 (0.38)
Average size of holding (ha)	12.5	-	12.5
Total	**53 (100)**	**211 (100)**	**264 (100)**

(Figures in the parentheses indicate percentages to the total)

5.2.2 Age Distribution

Age of the farmers influence their production decisions. Also, decisions directly relate to their experience in farming. Acceptance of new technologies is positively associated with the age of the farmers. Age was found to positively influence adoption of sorghum in Burkina Faso (Adesiina and Baidu-Forson, 1995), IPM on peanuts in Georgia (McNamara *et al*, 1991), and chemical control of rice stink bug in Texas (Harper *et al*, 1990). For the present study, the age distribution of sample farmers is given in the Table 5.3. Among the 53 IPM farmers, 15 percent were young (30 years old), 75 percent were middle aged (between 30-50 years) and 10 percent were above 50 years old. Among the 211 non IPM farmers, 11 percent were young (30 years old), 83 percent middle aged (between 30-50 years) and 6 percent were above 50 years old.

5.2.3 Farming Experience

Farming experience influences the farming efficiency and adoption of a new innovation. Years of farming experience is either unrelated (Islam and Halim 1976) or positively associated with adoption (Mangahas 1970). Wang (1967) reports that the relation between adoption of improved practices and farming experience is indeterminate. Experience of the sample farmers was grouped in to three categories such as less than 15 years, 15-25 years and more than 25 years. The details are provided in Table 5.3. Among the 53 IPM farmers, 13 percent of the farmers had up to 15 years of farming experience, 79 percent had between 15 and 25 years and 8 percent had above 25 years of farming experience. Among the 211 non IPM farmers, 14 percent had up to 15 years of farming experience, 78 percent had between 15 and 25 years, and 8 percent had above 25 years of farming experience.

5.2.4 Educational Status

Education has a significant bearing on the levels of adoption of improved technologies (Adeogun *et al*., 2008). About 83 percent of the IPM adopters had more than primary level of education. More than 60 percent of the non IPM farmers had only primary level of education and 14 percent of the non IPM farmers were illiterate.

5.2.5 Family Size

Size of the family and its composition determine the availability of family labour for farm operations and the consumption expenditure. Flinn *et al.,* (1980) found no significant impact of family size and Yim (1978) found no significant impact of family size on adoption of a new technology. Average size of the family is reported in Table 5.3.

Table 5.3 General characteristics of the sample households

Particulars		**IPM**	**Non-IPM**	**Total**
Age(years)	Up to 30	8 (15.09)	23 (10.90)	31 (11.74)
	30-40	16 (30.19)	74 (35.07)	90 (34.09)
	40-50	24 (45.28)	102 (48.34)	126 (47.73)
	More than 50	5 (9.43)	12 (5.69)	17 (6.44)
Experience (years)	Up to15	7 (13.21)	29 (13.74)	36 (13.64)
	15 to 25	42 (79.25)	165 (78.20)	207 (78.41)
	Above25	4 (7.55)	17 (8.06)	21 (7.95)
Literacy Level	Illiterate	2 (3.77)	30 (14.22)	32 (12.12)
	Primary level	7 (13.21)	130 (61.61)	137 (51.89)
	Secondary level	29 (54.72)	45 (21.33)	74 (28.03)
	Higher secondary level	15 (28.30)	6 (2.84)	21 (7.95)
	Degree	-	-	-
Family size(No)	Below 3	7 (13.21)	27 (12.80)	34 (12.88)
	3 to 4	42 (79.25)	160 (75.83)	202 (76.52)
	Above 4	4 (7.55)	24 (11.37)	28 (10.61)

(Figures in the parentheses indicate percentages to the total)

5.2.6 Income of the Sample Households

The total income realized per annum through on-farm, off-farm and non-farm employment by the sample farmers is given in the Table 5.4. The main source of income for all the categories of sample farmers came through the onion cultivation. Share of the onion to the total income was about 78.26 percent and 75.00 percent in case of IPM adopters and non IPM farmers respectively. In the study area, since onion was the main crop the share of income from other crops constitute was small. It ranges from 10 to 13 percent of the total income. The share of income from livestock also constitutes a small (10-12.5%) proportion of total income. None of the farmers were employed in the non-farm sector.

Table 5.4 Average annual income of the farm family

(in Rs./Household)

Income source	IPM	Non-IPM
Onion	90,000 (78.26)	60,000 (75.00)
Other crops	15,000 (13.04)	10,000 (12.50)
Livestock	10,000 (8.70)	10,000 (12.50)
Total	115,000 (100.00)	80,000 (100.00)

(Figures in the parentheses indicate percentages to the total)

5.2.7 Cropping Pattern in Survey Area

Onion was a common vegetable in all of the cropping sequences practiced by the growers in the surveyed area (Table 5.5). Details of cropping pattern was portrayed in Table 5.6.

Table 5.5 Cropping sequence in survey area

Cropping sequence	No. of farmers
Onion – Onion – Groundnut	213 (80.68)
Onion – Onion – Sorghum	51 (19.32)

(Figures in the parentheses indicate percentages to the total)

Table 5.6 Cropping pattern in survey area

S. No.	Sowing Season	Crops	Area in acres (in ha)		
			IPM	Non – IPM	Total
1.	July - Aug	Onion	57.14	141.71	198.85
2.	Oct - Nov	Onion	96.21	312.67	408.88
3.	Aug - Sep	Groundnut	60.51	216.12	276.63
4.	Jan - Feb	Sorghum	105.67	326.71	432.38

5.2.8 Insect Pests and their Management

Onion was damaged by series of pests and diseases and to control these pests and diseases various kinds of pesticides were used by the farmers.

Table 5.7 Pesticides used by the respondents against various pests

Name of the pesticide	Pest/disease
Profenophos	Sucking pest
Chlorpyriphos	Soil borne diseases
Triazophos	Fungal disease
Antrocol	Fungal disease
Bavistin	Fungal disease
Hostathion	White fly
Prophex	Fungal disease
Metazid	Sucking pest
Dithane	Fungal disease
Azephate	White fly
Polycure	Purple blotch

Quite often due to unfavourable weather conditions, diseases such as purple blotch, stemphylium blight, colletotrichum blight and insect pest like thrips, cutworms were attacking the standing onion crop and cause a major damage in production and quality. Details of pesticides used by the IPM farmers against various pests and diseases are given in Table 5.7.

5.2.9 Pattern of Pesticide Use

In the survey area, onion was cultivated in seasons, one during July- September and the other one during October – December. The cultivation of the crop was chosen based on the availability of water. Among the respondents 25% of the farmers grew the crop in both seasons and 75% of the sample farmers grew only in second season due to unavailability of water. The frequency of application of pesticides also differs among the seasons. Farmers used pesticides frequently since pest infestation was relatively high in onion. The frequency of pesticide use in both kharif and rabi season is furnished in the Table 5.8. It was higher in Oct – Dec (9 sprays) compared to the July – Sep (2 sprays).

Table 5.8 Frequency of pesticide use in controlling various pests and diseases of Onion

Season	Average number of pesticides application
July – Sep	2
Oct - Dec	9

5.2.10 Kinds of Pesticides

The growers used various pesticides of different groups in different formulations. Farmers used pesticides frequently since pest infestation was relatively high in onion. Among them Curacron (Profenophos 50% EC) was very popular and it was used by all the farmers. In the study area, the onion cultivators used different combinations of pesticides in each spray. Usually they combine a pesticide and a fungicide; some of the farmers also used micro nutrient mixtures in each spray. The details of kinds of pesticides used by the onion cultivators are presented in Table 5.9.

Table 5.9 Pesticides used by the onion farmers

Name of the pesticide	Quantity used (ml/ha)	Total cost (Rs)
Profenophos	750	475
Bumper (Propiconazole)	625	700
Mirodor (Azoxystrobin)	125	1000
Triazophos	1250	850
Acephate	750	2000
Chlorpyripos+ Cypermethrin	1250	825
Quinalphos (Ecolex)	1250	450
Monochrotophos	1250	500
Ridomil (Mancozeb+Mefanoxam)	2500	425
Carbendazim	1875	1000
Dithane M-45 (Mancozeb)	2000	1000
Propiconazole	650	500
Azoxystrobin	125	1000
Propineb	250g	200
Zineb	625g	300
Imidacloprid	650	1000
Fipronil	50g	100

5.2.11 Choice of Pesticide

Initially the farmers identify the pest and they assess the population level. Each pest and disease has a local name. Then they choose the pesticide by getting the advice either from the extension agents or the neighbors or the relatives or the pesticide dealers. The source of information differs among the IPM and non IPM farmers. Although farmers were able to get information for use of pesticides from various sources, pesticide sales agents were the main source of information regarding the use of chemicals to control sucking pests and fungal diseases for the non-IPM farmers. Sources of technical information for the control of various pests and diseases are furnished in the Table 5.10. Nearly 90% of the non-IPM farmers relied on pesticide sales agents and also neighbors and relatives were valued sources of information but extension agents and radio broadcast were not. But for the IPM adopters, extension agents are the main source of information and they also got some advice from the pesticide sales agent, neighbours and the relatives.

Table 5.10 Sources of technical information for the control of various pest and diseases

Source of information	IPM	Non IPM
Pesticide sales agent	17 (33.12)	190 (90.15)
Neighbor	18 (33.96)	179 (84.85)
Relatives	18 (33.96)	179 (84.85)
Extension workers	42 (79.25)	0
Radio broadcast	27 (50.94)	0
Total	53	211

(Figures in parentheses indicate the percentages to the total farmers at each level)

5.2.12 Farmers' Awareness on Pesticide Use and Related Issues

Most of the farmers were well aware of the negative impact of pesticides on environment and human health. Farmers' awareness level about the harmful effect of pesticide use is provided in the Table 5.11. Nearly 95% of the IPM farmers were aware of the harmful effect of pesticides on human health, environment and soil health, 85% of the non IPM respondents were aware of the ill effect of pesticides on environment and nearly 80% of the non IPM farmers were aware of the harmful effect of pesticides on human health and soil health.

Table 5.11 Farmers’ awareness about harmful effect of pesticide use

Issue	IPM	Non IPM
Harmful effect of pesticide on:		
Environment	50 (94.34)	179 (84.85)
Human health	50 (94.34)	168 (79.55)
Soil health	50 (94.34)	172 (81.44)

(Figures in parentheses indicate the percentages to the total farmers at each level)

5.2.13 Safety Measures Followed During and After Pesticide Application

Pesticides are toxic to both pests and humans. However, they need not be hazardous to humans and non-target animal species if suitable precautions were taken. Most pesticides will cause adverse effects if intentionally or accidentally ingested or if they are in contact with the skin for a long time. Pesticide particles may be inhaled with the air while they are being sprayed. An additional risk was the contamination of drinking-water, food or soil. Special precautions must be taken during transport, storage and handling. Spray equipment should be regularly cleaned and maintained to prevent leaks. People who work with pesticides should receive proper training in their safe use.

The World Health Organisation has also instructed that some precautions should be carried out during the pesticide application. It recommends that spray workers should wear overalls or shirts with long sleeves and trousers, a broad-brimmed hat, a turban or other headgear and sturdy shoes or boots. It instructs that the mouth and nose should be covered with a simple device such as a disposable paper mask, a surgical-type disposable or washable mask or any clean piece of cotton. People who mix and pack insecticides in bags must take special precautions. In addition to the protective clothing described above, it was recommended that gloves, an apron and eye protection such as a face shield or goggles be worn. Care should be taken not to touch any part of the body with gloves while handling pesticides. The discharge from the sprayer should be directed away from the body. Leaking equipment should be repaired and the skin should be washed after any accidental contamination. The US Environmental protection agency also recommends that pesticides should be stored away from children's reach. It also suggests that the pesticides can be stored in a locked cabinet or garden shed. Child-proof safety latches also may be installed on cabinets and can be purchased at local hardware stores and other retail outlets.

Table 5.12 Safety measures followed during and after application of pesticides

S.No	Safety Measures	IPM	Non IPM	Total sample
1.	Pesticides measured by measurement jar	53 (100.00)	211 (100.00)	264 (100.0)
2.	Aware of spray nozzle size	16 (30.18)	68 (32.23)	84 (31.81)
3.	Washing hands with soap	53 (100.00)	211 (100.00)	264 (100.00)
4.	Use mask	53 (100.00)	185 (87.68)	238 (90.15)
5.	Use gloves	53 (100.00)	185 (87.68)	238 (90.15)
6.	Wearing long pants, and long-sleeve shirts	53 (100.00)	211 (100.00)	264 (100.00)

(Figures in the parentheses indicate percentages to the total)

The safety measures followed during and after pesticide application by the sample farmers are given in Table 5.12. The tabular analysis showed that the safety measures like washing hands with soap after pesticide application, wearing long pants and long-sleeve shirts were followed by majority of the sample farmers. All the IPM farmers use masks and gloves and nearly 87 per cent of the non IPM farmers use masks and gloves. Only 30 per cent of the sample farmers were aware about the spray nozzle size.

5.3 Awareness and Adoption Levels of IPM Practices in Onion

Adoption is an outcome of a decision to accept a given innovation. Awareness of a need is generally perceived as a first step in the adoption process. As discussed earlier, six IPM packages were recommended by the scientists for onion. Awareness and adoption level of each package was calculated and it is presented in the Table 5.12. Based on Table 5.13, an awareness index (AWI) and an adoption index (ADI) were constructed and it is presented in the Table 5.14.

Table 5.13 Awareness and adoption levels of IPM practices in onion

(n=264)

Particulars	Awareness level	Adoption level
Trichoderma viride	65 (24.62)	46 (17.42)
Pseudomonas fluorescens	59 (22.35)	41 (15.53)
Yellow sticky trap	8 (3.03)	5 (1.89)
VAM	5 (1.89)	5 (1.89)
Neem products	65 (24.62)	38 (14.39)
Pheromone trap	0	0

(Figures in the parentheses indicate percentages to the total)

The results provided in Table 5.13 revealed that overall though awareness was up to 25 percent, the adoption was only up to 18 percent. By IPM component wise, although nearly 25 percent were aware of the important IPM practice *Trichoderma viride,* only 17.42

percent adopted it. In the same way, 22.35 percent were aware of *Pseudomonas fluorescens,* but only 15.53 percent adopted it. Respectively, 3.03 percent and 1.89 percent of the sample onion cultivators were aware of yellow sticky trap and Vesicular Arbuscular Mycorrhiza (VAM) but only 1.89 percent adopted those practices. In the same way 24.62 percent were aware of neem products and 14.39 percent adopted it. None of them were aware of pheromone traps and hence they were not adopted.

The indices for awareness and adoption are given in Table 5.14.

Table 5.14 Awareness and adoption Index for IPM in onion

Particulars	Index
Awareness index (AWI)	12.12
Adoption Index (ADI)	8.52

The results indicated that though the awareness index was 12.12, the adoption index was only 8.52, which shows only that 75 percent of the technology generated was adopted in the field.

5.4 Benefit Cost Analysis of Onion Cultivators

Economic evaluation was carried out among the 53 IPM farmers and the 211 non-IPM farmers. The IPM farmers were further classified into five sub groups, based on the usage of the IPM components. The streams of cost incurred and benefits derived for each farmer were calculated. The estimation of the cost of the cultivation for onion was not only used to realize the impact of IPM on onion, it will also be useful to understand the profitability of onion cultivation.

5.4.1 IPM Component and Cost

The IPM farmers adopted six technologies which were recommended by the scientists. The total cost of IPM components for onion was Rs 6405 per ha. The quantity of these IPM components and the total cost for those components are presented Table 5.15.

Table 5.15 Cost incurred per hectare towards each IPM component

IPM component	Unit cost (Rs)	Total cost(Rs)
Trichoderma viride (5g/kg) + 1.25 kg soil treatment	150/kg	1275
Pseudomonas fluorescens (5g/kg) + 1.25 kg soil treatment	150/kg	1275
VAM	30/kg	375
Yellow/blue sticky traps	30/trap	360
Pheromone trap	30/trap +15/tablet	720
Neem products	1200/l	2400
Total cost		**6405**

5.4.2 IPM Component and Cost for the IPM Farmers

As discussed earlier, it was found that among the 264 sample farmers there were 53 IPM adopters. Among the 53 IPM adopters, based on the IPM components used, the farmers were categorized into five groups and the remaining 211 non-IPM farmers were considered as the sixth group (non-IPM). Some of the groups were combined to form a single group based on the suggestion of experts. The fifth group consists of four subgroups and the average cost of those groups was measured. The total costs of IPM components for onion for different groups were calculated and furnished in the Table 5.16.

Table 5.16 Cost incurred per hectare towards each IPM component – IPM

Group	IPM components	No of Farmers	Total cost(Rs)
I	*Trichoderma Viride, Pseudomonas fluorescens,* Neem products	24	4950
II	*Trichoderma Viride, Pseudomonas fluorescens,* Neem products, Yellow sticky trap (4)	7	5320
	Trichoderma Viride, Pseudomonas fluorescens, Neem products, VAM (3)		
III	*Trichoderma Viride, Pseudomonas fluorescens*	6	2550
IV	*Trichoderma Viride,* VAM, Neem products (3)	9	3860
	Trichoderma Viride, Neem products (6)		
V	*Without Trichoderma Viride*	7	3460
	1. *Pseudomonas fluorescens,* Neem products, Yellow sticky trap (1)		
	2. *Pseudomonas fluorescens,* Neem products (3)		
	3. VAM, Neem products (1)		
	4. *Pseudomonas fluorescens, VAM,* Neem products (1)		
VI	*Non-IPM Farmers*	211	-

5.4.3 Onion Cultivation in Sample Farms

Onion (*Allium cepa L.)* is a cool season crop, hardy to frost but less sensitive to heat. It is usually cultivated during April-May and Oct-Nov. But in the study area it is cultivated two or three times in a year. Onion cultivation is a seasonal choice of occupation for farmers as Oct-Nov provides a favourable climate for onions.

Since water is the major constraint, all the farmers prefer to cultivate in the rabi season (Oct-Nov). The time of planting has a large impact on the yield and incidence of disease. Even though onion produced in rabi season is subject to heavy incidence of disease, the farmers felt that onion produced in the season of Oct-Nov fetched a higher yield.

Although onion can be grown in nearly all types of soils from sandy loam to heavy loam, clays were not satisfactory unless well supplied with humus to lighten them. The soils pH should preferably be 6.0-7.0. In the study area, the soils pH is in range of 6.6-7.2. Hence the study area is well suited for onion cultivation.

Though there were ample varieties available of small onion, the cultivators in the study area prefer to cultivate Co 4. The farmers feel that the light pink bulbs of Co 4 variety were attractive, bold in size and have consumer appeal. The variety was released in 1982 by Tamil Nadu Agricultural University (TNAU), Coimbatore. Normally it yields about 19 tonnes per hectare and the bulbs per plant vary from 8 to 13.

Initially the main field was thoroughly worked to remove all stubble and stones and was brought to a fine tilth by repeated ploughing. The ploughing was done by tractor-drawn implements and some of the sample farmers also used bullocks. Some farmers used farmyard manure with the final ploughing. After ploughing, ridges and furrows were formed with the maximum of 15 male labourers per hectare and after that the field was sprayed with herbicide. After the formation of ridges and furrows the treated bulbs (the farmers who were using bio-control agents) were planted with a maximum of 50 female labourers, and the field was irrigated immediately after planting, the young sprouts showed in 2-3 days.

The sample onion farmers placed 100-150 kg of DAP, 50-150 kg of potash, 150- 400 kg of groundnut cake and 50 – 150 kg of urea mixture at planting and 50kg of nitrogen was given 30 days after sowing. All three categories of farmers used the same level of fertilizers. On average, they used 130:120:80 NPK for the onion cultivation. Some of the farmers used a larger quantity of groundnut oil cake and some of them used neem oil cake. It was reported that neem oil cake and groundnut oil cake inhibit the mycelia growth of the pathogen. The oil cakes were well powdered before application for even distribution and quicker decomposition.

The field was regularly irrigated every four days depending on the rainfall and they withheld irrigation ten days before the harvest. After 30 days of sowing, hand weeding was done with a maximum of 60 female labourers per hectare. After that according to the intensity of the weeds, the hand weeding took place.

As discussed earlier, different kinds of pesticides were used to control the pests and diseases and the pests and diseases pose a serious threat during every lull after medium to sharp showers. The crop is severely affected by purple blotch (*Alternaria porri),* basal rot (*Fusarium oxysporum* f. sp. *cepae*) and infested with thrips (*Thrips tabaci),* leaf miner *(Liriomyza sp.)* and cutworm (*Spodoptera litura/ S. exigua*). The sample IPM farmers reported that the bubs that were treated with *Trichoderma viride* and *Pseudomonas fluorescens* have less incidence of root rot and very few were affected by root rot which were pulled out from the field and destroyed. The sample farmers who used yellow sticky traps reported that the incidence of thrips was drastically reduced and they also reported that due to the use of bio control agents the harvested bulbs were bigger in size, the colour was also good and the storage period was also longer. On an average the sample farmers used 2-9 sprays of pesticides and one male labourer and female labourer were required for each spray.

Traditionally, onion bulbs were harvested by hand once they attain maturity. On an average 30-40 female labourers were required to harvest one hectare of onion field. The harvested bulbs were heaped in the farm itself until they were marketed. When the farmers felt that the onion bulbs were ready for market, they packed the bulbs in sacks and transported them to the market by lorry or tractor.

5.4.4 Quantity of Inputs Used in Onion Cultivation

The quantities of inputs used in onion cultivation were analysed in order to study whether there was any difference among the IPM and non-IPM farmers. The results are furnished in Table 5.17. The data showed that the quantity of seed, fertilizer, human power and machine power was not significantly different among the onion cultivators except the plant protection chemicals. Regarding the planting material, on average the onion cultivators used 1500kg of onion bulbs per hectare. Formation of ridges and furrows, irrigation and application of pesticides and fertilizers were done by male labourers. Female labourers plant, weed, harvest and assist in the application of pesticides by mixing the chemicals. On an average 60-64 male labourers and 125-143 female labourers were required per hectare of onion.

Table 5.17 Quantity of inputs used in onion cultivation

S. No	Inputs		IPM farmers	Non-IPM farmers	Overall average
1.	Quantity of planting material (kg/ha)		1500	1500	1500
2.	Labour	Male labourers	63	64	64
		Female labourers	130	143	140
3.	Machine power (hrs/ha)		16.5	17	16.5
4.	Quantity of inorganic fertilizer [(N:P:K)/ha]		130:120:70	140:120:80	130:120:80
5.	Plant protection chemical (l/ha)		4.1	5.6	5.3
6.	Number of irrigations/ha		44	45	45

Machine power was used for the land preparation of both IPM and non-IPM onion. On average 16-17 hours of machine power was required to produce a hectare of onion. Regarding inorganic fertilizer, onion cultivators used on average 130:120:80 ratio of N:P:K to produce a hectare of onion. As mentioned earlier, thrips, leaf miner and cutworms were the common pests and purple blotch and basal rot were the common diseases in the study area. A huge difference exists between the IPM and non-IPM farmers in the usage of plant protection chemicals. Though the frequency of pesticides use is discussed later, the overall application of pesticides give some insight into understanding the usage of pesticides among the sample farmers. The IPM farmers used only 4.1 litres of chemicals for a hectare of onion cultivation. But non IPM farmers used 5.6 litres per hectare and overall the onion cultivators used 5.3 litres of plant protection chemicals for a hectare of onion production. On an average 45 times of irrigation was required for a hectare of onion cultivation.

5.4.5 Cost and Returns of Onion Cultivation

Data on the cost per unit of output or outcome is also presented as part of the impact analysis. Cost of production indicates the expenses incurred per unit of output. The items of cost that go into the cost of production are both fixed costs and variable costs.

Economics of onion production were estimated separately for IPM adopters and the non-IPM farmers. Among the sample farmers, only 25 percent of farmers cultivated onion both in kharif and rabi season, the remaining 75 percent of the farmers cultivated onion only in rabi season. Hence the analysis was completed for the rabi season, but the cost structure revealed that total cost of onion production, yield and net returns were much higher in rabi season compared to that of kharif season for all the categories of onion producers. Barakade (2011) found the same in his study in Satara district of Maharashtra. As discussed earlier, the IPM farmers were disaggregated into five groups and the economics of onion production was estimated for each group separately and the results are presented in the Table 5.18. The streams of cost incurred and benefits derived for each farmer were calculated.

The market price of inputs prevailing at the time of their use was considered in calculating the cost of cultivation. The gross return was calculated on the basis of the average market price of the produce at the time when the produce was sold and the net returns (Rs/ha) were calculated by deducting the cost of cultivation from the gross income.

The economics of onion production among IPM and non IPM farmers indicated that the total cost of cultivation does not differ much. There were some differences in the cost of pesticides, but they were compensated by the IPM components. But there was large difference in terms of yield and net income and the benefit cost ratios (BCR) also differ. The BCR were higher for the IPM cultivators, ranging from 2.10 to 2.27. The BCR was much lower (1.66) for the non-IPM farmers.

Table 5.18 Cost of cultivation for different group of farmers in the study area

(Rs/ha)

Particulars	**Group I**	**Group II**	**Group III**	**Group IV**	**Group V**	**Non-IPM**
Ploughing	9650	9900	9400	9400	9800	11010
Seed material (bulb) and sowing	27060	26820	26940	27060	26700	27300
Weeding cost	7050	7170	7290	7290	7170	7410
Cost of fertilizer	14000	13800	13500	14700	13800	14700
Cost of pest control	13825	13675	13575	13650	14125	20410
IPM component cost	4950	5320	2550	3860	3460	0
Irrigation charges	10000	10000	11000	10000	10000	10500
Harvesting cost	3500	3620	3500	3740	3620	3740
Interest value for variable cost	1576	1580	1536	1570	1552	1663
Depreciation+Interest on fixed capital + Land revenue	750	700	650	700	650	600
Total cost	92361	92585	89941	91970	90877	97333
Yield (t/ha)	13.5	14	13	13.3	12.75	10.8
Gross income (Rs 15/kg)	202500	210000	195000	199500	191250	162000
Net returns	110139	117415	105059	107530	100373	64667
BCR	2.19	2.27	2.17	2.17	2.10	1.66

5.4.6 Input Costs and Returns of Onion Cultivation

Input costs of onion production were estimated for various cultivars and the results are presented in Table 5.19. Major inputs were seeds, fertilizers, human labour, machine power, herbicide and pesticides. Both the categories of onion cultivators, it was found that human power was the major cost. In case of onion IPM cultivators, it accounted for 33.05 percent of the total cost of cultivation. For non IPM farmers, it accounted for 34.07 percent of the total cost of cultivation. Next to the human labour, seed material was the major cost. Nearly 24 percent of the total cost of cultivation was seed material for all the three categories of onion cultivators in the study area. The cost spent on pest control occupied third place. Both the categories of the onion cultivators spent nearly 19 percent of the total cost of cultivation for onion pest control. But the share differed among them. Onion IPM farmers spent nearly 15 percent for the chemicals and 5 percent for the IPM components. Non IPM farmers spent the entire share (18.4 percent) of their cost of pest control on chemicals. Respectively 14.77 percent and 15.10 percent of the total cost of cultivation of onion was spent on fertilizers by the onion IPM and non IPM cultivators. Machine power was small cost share. Nearly both the categories of the farmers spent 7 percent of the total cost of cultivation of onion on machine power. The share of interest on the variable cost, depreciation on the fixed assets, interest rate on fixed capital and land revenue made up nearly 2.5 percent of the total cost of cultivation. On average, the IPM farmers obtained 13.8 tonnes of yield per hectare. The non IPM farmers obtained 10.8 tonnes of onion bulb from a hectare of onion cultivation. The total cost of cultivation of onion was more or less same for all the onion farmers. The IPM and non IPM farmers spent Rs 94,861 and Rs 97,333 respectively to produce a hectare of small onion. Since the total cost of cultivation was nearly the same and the yield differences were large, the gross income and the net returns also differ a lot among the three categories of onion cultivators. Onion IPM farmers received Rs 105,839 as their net revenue and non IPM farmers received Rs 64,667 per hectare of onions.

Table 5.19 Input cost and returns of onion cultivation

(Rs/ha)

Particulars	IPM	Non IPM
Seed material	22500 (23.72)	22500 (23.12)
Human labour	31350 (33.05)	33160 (34.07)
Machine power	6600 (6.96)	6800 (6.99)
Fertilizers	14009 (14.77)	14700 (15.10)
Pesticides	13787 (14.53)	17910 (18.40)
IPM components	4345 (4.58)	-
Interest value and Depreciation value	2270 (2.39)	2263 (2.33)
Total cost	94861 (100.00)	97333 (100.00)
Yield (t/ha)	13.38	10.8
Gross income	200700	162000
Net returns	105839	64667
BCR	2.12	1.66

(Figures in the parentheses denote percentage to the total)

5.4.7 Summary of Output and Returns of Onion Cultivation

The comparison of per hectare total expenditure, yield, revenue, gross margin, per kg cost of production and net returns per kilogram of onions are reported in Table 5.20. To evaluate the significance of the differences in the mean values of these variables, two-group mean-comparison tests were performed between the IPM and non IPM farmers. The results indicated that a significant difference exists between IPM and non IPM onion cultivators on all variables such as total cost of production, yield, gross revenue and net revenue. The Table 5.20 also indicates that the onion IPM farmers spent Rs 7.09 per kilogram of onion produced, while the net returns were Rs 7.91 per kilogram of onion produced. But the non IPM farmers incurred Rs 9.01 in cost for a kilogram of onion produced, while the net returns were Rs 5.99 per kilogram of onion produced.

Table 5.20 Summary of output and returns of onion cultivation

(Cost and returns in Rs/ha)

S. No	Output and Returns	IPM	Non IPM	t-values
1.	Total cost of cultivation	94,861	97,333	-3.69***
2.	Average production tonnes / ha	13.38	10.8	6.23***
3.	Gross returns @ Rs 15/kg	200,700	162,000	5.92***
4.	Net returns	105,839	64,667	5.51***
5.	Cost of production / kg	7.09	9.01	
6.	Net returns/kg	7.91	5.99	

Note: *** denotes statistical significance at the one percent level.

5.4.8 Partial Budgeting

Partial budgeting is a planning and decision-making framework used to compare the costs and benefits of alternatives faced by a farm business. To estimate additional costs and returns from growing one hectare of onion by adopting integrated pest management (IPM) to control the pests and diseases rather using conventional practice for the pest control, partial budgeting was employed. Different types of comparisons were carried out as follow.

1. Comparison between IPM and non IPM onion cultivators
2. Comparison among the groups of IPM cultivators
3. Comparison between the groups of IPM cultivators and non IPM onion cultivators

5.4.8.1 Comparison between IPM and Non IPM Onion Cultivators

Adoption of the components of integrated pest management (IPM) would bring an additional benefit to the farmers of about Rs. 41,179 per hectare compared to non adoption of IPM by decreasing the cost by Rs. 6824. Table 5.21 shows that due to adoption of IPM in onion there was an increase in cost of IPM of Rs. 4345, and a reduction in cost of human labour, machine power, fertilizers and pesticides of Rs. 1810, Rs.200, Rs. 691 and Rs. 4123 respectively. The reduced cost benefited the farmers and resulted in an increased in net gain of Rs. 41,179.

Table 5.21 A comparative economics of production of IPM vs non IPM

(Rs/ha)

Proposed change			
Added Income		**Reduced income**	
	38700		Nil
Reduced cost		**Added cost**	
Human labour	1810		
Machine power	200		
Fertilizers	691		
Pesticides	4123	IPM component	4345
Total	6824		4345
Added Income + Reduced cost	45,524	Reduced income + Added cost	4345
Net change = Rs 41,179			

5.4.8.4 Comparison Among the Groups of IPM Cultivators

To estimate additional costs and returns among the IPM adopters partial budgeting was worked out between the groups of IPM cultivators and non IPM onion cultivators. The results were presented in Tables 5.22, 5.23, 5.24, 5.25 and 5.26 for the groups I to V respectively.

From the tables it can be deciphered that the onion IPM adopters got more net returns than non IPM adopters irrespective of the groups. At the same time they received less net returns than IPM farmers. Among the IPM adopters the farmers belong to Group II who use maximum components of the onion IPM practices (*Trichoderma Viride, Pseudomonas fluorescens,* Neem products, Yellow sticky trap/VAM) received more profit than all other farmers and the interesting result was the farmers who were not using *Trichoderma Viride* (Group V) received less profit compared to other farmers. In the same way, the farmers who were not using Pseudomonas fluorescens also received less net returns compared to other group of farmers. The farmers who used only bio-control agents (*Trichoderma Viride, Pseudomonas fluorescens*) received less yield compared to other farmers who used biocontrol agents along with other components. Hence, from the results it can be inferred that the farmers who used all the components of IPM for onion received more net returns.

Table 5.22 A comparative economics of Group I versus Others

(Rs/ha)

Group	Added income	Reduced cost	Added return	Reduced income	Added cost	Reduced returns	Change in net returns
Group II	0	860	860	7500	590	8090	-7230
Group III	7500	1240	8740	0	3520	3520	5220
Group IV	3000	1180	4180	0	1515	1515	2665
Group V	11250	690	11940	0	2050	2050	9890
Non IPM	40500	9985	50485	0	4950	4950	45535

Table 5.23 A comparative economics of Group II versus Others

(Rs/ha)

Group	Added income	Reduced cost	Added return	Reduced income	Added cost	Reduced returns	Change in net returns
Group I	7500	590	8090	0	860	860	7230
Group III	15000	1240	16240	0	3790	3790	12450
Group IV	10500	1380	11880	0	1985	1985	9895
Group V	18750	450	19200	0	2080	2080	17120
Non IPM	48000	10085	58085	0	5320	5320	52765

Table 5.24 A comparative economics of Group III versus Others

(Rs/ha)

Group	Added income	Reduced cost	Added return	Reduced income	Added cost	Reduced returns	Change in net returns
Group I	0	3520	3520	7500	1240	8740	-5220
Group II	0	3790	3790	15000	1240	16240	-12450
Group IV	0	2945	2945	4500	1000	5500	-2555
Group V	3750	2280	6030	0	1360	1360	4670
Non IPM	33000	10365	43365	0	3050	3050	40315

Table 5.25 A comparative economics of Group IV versus Others

(Rs/ha)

Group	Added income	Reduced cost	Added return	Reduced income	Added cost	Reduced returns	Change in net returns
Group I	0	1515	1515	3000	1180	4180	-2665
Group II	0	1985	1985	10500	1380	11880	-9895
Group III	4500	1000	5500	0	2945	2945	2555
Group V	8250	875	9125	0	1900	1900	7225
Non IPM	37500	9230	46730	0	3860	3860	42870

Table 5.26 A comparative economics of Group V versus Others

(Rs/ha)

Group	Added income	Reduced cost	Added return	Reduced income	Added cost	Reduced returns	Change in net returns
Group I	0	2050	2050	11250	690	11940	-9890
Group II	0	2080	2080	18750	450	19200	-17120
Group III	0	1360	1360	3750	2280	6030	-4670
Group IV	0	1900	1900	8250	875	9125	-7225
Non IPM	29250	9855	39105	0	3460	3460	35645

5.5 Determinants of Adoption of Integrated Pest Management (IPM) in Onion

Probit regression was employed to identify the influential factors determining farmers' decisions to adopt Integrated Pest Management (IPM) in onion. Table 5.27. presents definitions for the variables used in the empirical analysis.

Table 5.27 Description of the variables used in the Probit model

Variables	Type	Description
Dependent variable		
IPM onion adoption	Binary	1 if the farmer adopt the IPM technology
Independent variable		
Age	Continuous	Household Head : Age in years
Age^2	Continuous	Household Head : Age in squared
Education	Binary	1 if the household head attended more than primary school
HS1(0-10)	Continuous	Household size: Age between 0 to 10
HS2 (11-16)	Continuous	Household size: Age between 11 to 16
HS 3 (17-60)	Continuous	Household size: Age between 17 to 60
HS 4 (61-80)	Continuous	Household size: Age between 61 to 80
Total land	Continuous	Total land area owned (in ha)
Pesticide cost	Binary	1 if the choice of pesticide based on the pesticide cost
Extensionage	Binary	1 if the choice of pesticide based on the advice of the extension agent
Pesticide dealer adv	Binary	1 if the choice of pesticide based on the advice of the pesticide dealers
Relative adv	Binary	1 if the choice of pesticide based on the advice of the relatives
Village1	Binary	1 if the household belongs to Irur village
Village2	Binary	1 if the household belongs to Sengattupatti village
Village3	Binary	1 if the household belongs to Chatiramanai village

Table 5.28 Results of Probit estimation for IPM onion adoption

Variable	Coefficient	t
Age(years)	-0.52	-0.94
Age^2	0.04	0.68
Education	1.13	2.67^{***}
HS1(0-10)	0.45	1.47
HS2 (11-16)	0.78	2.32^{**}
HS3 (17-60)	-0.33	-0.92
HS4 (61-80)	-0.07	-0.19
Total land	-0.07	-0.08
Pesticide cost	-0.38	-0.72
Extensionage	2.94	5.66^{***}
Pesticide dealer adv	-1.81	-3.71^{***}
Relative adv	-0.25	-0.48
Village1	-1.18	-1.89^{**}
Village2	-1.42	-1.89^{**}
Constant	15.86	2.93^{***}
Number of observations	264	
Pseudo R^2	0.79	

Note : Significance of t-statistics of mean difference is at the *10%, **5% and ***1% levels.

Table 5.28 provides the results of the probit regression. Level of education was assumed to increase farmers' ability to obtain, process, and use information relevant to the adoption of integrated pest management. Education was therefore expected to increase the probability of adoption of IPM, and in the present study the results showed that education positively and significantly influence the adoption of IPM. Household size was found to be positively correlated to IPM adoption due to increased availability of labour (Bonabana, 2002). Affects on adoption may vary depending on the ages of household members. The household having younger children was more likely to adopt, because they were more concerned about the negative effect of the pesticides. The household members who were 17 years or older will participate in on-farm labour activities. Availability of labour was a potential factor for adoption of sustainable agriculture technologies. Hence, the household size was disintegrated into four groups and in the present study, the household size h age between 11 to 16 years positively and significantly influences the adoption of IPM.

Access to extension service results in households making better farming decisions and interactions with extension agents positively influences the adoption of the technology. Results showed that access to extension service positively and significantly influences the adoption of IPM in onion.

The significant negative coefficient of choosing a pesticide with the advice of pesticide dealers indicated that farmers getting more advice from pesticide dealers were less inclined to adopt IPM. This suggests that pesticides dealers were not recommending the IPM technology, which may be because of lack of knowledge or may be with the intention of increasing their sales.

Other variables were also tested but not included in the final model as they were either non-significant or correlated with other variables. Age was non-significant as a predictor of adoption, which was contrary to expectation. Younger farmers were more likely to be risk takers and hence perhaps more likely to be adopters than older farmers. However, in this example much more is known concerning the technology, and its associated risk was small. Thus, the affect of age on the adoption process was reduced.

Table 5.29 Results of marginal effects of Probit estimation for IPM onion adoption

Variable	Coefficient	t
Age (years)	-0.028	-0.80
Age^2	0.002	0.61
Education	0.006	0.25
HS1(0-10)	-0.024	1.08
HS2 (11-16)	-0.042	1.74*
HS3 (17-60)	-0.018	-0.86
HS4 (61-80)	-0.004	-0.19
Total land	-0.004	-0.08
Pesticide cost	-0.018	-0.77
Extensionage	0.161	1.82**
Pesticide dealer adv	-0.273	-2.52***
Relative adv	-0.014	-0.43
Village1	-0.049	-1.73*
Village2	-0.067	-1.79*
Number of observations	264	

Note : Significance of t-statistics of mean difference is at the *10%, **5% and ***1% levels.

The explanation of the magnitude of effect of an X_i variable through the coefficients (β_i) is not straight forward in a probit model. Hence to explain the effect of the independent variable elasticities were developed. The elasticity of probability may be defined as a proportionate change in probability of P(Y=1) due to a proportionate change in X_i. Marginal effects of this regression are provided in Table 5.29. The marginal effect of an independent variable is the change in the probability of observing a certain outcome, if the independent variable changes by one unit, with other variables constant. The parameter dy/dx shows that a one percent change in X_i would bring the dy/dx percent change in probability for a particular value of the probit model.

5.6 Economic Impact of Integrated Pest Management (IPM) in Onion

5.6.1 Single Binary Treatment

The Economic impact of integrated pest management in onion was examined by using ATT (Average treatment effect on treated) analysis and it was done with propensity score matching (PSM). As it was discussed earlier, the basic idea behind the propensity score matching (PSM) is to match each participant with an identical nonparticipant and then measure the average difference in the outcome variable between the participants and the nonparticipants. The choice of explanatory variables (conditioning variables) in predicting propensity scores is crucial in propensity score matching analysis. The selection of covariates should fulfill the assumption of unconfoundedness. Therefore there is a need to select variables that influence both treatment and outcomes but were not affected by treatment (Caliendo and Kopeining, 2008).

The estimated parameters from the probit model that were used to identify the factors that determine the adoption of IPM in onion were utilized to estimate the propensity score. The propensity scores represent the estimated propensity of being an adopter. The dependent variable takes the value of '1' if the farmer is an adopter and '0' otherwise, the larger the score the more likely the individual would adopt IPM in onion. After estimating the propensity score, the assumption of unconfoundedness was tested by checking the balancing property i.e., observations with the same propensity score must have the same distribution of observable characteristics independent of treatment status. After balancing has been done, different commands were used to carry out different types of matching and then the average treatment effect was derived. The area of common support were those propensity scores within the range of the lowest and highest estimated values for households in the treatment group. The output shows that the identified region of common support was [.02610825, .99991729], the final number of blocks was 5 and the balancing property was satisfied. Initially the balancing property was not satisfied since the variable *extensionage* was not balanced. And after a few iterations by dropping the *extensionage* balancing property was satisfied. The details on the adopters and non-adopters in each block are provided in Table 5.30.

Table 5.30. Distribution of onion IPM and non-IPM based on the propensity scores

Inferior of block of p score	IPM	Non-IPM	Total
0.026	9	71	80
0.2	3	12	15
0.4	7	9	16
0.6	10	3	13
0.8	24	2	26
Total	**53**	**97**	**150**

As mentioned earlier, the main objective of propensity score estimation was to balance the distribution of relevant variables in the groups of adopters and non-adopters rather than obtaining precise prediction of selection into treatment. Because the matching procedure conditions on the propensity score but does not condition on individual covariates, it was checked whether the distribution of variables are 'balanced' across the adopter and non-adopter groups. Rosenbaum and Rubin (1983) recommend that standardized bias (SB) and *t*-test for differences be used to check matching quality. The reduction in the median absolute standardized bias between the matched and unmatched models was used to examine the balancing powers of the estimations. The results of reduction in standardized percentage bias across covariates are provided in Table 5.31. Detailed effects can be seen from the figures attached in the Appendix II to VII.

Comparison of means of observable farm characteristics was done for the unmatched and matched sample and the results are provided in Table 5.32. The results indicated that there were no observable characteristics significantly different (at 1% level significance) between the IPM and non-IPM adopters. In contrast, when the unmatched sample was used except 'totalland' and 'pestiecost' all are significantly different at each other. Hence the results in Table 5.31 suggested that the matched non-IPM observations can serve as a good surrogate for the missing counterfactual which would allow more accurate estimation of the IPM impact.

Table 5.31. Standardized percentage bias reduction across covariates

Observable variables	NNM sample	Kernel matched sample	Radius matched sample
Age	93.8	89.5	93.1
Age^2	92.9	90.5	92.2
HS (1-10)	81.5	95.8	75.6
HS (11-16)	89.9	94.2	96.7
HS (17-60)	95.1	73.0	74.9
HS (61-80)	3.8	-19.8	52.9
Education	54.4	60.0	58.5
Totalland	-832.8	-70.8	-887.5
Pestiecost	-4.0	73.9	21.4
Pesticideadv	73.4	96.5	77.0
Relativeadv	80.8	94.1	32.4

Table 5.32 Comparison of means of observable farm characteristics (Unmatched and matched samples) : p-value of difference

Observable variables	Unmatched sample	NN matched sample	Kernel matched sample	Radius matched sample
Age	0.000	0.797	0.570	0.775
Age^2	0.000	0.774	0.608	0.750
HS (1-10)	0.000	0.687	0.895	0.592
HS (11-16)	0.000	0.836	0.877	0.946
HS (17-60)	0.000	0.932	0.440	0.662
HS (61-80)	0.050	0.348	0.216	0.642
Education	0.000	0.404	0.300	0.449
Totalland	0.768	0.330	0.768	0.304
Pestiecost	0.052	0.319	0.692	0.465
Pesticideadv	0.000	0.291	0.856	0.367
Relativeadv	0.057	0.870	0.944	0.568

Given that the balancing property was satisfied and the common support was imposed, the estimated propensity scores from the probit model were used to conduct nearest neighbor matching (NNM), kernel based matching (KBM) and radius based matching (RBM). Table 5.33 presents the average treatment effects estimated by nearest neighbour matching (NNM), kernel based matching (KBM) and radius based matching (RBM) as well as the indicators of matching quality from the matching models. The matching approaches in Table 5.33 generally indicated that adoption of integrated pest management (IPM) in onion exerts a positive and significant impact on productivity and net income. The statistical significance of the ATT was tested using t-values calculated from bootstrapped standard errors. Following Becker and Ichino (2002), the bootstrapped standard errors were calculated by 100 replications. The estimated standard errors were then used to calculate t-values. The number of matched pairs differed across different matching methods. In nearest neighbor matching method 53 adopters were matched with 19 non-adopters. Both in kernel based matching (KBM) and radius based matching (RBM) 53 adopters were matched with 97 non-adopters.

Impact of IPM in onion on Yield

Table 5.33 showed that IPM adopters have a significantly higher yield than the non-adopters. The results of nearest neighbor matching indicated that onion IPM farmers obtained 2503 kg higher yield per hectare than the non-IPM farmers. The results from kernel based matching (KBM) and radius based matching (RBM) indicated that the yield obtained from the onion IPM cultivators was higher by 2470kg/ha and 2632kg/ha respectively.

Impact of IPM in onion on Net returns

The results in Table 5.33 indicated that the net income of onion IPM growers was significantly higher than the non-IPM farmers. The results of nearest neighbor matching indicated that the onion IPM farmers received Rs 40,746 more net income than the non-IPM farmers in a hectare. The results from kernel based matching (KBM) and radius based matching (RBM) indicates that the net revenue obtained from the onion IPM cultivators was higher by Rs 40,549/ha and Rs 41,521/ha respectively.

Impact of IPM in onion on Pesticide expenditure

The results in Table 5.33 indicated that the amount spent by the onion IPM growers for pesticides was significantly lower than that spent by the non-IPM cultivators. The results of nearest neighbor matching indicated that due to the adoption of integrated pest management (IPM) in onion the cost for pesticide expenditure was reduced by Rs. 6847/ha. The results from kernel based matching (KBM) and radius based matching (RBM) indicates that the IPM farmers spent Rs 6828/ha and Rs 6841/ha less than the non-IPM farmers respectively.

Table 5.33 Average treatment effects

(NNM, KBM and RBM: the impact of onion IPM on yield, net returns and pesticide expenditure)

Matching Algorithm	Outcome	ATT	Number of treated	Number of control
Nearest neighbor matching (NNM)	Onion yield (kg/ha)	2503.56^{***}(5.92)	53	19
	Net returns (Rs/ha)	$40,746^{***}$(7.22)	53	19
	Pesticide expenditure (Rs/ha)	-6847^{***}(6.39)	53	19
Kernel-based matching (KBM)	Onion yield (kg/ha)	2470.66^{***}(4.56)	53	97
	Net returns (Rs/ha)	$40,549^{***}$(-6.26)	53	97
	Pesticide expenditure (Rs/ha)	-6838^{***}(-7.39)	53	97
Radius matching (RBM)	Onion yield (kg/acre)	2632.97^{***}(14.88)	53	97
	Net returns (Rs/acre)	$41,521^{***}$(13.31)	53	97
	Pesticide expenditure (Rs/ha)	-6841^{***}(16.19)	53	97

Note: Numbers in parentheses are t-values. Values are significantly different from zero at ***1% level. ATT is the average treatment effect for the treated.

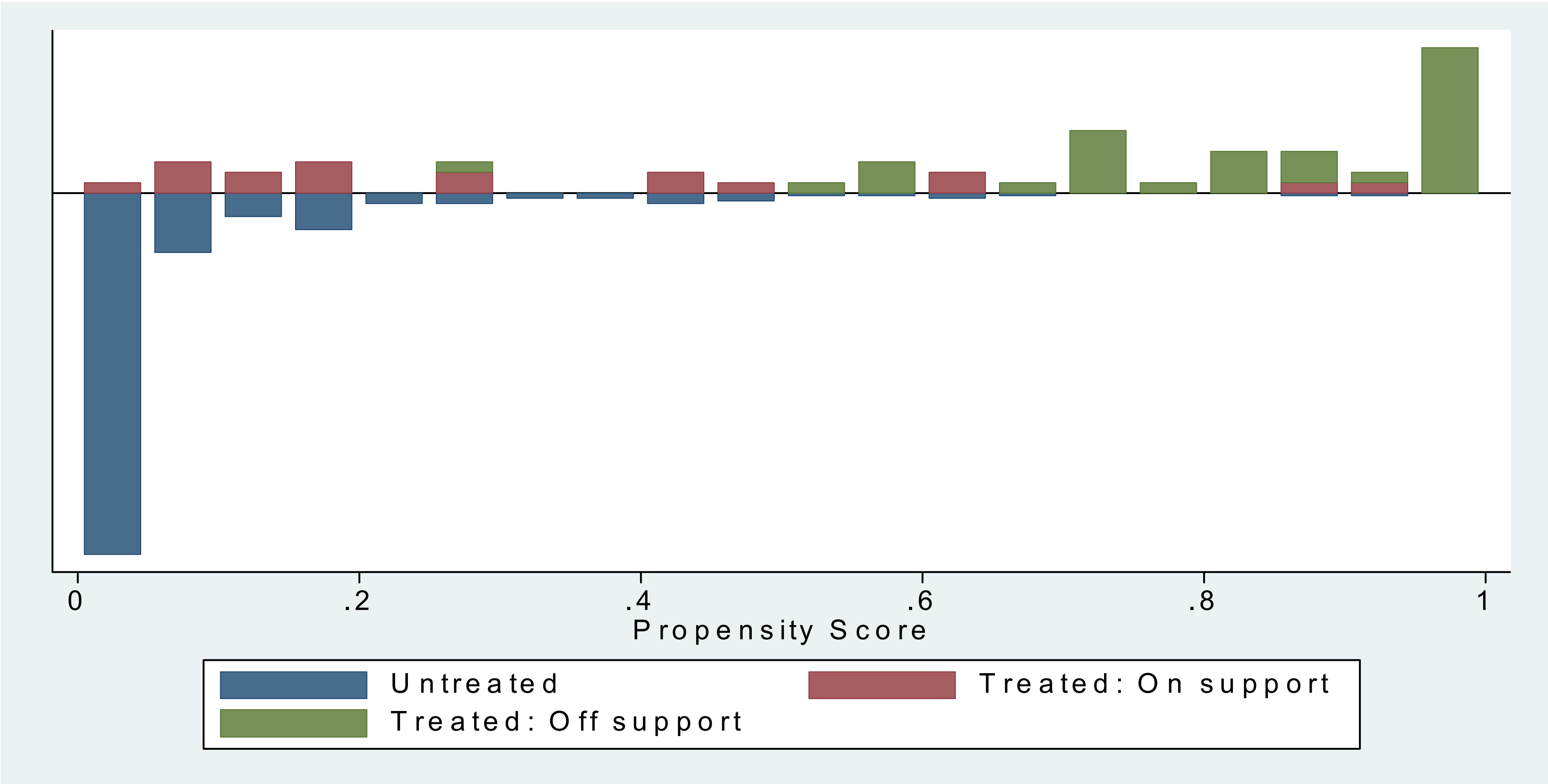
The propensity score distribution and the common support for propensity score distribution is depicted in Figure 5.1, figure 5.2 and Figure 5.3 for the nearest neighbor matching (NNM), kernel-based matching (KBM) and caliper/radius matching (RBM) respectively. The results on reduction in the median absolute standardised bias between the matched and unmatched models, the pseudo R^2 and the p-values are provided in Table 5.34. Before matching, the median absolute bias was 45.0 and it was reduced 14.5, 9.3 and 20.7 for the nearest neighbor matching (NNM), kernel-based matching (KBM) and caliper/radius matching (RBM) respectively. As indicated by the median absolute bias measure, the kernel approach has the best matching quality.

The pseudo R^2 from the propensity score estimation and from re-estimation of the propensity score after matching are also presented in the fifth and sixth columns of Table 5.34. The p-values of the likelihood ratio tests before and after matching are presented in the seventh and eighth columns of Table 5.34.

Table 5.34 Indicators of covariate balancing, before and after matching

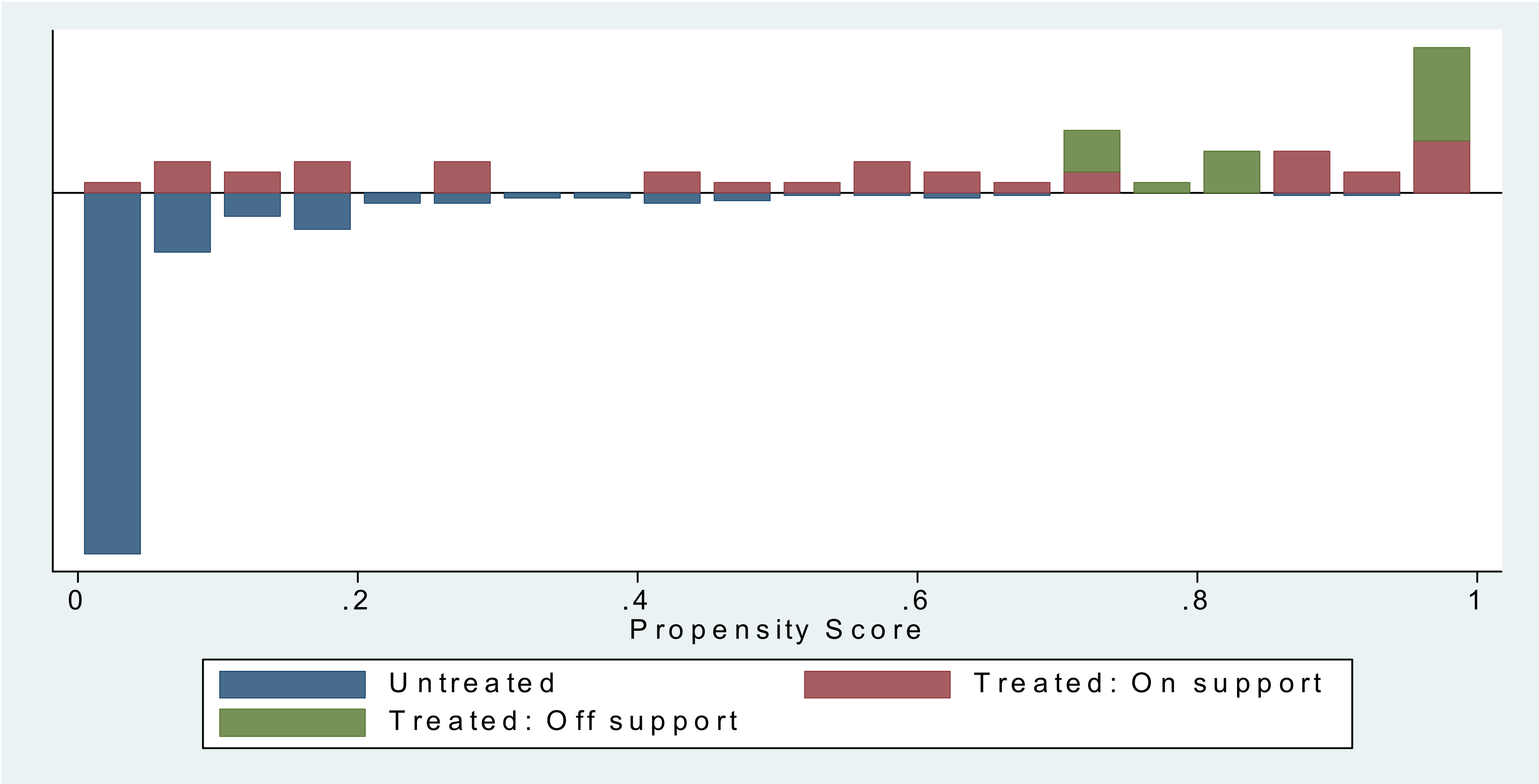
Matching algorithm	Median absolute bias (before matching)	Median absolute bias (after matching)	% bias reduction (total)	Pseudo R^2 (unmatched)	Pseudo R^2 (matched)	P-value of LR (unmatched)	p-value of LR (matched)
Nearest neighbor matching	45.0	14.5	67.78	0.545	0.152	0.000	0.868
Kernel – based matching	45.0	9.3	79.33	0.545	0.064	0.000	0.939
Caliper/Radius matching	45.0	20.7	54.00	0.545	0.110	0.000	0.963

Figure 5.1 Propensity score estimation and common support for propensity score estimation: Nearest neighbor matching



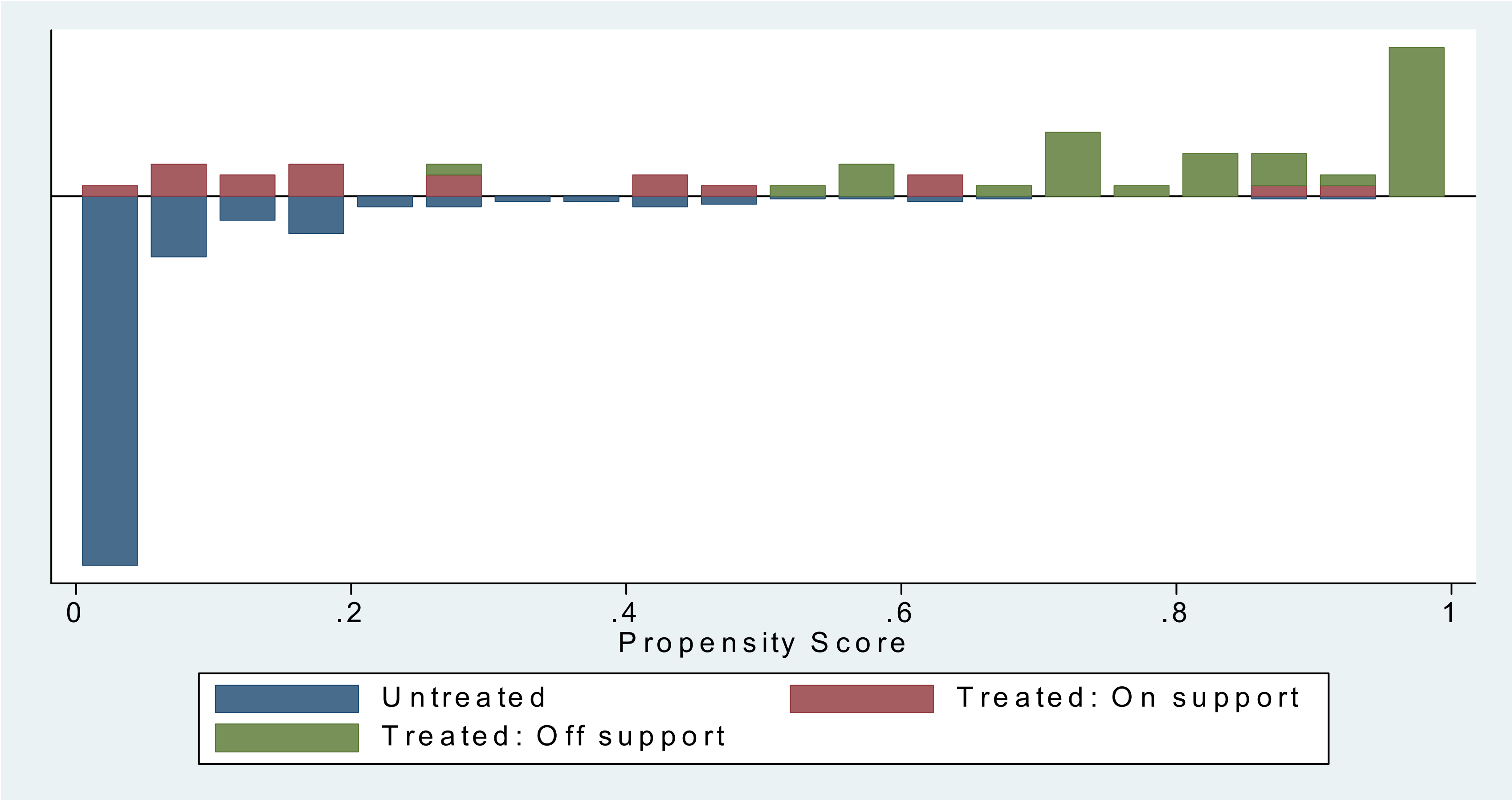
Treated on support indicates the individuals in the adoption group who find a suitable match
Treated off support indicates the individuals in the adoption group who did not find a suitable match

Figure 5.2 Propensity score estimation and common support for propensity score estimation: Kernel based matching



Treated on support indicates the individuals in the adoption group who find a suitable match
Treated off support indicates the individuals in the adoption group who did not find a suitable match

Figure 5.3 Propensity score estimation and common support for propensity score estimation: Caliper/Radius matching



Treated on support indicates the individuals in the adoption group who find a suitable match
Treated off support indicates the individuals in the adoption group who did not find a suitable match

5.6.2 Multiple Simultaneous Treatments

To identify the relative effect of the groups of IPM farmers, multiple simultaneous treatments were conducted. The groups were disintegrated based on the suggestions of the scientists. According to them, *Trichoderma viride* and Pseud*omonas fluorescens* are the important components in the IPM package for onion. Hence to know the relative effect of these components and others, a multi-level treatment was completed with propensity score matching. As discussed earlier, from the data it was deciphered that none of the farmers used any single component alone; they used group of components. The group of farmers are again shown in Table 5.35.

Table 5.35 Classification of IPM farmers

Group	IPM components	No of Farmers
I	*Trichoderma viride, Pseudomonas fluorescens,* Neem products	24
II	*Trichoderma viride, Pseudomonas fluorescens,* Neem products, Yellow sticky trap (4)	7
	Trichoderma viride, Pseudomonas fluorescens, Neem products, VAM (3)	
III	*Trichoderma viride, Pseudomonas fluorescens*	6
IV	*Trichoderma viride,* VAM, Neem products (3)	9
	Trichoderma viride, Neem products (6)	
V	*Without Trichoderma viride*	7
VI	*Non-IPM Farmers*	211

There were some farmers who used *Trichoderma viride* with other components and also there were some farmers who used *Pseudomonas fluorescens* with other components. Table 5.35 indicated that the fourth group farmers used the components without *Pseudomonas fluorescens* and the fifth group farmers used the components without *Trichoderma viride,* and the interesting part was there were also some farmers who used bio-control agents (*Trichoderma viride, Pseudomonas fluorescens*) alone. The summary statistics of the outcome variable are provided in Table 5.36.

Table 5.36 Summary statistics of the outcome variables

Group	Yield (kg/ha)			
	Mean	Std.Dev	Min	Max
I (25)	13465	455	12550	14063
II (7)	14089	460	13500	14750
III (5)	13025	575	12590	14000
IV (10)	13331	586	12500	13800
V (6)	12754	674	11500	13500
VI (211)	10818	786	9000	12125
Group	**Net returns (Rs/ha)**			
	Mean	**Std.Dev**	**Min**	**Max**
I (25)	110139	3602	98875	111234
II (7)	117415	3642	106785	116673
III (5)	105059	4552	98795	110740
IV (10)	107530	4637	101875	114695
V (6)	100373	3709	99865	110740
VI (211)	64667	6498	53910	71619
Group	**Pesticide Expenditure (Rs/ha)**			
	Mean	**Std.Dev**	**Min**	**Max**
I (25)	13825	160	13604	13985
II (7)	13675	205	13577	13876
III (5)	13575	179	13708	14102
IV (10)	13650	164	13606	13890
V (6)	14125	162	13696	14070
VI (211)	20410	166	19350	21998

Impact on Yield, Net Returns and Pesticide Expenditure

Table 5.37 showed the treated and control observations for each matching procedure. The results of relative effect of IPM in onion on yield, net returns and pesticide expenditure with different matching procedures are presented in Table 5.38, 5.39 and 5.40 respectively. Since the sample size was small for some of the groups, the common support does not exist for some groups. Hence, all the relative effects among the groups could not be found. The results indicated that the yield and net returns for the group of IPM farmers were significantly higher than for the non-IPM farmers. It can also be deciphered that the farmers belonging to the second group received relatively higher yield and net returns than the other groups of farmers. Among the groups of the farmers, those who did not used *Trichoderma viride* received significantly lower yield and net returns than others and also the farmers who did not used *Pseudomonas fluorescens* received significantly lower yield and net returns than others. Hence it can be concluded that the farmers who used *Trichoderma viride* and *Pseudomonas fluorescens* with yellow sticky trap or VAM received higher yield and net returns and their pesticide expenditure were also reduced. These multiple treatment results substantiate the results of partial budgeting. Regarding the pesticide expenditure, there was no significant difference, but the pesticide expenditure of the group of IPM farmers was significantly lower than for the non-IPM farmers.

Table 5.37 Common support between treatment and control observations for our sample by participation status

Group I versus Others

Matching Algorithm		Group I to Group II			Group I to Group III			Group I to Group IV			Group I to Group V			Group I to Group VI		
		Off support	On support	Total	Off support	On support	Total	Off support	On support	Total	Off support	On support	Total	Off support	On support	Total
NNM	Control	0	7	7	06	6	6	0	9	9	0	7	7	0	211	211
	Treated	21	3	24	22	2	24	20	4	24	20	4	24	17	7	24
	Total	21	10	31	22	8	30	20	13	33	20	11	31	17	218	235
KBM	Control	0	7	7	0	6	6	0	9	9	0	7	7	0	211	211
	Treated	15	9	24	21	3	24	14	10	24	16	8	24	17	7	24
	Total	15	16	31	21	9	30	14	19	33	16	15	31	17	218	235
RBM	Control	0	7	7	0	6	6	0	9	9	0	7	7	0	211	211
	Treated	21	3	24	22	2	24	20	4	24	20	4	24	17	7	24
	Total	21	10	31	22	8	30	20	13	33	20	11	31	17	218	235

Group II versus Others

Matching Algorithm		Group II to Group I			Group II to Group III			Group II to Group IV			Group II to Group V			Group II to Group VI		
		Off support	On support	Total	Off support	On support	Total	Off support	On support	Total	Off support	On support	Total	Off support	On support	Total
NNM	Control	0	24	24	0	6	6	0	9	9	0	7	7	0	211	211
	Treated	4	3	7	7	0	7	5	2	7	4	3	7	7	0	7
	Total	4	27	31	7	6	13	5	11	16	4	10	14	7	211	218
KBM	Control	0	24	24	0	6	6	0	9	9	0	7	7	0	211	211
	Treated	3	4	7	7	0	7	5	2	7	1	6	7	7	0	7
	Total	3	28	31	7	6	13	5	11	16	1	13	14	7	211	218
RBM	Control	0	24	24	0	6	6	0	9	9	0	7	7	0	211	211
	Treated	4	3	7	7	0	7	5	2	7	4	3	7	4	3	7
	Total	4	27	31	7	6	73	5	11	16	4	10	14	4	214	218

Group III versus Others

Matching Algorithm		Group III to Group I			Group III to Group II			Group III to Group IV			Group III to Group V			Group III to Group IV		
		Off support	On support	Total	Off support	On support	Total	Off support	On support	Total	Off support	On support	Total	Off support	On support	Total
NNM	Control	0	24	24	0	7	7	0	9	9	0	7	7	0	211	211
	Treated	4	2	6	6	0	6	6	0	6	6	0	6	5	1	6
	Total	4	26	30	6	7	13	6	9	15	6	7	13	5	212	217
KBM	Control	0	24	24	0	7	7	0	9	9	0	7	7	0	211	211
	Treated	1	5	6	6	0	6	6	0	6	5	1	6	3	3	6
	Total	1	29	30	6	7	13	6	9	15	5	8	13	5	212	217
RBM	Control	0	24	24	0	7	7	0	9	9	0	7	7	0	211	211
	Treated	4	2	6	6	0	6	6	0	6	6	0	6	4	2	6
	Total	4	26	30	6	7	13	6	9	15	6	7	13	4	213	217

Group IV versus Others

Matching Algorithm		Group IV to Group I			Group IV to Group II			Group IV to Group III			Group IV to Group V			Group IV to Group VI		
		Off support	On support	Total	Off support	On support	Total	Off support	On support	Total	Off support	On support	Total	Off support	On support	Total
NNM	Control	0	24	24	0	7	7	0	6	6	0	7	7	0	211	211
	Treated	6	3	9	8	1	9	9	0	9	7	2	9	8	1	9
	Total	6	27	33	8	8	16	9	6	15	7	9	16	8	212	220
KBM	Control	0	24	24	0	7	7	0	6	6	0	7	7	0	211	211
	Treated	4	5	9	8	1	9	9	0	9	5	4	9	8	1	9
	Total	4	29	33	8	8	16	9	6	15	5	11	16	8	212	220
RBM	Control	0	24	24	0	7	7	0	6	6	0	7	7	0	211	211
	Treated	5	4	9	7	2	9	9	0	9	7	2	9	5	3	8
	Total	5	28	33	7	9	16	9	6	15	7	9	16	5	214	219

Group V versus Others

Matching Algorithm		Group V to Group I			Group V to Group II			Group V to Group III			Group V to Group IV			Group V to Group VI		
		Off support	On support	Total	Off support	On support	Total	Off support	On support	Total	Off support	On support	Total	Off support	On support	Total
NNM	Control	0	24	24	0	7	7	0	6	6	0	9	9	0	211	211
	Treated	3	4	7	4	3	7	7	0	7	7	0	7	5	2	7
	Total	3	28	31	4	10	14	7	6	13	7	9	16	5	213	218
KBM	Control	0	24	24	0	7	7	0	6	6	0	9	9	0	211	211
	Treated	1	6	7	2	5	7	6	1	7	7	0	7	5	2	7
	Total	1	30	31	2	12	14	6	7	13	7	9	16	5	213	218
RBM	Control	0	24	24	0	7	7	0	6	6	0	9	9	0	211	211
	Treated	3	4	7	3	4	7	7	0	7	5	2	7	5	2	7
	Total	3	28	31	3	11	14	7	6	13	5	11	16	5	213	218

Group VI versus Others

Matching Algorithm		Group VI to Group I			Group VI to Group II			Group VI to Group III			Group VI to Group IV			Group VI to Group V		
		Off support	On support	Total	Off support	On support	Total	Off support	On support	Total	Off support	On support	Total	Off support	On support	Total
NNM	Control	0	24	24	0	7	7	0	6	6	0	9	9	0	7	7
	Treated	184	27	211	207	4	211	204	7	211	28	183	211	187	24	211
	Total	184	51	235	207	11	218	204	13	217	28	192	220	184	31	218
KBM	Control	0	24	24	0	7	7	0	6	6	0	9	9	0	7	7
	Treated	14	197	211	3	208	211	10	201	211	8	203	211	6	205	211
	Total	14	221	235	3	215	218	10	207	217	8	212	220	6	212	218
RBM	Control	0	24	24	0	7	7	0	6	6	0	9	9	0	7	7
	Treated	184	27	211	207	4	211	204	7	211	28	183	211	187	24	211
	Total	184	51	235	207	11	218	204	13	217	28	192	220	187	31	218

Table 5.38 Average treatment effects with multiple treatments (NNM, KBM and RBM: the impact of onion IPM on yield)

Table 5.38.1 Group I versus others

Matching Algorithm	Group I to Group II	Group I to Group III	Group I to Group IV	Group I to Group V	Group I to Group VI
NNM	-958.3***(-3.86)	481.5**(2.05)	225.6***(7.32)	462.5 (0.14)	2506***(4.68)
KBM	-805.2***(-3.37)	684.7**(1.76)	253.7**(2.34)	550.1*(1.82)	2597***(6.25)
RBM	-958.3***(-2.81)	720.1**(2.31)	156.1***(4.24)	428.6 (1.57)	2684***(4.82)

Table 5.38.2 Group II versus others

Matching Algorithm	Group II to Group I	Group II to Group III	Group II to Group IV	Group II to Group V	Group II to Group VI
NNM	958.3***(3.86)	No Match	686.1**(2.15)	953.2***(2.97)	3425***(4.76)
KBM	805.2***(3.37)	No Match	723.8***(4.52)	901.2***(3.12)	3068***(3.65)
RBM	958.3***(2.81)	No Match	423.5 (1.56)	987.5$^{***(}$3.26)	3256***(5.92)

Note: ***, **, * denote statistical significance at the one percent, five percent and ten percent levels, respectively.

Table 5.38.3 Group III versus others

Matching Algorithm	Group III to Group I	Group III to Group II	Group III to Group IV	Group III to Group V	Group III to Group VI
NNM	-481.5**(-2.05)	No Match	No Match	No Match	2104.8***(2.97)
KBM	-684.7**(-1.76)	No Match	No Match	-425.3(-1.56)	2267.2***(3.25)
RBM	-720.1**(-2.31)	No Match	No Match	No Match	2156.6***(6.46)

Table 5.38.4 Group IV versus others

Matching Algorithm	Group IV to Group I	Group IV to Group II	Group IV to Group III	Group IV to Group V	Group IV to Group VI
NNM	-225.6***(-7.32)	-686.1**(-2.15)	No Match	558.2***(3.12)	2674.8***(3.12)
KBM	-253.7**(-2.34)	-723.8***(-4.52)	No Match	615.1***(2.92)	2571.2***(2.65)
RBM	-156.1***(-4.24)	-423.5 (-1.56)	No Match	584.3**(1.96)	2598.6***(4.23)

Note: ***, **, * denote statistical significance at the one percent, five percent and ten percent levels, respectively.

Table 5.38.5 Group V versus others

Matching Algorithm	Group V to Group I	Group V to Group II	Group V to Group III	Group V to Group IV	Group V to Group VI
NNM	-462.5 (-0.14)	-686.1**(-2.15)	No Match	-558.2***(-3.12)	1224.3***(2.63)
KBM	-550.01*(-1.82)	-723.8***(-4.52)	425.3 (1.56)	-615.1***(-2.92)	1203.6***(4.02)
RBM	-428.6 (-1.57)	-423.5 (-1.56)	No Match	-584.3**(-1.96)	1328.4***(2.82)

Table 5.38.6 Group VI versus others

Matching Algorithm	Group VI to Group I	Group VI to Group II	Group VI to Group III	Group VI to Group IV	Group VI to Group V
NNM	-2506***(-4.68)	-3425***(-4.76)	-2104.8***(-2.97)	-2674.8***(-3.12)	-1224.3***(-2.63)
KBM	-2597***(-6.25)	-3068***(-3.65)	-2267.2***(-3.25)	-2571.2***(-2.65)	-1203.6***(-4.02)
RBM	-2684***(-4.82)	-3256***(-5.92)	-2156.6***(-6.46)	-2598.6***(-4.23)	-1328.4***(-2.82)

Note: ***, **, * denote statistical significance at the one percent, five percent and ten percent levels, respectively.

Table 5.39 Average treatment effects with multiple treatments (NNM, KBM and RBM: the impact of onion IPM on net returns)

Table 5.39.1 Group I versus others

Matching Algorithm	Group I to Group II	Group I to Group III	Group I to Group IV	Group I to Group V	Group I to Group VI
NNM	-9271***(-4.12)	6898***(3.12)	2912**(1.98)	10912 (1.12)	48123***(6.92)
KBM	-8973***(-2.87)	6712***(2.67)	3121***(2.71)	10017*(1.92)	47112***(5.17)
RBM	-7158***(-2.32)	5671***(2.98)	2312**(2.12)	9812** (2.12)	45920***(6.87)

Table 5.39.2 Group II versus others

Matching Algorithm	Group II to Group I	Group II to Group III	Group II to Group IV	Group II to Group V	Group II to Group VI
NNM	9271***(4.12)	No Match	10271***(2.36)	16121***(3.71)	54121***(3.92)
KBM	8973***(2.87)	No Match	11731***(2.41)	16912***(3.37)	52712***(4.61)
RBM	7158***(2.32)	No Match	9912** (1.89)	17121***(2.86)	52912***(5.72)

Note: ***, **, * denote statistical significance at the one percent, five percent and ten percent levels, respectively.

Table 5.39.3 Group III versus others

Matching Algorithm	Group III to Group I	Group III to Group II	Group III to Group IV	Group III to Group V	Group III to Group VI
NNM	-6898***(-3.12)	No Match	No Match	No Match	41211***(2.71)
KBM	-6712***(-2.67)	No Match	No Match	-4212 (-1.71)	40121***(2.67)
RBM	-5671***(-2.98)	No Match	No Match	No Match	41107***(3.24)

Table 5.39.4 Group IV versus others

Matching Algorithm	Group IV to Group I	Group IV to Group II	Group IV to Group III	Group IV to Group V	Group IV to Group VI
NNM	-2912**(-1.98)	-10271***(-2.36)	No Match	9812***(2.71)	42712***(3.37)
KBM	-3121***(-2.71)	-11731***(-2.41)	No Match	8121**(1.71)	43121***(3.12)
RBM	-2312**(-2.12)	-9912** (-1.89)	No Match	7312***(2.93)	42131***(4.08)

Note: ***, **, * denote statistical significance at the one percent, five percent and ten percent levels, respectively.

Table 5.39.5 Group V versus others

Matching Algorithm	Group V to Group I	Group V to Group II	Group V to Group III	Group V to Group IV	Group V to Group VI
NNM	-10912 (1.12)	-16121***(-3.71)	No Match	-9812***(-2.71)	37121***(4.71)
KBM	-10017*(1.92)	-16912***(-3.37)	-4212 (1.71)	-8121**(-1.71)	36912***(4.31)
RBM	-9812** (2.12)	-17121***(-2.86)	No Match	-7312***(-2.93)	35976***(4.67)

Table 5.39.6 Group VI versus others

Matching Algorithm	Group VI to Group I	Group VI to Group II	Group VI to Group III	Group VI to Group IV	Group VI to Group V
NNM	-48123***(-6.92)	-54121***(-3.92)	-41211***(-2.71)	-42712***(-3.37)	-37121***(-4.71)
KBM	-47112***(-5.17)	-52712***(-4.61)	-40121***(-2.67)	-43121***(-3.12)	-36912***(-4.31)
RBM	-45920***(-6.87)	-52912***(-5.72)	-41107***(-3.24)	-42131***(-4.08)	-35976***(-4.67)

Note: ***, **, * denote statistical significance at the one percent, five percent and ten percent levels, respectively.

Table 5.40 Average treatment effects with multiple treatments (NNM, KBM and RBM: the impact of onion IPM on pesticide expenditure)

Table 5.40.1 Group I versus others

Matching Algorithm	Group I to Group II	Group I to Group III	Group I to Group IV	Group I to Group V	Group I to Group VI
NNM	191^{*} (1.79)	271 (1.61)	219^{*} (1.81)	-312^{**} (-2.36)	-6912^{***} (-3.41)
KBM	201^{*} (1.91)	312^{*} (1.91)	230^{**} (2.12)	-393^{***} (-3.12)	-6871^{***} (-3.71)
RBM	171^{*} (1.81)	241^{**} (2.12)	261^{*} (1.97)	-293^{***} (-2.41)	-7112^{***} (-3.13)

Table 5.40.2 Group II versus others

Matching Algorithm	Group II to Group I	Group II to Group III	Group II to Group IV	Group II to Group V	Group II to Group VI
NNM	-191^{*}(-1.79)	No Match	-101(-1.12)	-612^{**}(-2.12)	-7012^{***}(-2.93)
KBM	-201^{*}(-1.91)	No Match	71 (0.98)	-531^{*}(-1.93)	-6981^{***}(-3.12)
RBM	-171^{*}(-1.81)	No Match	82 (0.71)	-561^{*}(-1.96)	-6812^{***}(-3.09)

Note: ***, **, * denote statistical significance at the one percent, five percent and ten percent levels, respectively.

Table 5.40.3 Group III versus others

Matching Algorithm	Group III to Group I	Group III to Group II	Group III to Group IV	Group III to Group V	Group III to Group VI
NNM	-271 (-1.61)	No Match	No Match	No Match	-6931**(-2.25)
KBM	-312* (-1.91)	No Match	No Match	-691 (-0.21)	-7131**(-2.38)
RBM	-241** (-2.12)	No Match	No Match	No Match	-7012***(-3.71)

Table 5.40.4 Group IV versus others

Matching Algorithm	Group IV to Group I	Group IV to Group II	Group IV to Group III	Group IV to Group V	Group IV to Group VI
NNM	-219* (-1.81)	-101(-1.12)	No Match	-631***(-2.91)	-6121***(-3.71)
KBM	-230** (-2.12)	71 (0.98)	No Match	-570**(-2.34)	-6812***(-2.84)
RBM	-261* (-1.97)	82 (0.71)	No Match	-492**(-2.46)	-6751***(-2.95)

Note: ***, **, * denote statistical significance at the one percent, five percent and ten percent levels, respectively.

Table 5.40.5 Group V versus others

Matching Algorithm	Group V to Group I	Group V to Group II	Group V to Group III	Group V to Group IV	Group V to Group VI
NNM	312^{**} (2.36)	612^{**}(2.12)	No Match	631^{***}(2.91)	-6712^{**}(-2.42)
KBM	393^{***} (3.12)	531^{*}(1.93)	691 (0.21)	570^{**}(2.34)	-6212^{**}(-2.31)
RBM	293^{***} (2.41)	561^{*}(1.96)	No Match	492^{**}(2.46)	-6614^{***}(-2.63)

Table 5.40.6 GroupVI versus others

Matching Algorithm	Group VI to Group I	Group VI to Group II	Group VI to Group III	Group VI to Group IV	Group VI to Group V
NNM	6912^{***} (3.41)	7012^{***}(2.93)	6931^{**} (2.25)	6121^{***} (3.71)	6712^{**} (2.42)
KBM	6871^{***} (3.71)	6981^{***}(3.12)	7131^{**} (2.38)	6812^{***} (2.84)	6212^{**} (2.31)
RBM	7112^{***} (3.13)	6812^{***}(3.09)	7012^{***} (3.71)	6751^{***} (2.95)	6614^{***} (2.63)

Note: ***, **, * denote statistical significance at the one percent, five percent and ten percent levels, respectively.

5.7 Economic Benefits of IPM to Producers and Consumers

To measure the aggregate social benefits of integrated pest management research on onion, economic surplus analysis was carried out. The return of investment was also calculated for the change in consumer and producer surplus over time that results from technological change in onion.

The yield change, quality improvement, cost reduction, and adoption rate were taken from the budgets and the survey data. Price and quantity data were obtained from the season and crop report which was published by Government of Tamil Nadu. The average production for the last five years was used as a base quantity for the analysis. The probability of success of the IPM onion research was considered to be 100 percent because it was successfully completed. From the survey data, the adoption rate for IPM on onion in the study area was obtained (8.52%). The adoption rate was rounded to 8 percent for the surveyed year and it was assumed to be lower in the previous years. Birthal (2003) indicated that adoption of IPM remains restricted to barely 2 percent of the area treated with plant protection inputs. Since the IPM technology was popular for rice and cotton, the adoption rate for IPM in onion was taken as 0.02 for the initial years. Adoption was assumed to have started and gradually increase among onion cultivators and will reach 60 percent adoption by 2022 in the surveyed area and 40 percent adoption in the state.

The economic surplus analysis was carried out for the survey area (Perambalur and Trichy districts) and for the whole state (Tamil Nadu). Even for the surveyed area, two types of analysis were conducted. The first one was for the current period (2008-2012) and the second one was for the next 15 years.

Demand and supply elasticities were needed as they represent the responsiveness of supply and demand to changes in price. For the present study, demand and supply elasticities were derived from previous studies. Kumar (2010) found the price elasticity of demand for vegetables to be -0.515 and for rice -0.247. Since onion was considered an indispensable ingredient of most Indian cooking, providing the pungent foundation for a thousand different curries and other dishes, the price elasticity of demand for onion will be close to rice. Therefore an average price elasticity of -0.3 was assumed in the present study. It implies that a one percent price reduction increases the quantity demanded of onion by only three tenths of one percent. A supply elasticity of 1.0 was assumed, which implies that a one percent increase in price of onion will increase the supply by another one percent. Research costs (in Tamil Nadu) were obtained from the office of Tamil Nadu Agricultural University.

The values that were used to calculate the economic surplus are presented in Table 5.41.

Table 5.41. Summary data used for simulation of economic gains from onion IPM

S. No	Particulars	Values
1.	Production in Tamil Nadu (tones)	273,588
2.	Production in the study area (tones)	99565
3.	Yield change (%)	34
4.	Reduction in cost (%)	11
5.	Price elasticity of demand	-0.30
6.	Price elasticity of supply	1.00
7.	Probability of success	1.00

Net benefits were calculated and discounted at five percent to reflect the fact that benefits received sooner were worth more than benefits received later and summed to obtain a present value. An internal rate of return (IRR) was also estimated. The value of the IRR is an indicator of whether it is suitable or not to continue investing in these technologies.

Scenario 1: Net benefit of IPM in onion in the study area (2008-2012)

Under a closed economy assumption, the benefits of the IPM cropping strategy were first evaluated from 2008-2012 for the study area (Perambalur and Trichy districts) where the strategy was implemented and then projected for the state.

Table 5.42 Net benefit of IPM in onion in the study area (2008-2012)

Adoption rate	NPV (Rs. in crore)	NPV (in million US$)	IRR
8.00%	6.23	1.17	250

Note: Indian rupees were converted to US dollars by taking the average exchange rate of 1US$ = Rs.53

Results from Table 5.42 suggested that the net present value of the potential research was Rs. 6.23 crores and the internal rate of return (IRR) was 250%.

Scenario 2: Net benefit of IPM in onion in the study area (2008-2022)

The benefits of IPM research on onion were projected from 2008, the year of implementation of the technology to 2020. The benefits were calculated for the closed economy system and sensitivity analyses were also conducted using different adoption rates.

Table 5.43 Net benefit of IPM in onion in the study area (2008-2022)

Adoption rate	NPV (Rs. in crore)	NPV (in million US$)	IRR
20.00%	41.11	7.56	256
40.00%	65.54	12.36	274
60.00%	93.71	17.68	303

The potential research benefits generated by IPM in onion were projected to be about Rs. 41.11 crores for an adoption rate of 20% and increase proportionally with the adoption rate. The maximum benefits expected can reach Rs. 94 crores with an adoption rate of 60%. The internal rate of return (IRR) was also increase proportionally with the adoption rate. It varies from 256% for an adoption rate of 20% to 303% when the adoption rate reaches 60%.

Scenario 3: Net benefit of IPM in onion in Tamil Nadu (2008-2022)

The benefits of IPM research on onion were projected from 2008, the year of implementation of the technology to 2022. The benefits were calculated for the closed economy system and sensitivity analyses were also conducted using different adoption rates.

Table 5.44 Net benefit of IPM in onion in Tamil Nadu (2008-2022)

Adoption rate (%)	NPV (Rs. in crore)	NPV (in million US$)	IRR
40.00	182.39	34.41	677
50.00	217.45	41.02	709
60.00	260.71	49.18	746

The potential research benefits generated by IPM in onion were projected to be about Rs. 182.39 crores for an adoption rate of 40% and increases proportionally with the adoption rate. The maximum benefits expected can reach Rs. 260 crores with an adoption rate of 60%. The internal rate of return (IRR) varies from 677% for an adoption rate of 40% to 746% when the adoption rate reaches 60%.

The results of economic surplus also indicated that the size of economic surplus for adopting the IPM strategy in onion was quite large and the consumers gain a larger share (77%) than producers (23%).

CHAPTER VI

SUMMARY AND CONCLUSION

Agriculture has been the backbone of the Indian economy and it will continue to remain so for a long time. It has to support almost 17 per cent of the world population from 2.3 per cent of world geographical area and 4.2 per cent of world's water resources. The growth of the horticulture sector significantly improved within agriculture and been recognized as a diversified field in the last decade to sustain agriculture based economy. India has varying climatic conditions and provides an opportunity for growing a large number of horticulture crops including vegetables. There were approximately 250 million farmers in Asia growing vegetables, which is generally quite labour intensive and undertaken for the most part by smallholder farmers. The cumulative growth rate of vegetable productivity in India is more than the world productivity of 15.1 percent during 1992-2008. India is the second largest producer of vegetables next only to China and accounts for 13.4 percent of world production. It has an annual production of 81 million tonnes from 5.12 million ha of land.

Insect pests, diseases, and weeds were the major constraints limiting agricultural productivity growth. It is estimated that herbivorous insects eat about 26 percent of the potential food production. Pest problem is one of the major constraints for achieving higher production in agriculture crops. India loses about 30 percent of its crops due to pests and diseases each year. The insect pests inflict crop losses to the tune of 40 percent in vegetable production. As a result of insect pest attacks, farmers use the pesticides throughout the period of growth and sometimes even at the fruiting stage. Vegetables and fruit receive a large quantity of pesticides, and with a cropped area of three per cent, they consume 13 per cent of the total pesticides in the country. As the vegetables were harvested at shorter intervals, chemical methods of plant protection have become risky and hazardous. To combat the insecticide resistant insects, IPM techniques were being devised. Integrated Pest management (IPM) would provide an acceptable and affordable basis for pest control in vegetables.

The onion is an important vegetable and has been grown in almost all the parts of India for thousands of years. Onions were regarded as a highly export-oriented crop and earn valuable foreign exchange for the country. Though India produces a significant quantity of onions it is not regular and sufficient enough to meet the demands for both domestic requirement and exports. Amongst the onion producing countries in the world India ranks second in area and production, the first being China. India being a second major onion producing country in the world has a productivity of 10.16 MT/ha. In Tamil Nadu the average per hectare yield of onion is 9.63 MT only. Productivity of onion shows variable trends as the crop is susceptible to various weather variations. Yield obtained in India with those obtained in developed countries showed that there is a wide gap between the optimum yield of the onion crop in the country and the yields actually obtained by the farmers.

Indiscriminate use of insecticides in onion cultivation with intensive agronomic practices affected both farm profitability and the farm. To combat the pests with eco-friendly practices, the scientists developed six components of an IPM package for onion. Adoption of integrated pest management (IPM) may provide an acceptable and affordable basis for pest control in vegetables. To study the impact of IPM technologies in onion, it is essential to know about the economic success of the IPM packages and to provide reasonable recommendations to the farmers. Hence the study was carried out with the following objectives: (1) To assess the nature and the extent of adoption of IPM technologies among the onion growers, (2) To identify the determinants of adoption of IPM technologies, (3) To assess the tangible and intangible benefits of adopting IPM technologies, (4) To assess the joint economic benefits of IPM technologies to producers and consumers.

Multi-stage sampling design was employed in the present study for selection of sample respondents. In the first stage, the districts were selected based on the concentration of the area under onion. Onion is cultivated in almost all the districts of Tamil Nadu with an area ranging from 1000 hectares to 3000 hectares. The analysis on area distribution across the districts where onion was cultivated revealed that onion was cultivated on more than 3000 hectares in Trichy and Perambalur districts. The area cultivation for onion increased by 6 % and 7 % annually respectively in Trichy and Perambalur districts from 1996-97 to 2010-11. Thus, based on the concentration of area, Perambalur and Trichy districts were purposively selected to study the impact of IPM (Integrated Pest Management) in Onion.

In the second stage, major onion growing blocks from each district were selected. Since the area under onion was high, two blocks were selected in Perambalur district and one was selected in Trichy district. Based on the proportion of area under crops (top two blocks in Perambalur, top first in Trichy) to the gross cropped area the blocks were purposively selected. Then during the third stage, major onion growing villages were selected from each block viz., Irur village of Alathur block, Chattiramani village of Perambalur block and Sengatupatti village of Turaiyur block were selected. The sample size was derived based on the confidence interval method. Sample size was fixed with 10% precision levels and a 95% confidence level with a 0.5 probability. Both primary and secondary data were collected for the study.

The results were summarized under the following sections: (i) Pesticide consumption of India and Tamil Nadu, (ii) General characteristics of the sample households, (iii) Awareness and adoption level of Integrated Pest Management (IPM) in onion, (iv) Benefit cost analysis of onion cultivators, (v) Determinants of adoption of Integrated Pest Management (IPM) in onion, (vi) Economic impact of Integrated Pest Management (IPM) in onion, (vii) Join Economic benefits of IPM to producers and consumers.

6.1 Pesticide Consumption of India and Tamil Nadu

India is the second largest manufacturer of pesticides in Asia after China. The overall growth rate of pesticide consumption for the period from 1989-90 to 2008-09 in the India and Tamil Nadu state was -3.47 percent and -5.43 percent respectively. It may be due to a host of factors associated with technological development particularly pest and disease resistant vegetable crops, policies and an increased tendency to grow vegetables organically.

6.2 General Characteristics of the Sample Households

Sample households were classified into two categories: IPM farmers and non-IPM farmers. The farmers who used some of the IPM components were considered as IPM farmers. The majority of sample respondents were small and medium size farmers. Average size of the land holding varied between 0.82 ha and 12.5 ha for IPM adopters and it was between 0.75 ha and 4.2 ha for non-IPM adopters. Experience of the sample farmers was grouped in to three categories such as less than 15 years, 15-25 years and more than

25 years. Among the 53 IPM farmers, 13 percent of the farmers had up to 15 years of farming experience, 79 percent had between 15 and 25 years and 8 percent had above 25 years of farming experience. Among the 211 non IPM farmers, 14 percent had up to 15 years of farming experience, 78 percent had between 15 and 25 years, and 8 percent had above 25 years of farming experience. The majority of the IPM adopters were more educated farmers. About 83 percent of the IPM adopters had more than primary level of education. More than 60 percent of the non IPM farmers had only primary level of education and 14 percent of the non IPM farmers were illiterate.

The main source of income for both the categories of sample farmers came through the onion cultivation. Share of the onion to the total income was about 78.26 percent in IPM adopters and 75.00 percent in case of non IPM farmers. The share of income from livestock also constitutes a small (10-12.5%) proportion of total income. None of the farmers were employed in the non-farm sector.

Onion is a common vegetable in all of the cropping sequences practiced by the growers in the surveyed area. Onion followed by groundnut was the common cropping sequence at all locations. Most of the farmers grew the Co4 variety of Onion. In the survey area, onion was cultivated in seasons, one during July- September and the other one during October – December. The cultivation of the crop was chosen based on the availability of water. Among the respondents 25 percent of the farmers grew the crop in both seasons and 75 percent of the sample farmers grew only in second season due to unavailability of water. The frequency of application of pesticides also differed among the seasons. The frequency of pesticide use was higher in Oct – Dec (9 sprays) compared to the July – Sep (2 sprays). The growers used various pesticides of different groups in different formulations. Farmers used pesticides frequently since pest infestation was relatively high in onion. Among them Curacron (Profenophos 50% EC) was very popular and it was used by all the farmers. In the study area, the onion cultivators used different combinations of pesticides in each spray. Usually they combined a pesticide and a fungicide; some of the farmers also used micro nutrient mixtures in each spray. Most of the farmers were well aware of the negative impacts of pesticides on environment and human health.

Although nearly 25 percent were aware of the important IPM practice *Trichoderma viride,* only 17.42 percent adopted it. In the same way, 22.35 percent were aware of *Pseudomonas fluorescens,* but only 15.53 percent adopted it. Respectively, 3.03 percent and 1.89 percent of the sample onion cultivators were aware of yellow sticky trap and Vesicular Arbuscular Mycorrhiza (VAM) but only 1.89 percent adopted those practices. In the same way 24.62 percent were aware of neem products and 14.39 percent adopted it. None of them were aware of pheromone traps and hence they were not adopted.

6.3 Awareness and Adoption Level of Integrated Pest Management

The results also showed that though the awareness index was 12.12, the adoption index was only 8.52, which shows only that 75 percent of the technology generated was adopted in the field.

6.4 Benefit Cost Analysis of Onion Cultivators

Economic evaluation was carried out among the fifty three IPM farmers and 211 non-IPM farmers. The IPM farmers were further classified into five sub groups, based on the usage of the IPM components. The IPM farmers adopted six technologies which were recommended by the scientists. The total cost of IPM components for onion was Rs 6405 per ha. The quantities of inputs used in onion cultivation were analysed in order to study whether there is any difference among the IPM and non-IPM farmers. Regarding the planting material, on an average the onion cultivators use 1500kg of onion bulbs per hectare. On an average 60-64 male labourers and 125-143 female labourers were required per hectare of onion. On an average 16-17 hours of machine power was required to produce a hectare of onion. Thrips, leaf miner and cutworms were the common pests, and purple blotch and basal rot were the common diseases in the study area. A huge difference existed between the IPM and non-IPM farmers in the usage of plant protection chemicals. The IPM farmers used only 4.1 litres of chemicals for a hectare of onion cultivation. But non IPM farmers used 5.6 litres of chemicals per hectare and overall the onion cultivators use 5.3 litres of plant protection chemicals for a hectare of onion production. On an average 45 times of irrigation was required for a hectare of onion cultivation. The economics of onion production among IPM and non IPM farmers indicated that the total cost of cultivation did not differ much. There were some differences in the cost of pesticides, but they were compensated by the IPM components. But there was large difference in terms of yield and net income and the benefit cost ratios (BCR) also differ. The BCR for the IPM cultivators was ranging from 2.10 to 2.27 and it was much lower (1.66) for the non-IPM farmers.

Input costs of onion production were estimated for various cultivars. Major inputs were seeds, fertilizers, human labour, machine power, herbicide and pesticides. Both the categories of the onion cultivators spent nearly 19 percent of the total cost of cultivation for pest control. But the share differed among them. Onion IPM farmers spent nearly 15 percent for the chemicals and 5 percent for the IPM components. Non IPM farmers spent the entire share (18.4 percent) of their cost of pest control on chemicals. On an average, the IPM farmers obtained 13.38 tonnes of yield per hectare. The non IPM farmers obtained 10.8 tonnes of onion bulb per hectare. The total cost of cultivation of onion was more or less the same for both the categories of farmers. The IPM farmers incurred Rs 94,861 per hectare of onion. The non IPM farmers incurred Rs 97,333 to produce a hectare of small onion. Since the total cost of cultivation was nearly the same and the yield differences were large, the gross income and the net returns also differ a lot among the three categories of onion cultivators. Onion IPM farmers received Rs 105,839/ha as their net revenue. Non IPM farmers received Rs 64,667/ha as their net revenues.

There was a significant difference existed between IPM and non IPM onion cultivators on all variables such as total cost of production, yield, gross revenue and net revenue. The onion IPM farmers spent Rs 7.09 per kilogram of onion produced, while the net returns were Rs 7.91 per kilogram of onion produced. But the non IPM farmers incurred a cost of Rs 9.01 per kilogram of onion produced, while the net returns was Rs 5.99 per kilogram of onion produced.

The results of partial budgeting indicated that adoption of integrated pest management (IPM) for pest control would bring an additional benefit to the farmers of about Rs. 41,179 per hectare compared to non adoption of IPM by decreasing the cost by Rs. 6824.

To estimate additional costs and returns among the different groups of IPM adopters partial budgeting was worked out between the groups of IPM cultivators and non IPM onion cultivators. The onion IPM adopters got more net returns than non IPM adopters irrespective of the groups. Among the IPM adopters the farmers belong to Group II who use maximum components of the onion IPM practices (*Trichoderma Viride, Pseudomonas fluorescens,* Neem products, Yellow sticky trap/VAM) received more profit than all other farmers and the interesting result was the farmers who were not using *Trichoderma Viride* (Group V) received less profit compared to other farmers. In the same way, the farmers who were not using Pseudomonas fluorescens also received less net returns compared to other group of farmers. The farmers who use only bio-control agents (*Trichoderma Viride, Pseudomonas fluorescens*) received less yield compared to other farmers who use biocontrol agents along with other components. Hence, from the results it can be inferred that the farmers who use all the components of IPM for onion received more net returns.

6.5. Determinants of Adoption of Integrated Pest Management (IPM) in Onion

Probit regression was employed to identify the influential factors determining farmers' decisions to adopt Integrated Pest Management (IPM) in onion. The results showed that education positively and significantly influence the adoption of IPM. Household size was found to be positively correlated to IPM adoption due to increased availability of labour. The household members who were 17 years old and above will participate in on-farm labour activities. Availability of labour was a potential factor for adoption of sustainable agriculture technologies. Hence, the household size was disintegrated into four groups and in the present study, the household size with age between 11 to 16 years positively and significantly influences the adoption of IPM. Access to extension service positively and significantly influences the adoption of IPM in onion. The significant negative coefficient of choosing a pesticide with the advice of pesticide dealers indicates that farmers getting more advice from pesticide dealers were less inclined to adopt IPM. This suggests that pesticides dealers were not recommending the IPM technology, which may be because of lack of knowledge or may be with the intention of increasing their sales.

6.6 Economic Impact of Integrated Pest Management (IPM) in Onion

The Economic impact of integrated pest management in onion was examined by using ATE (Average treatment effect) analysis and it was done with propensity score matching (PSM). IPM adopters have a significantly higher yield than the non-adopters. The results of nearest neighbour matching indicated that onion IPM farmers obtained 2503 kg higher yield per hectare than the non-IPM farmers. The results from kernel based matching (KBM) and radius based matching (RBM) indicated that the yield obtained from the onion IPM cultivators was higher by 2470kg/ha and 2632kg/ha respectively.

The net income of onion IPM growers was significantly higher than the non-IPM farmers. The results of nearest neighbour matching indicated that the onion IPM farmers received Rs 40,746 more net income than the non-IPM farmers in a hectare. The results from kernel based matching (KBM) and radius based matching (RBM) indicates that the net revenue obtained from the onion IPM cultivators was higher by Rs 40,549/ha and Rs 41,521/ha respectively. The amount spent by the onion IPM growers for pesticides is significantly lower than that spent by the non-IPM cultivators. The results of nearest neighbour matching indicated that due to the adoption of integrated pest management (IPM) in onion the cost for pesticide expenditure was reduced by Rs. 6847/ha. The results from kernel based matching (KBM) and radius based matching (RBM) indicates that the IPM farmers spent Rs 6828/ha and Rs 6841/ha less than the non-IPM farmers respectively.

To identify the relative effect of the groups of IPM farmers, multiple simultaneous treatments were conducted. The relative effect of IPM in onion on yield, net returns and pesticide expenditure with different matching procedures indicated that the yield and net returns for the group of IPM farmers were significantly higher than for the non-IPM farmers. It was also found that the farmers belonging to the second group received relatively higher yield and net returns than the other groups of farmers.

Among the groups of the farmers, those who did not use *Trichoderma viride* received significantly lower yield and net returns than others and also the farmers who did not use *Pseudomonas fluorescens* received significantly lower yield and net returns than others. Hence it can be concluded that the farmers who use *Trichoderma viride* and *Pseudomonas fluorescens* with yellow sticky trap or VAM received higher yield and net returns and their pesticide expenditure were also reduced. These multiple treatment results substantiate the results of partial budgeting. Regarding the pesticide expenditure, there was no significant difference, but the pesticide expenditure of the group of partial IPM farmers is significantly lower than for the non-IPM farmers.

6.7 Joint Economic Benefits of IPM to Producers and Consumers

To measure the aggregate social benefits of integrated pest management research on onion, economic surplus analysis was carried out. The return to investment was also calculated for the change in consumer and producer surplus over time that results from technological change in onion. The economic surplus analysis was carried out for the survey area (Perambalur and Trichy districts) and for the whole state (Tamil Nadu). Even for the surveyed area, two types of analysis were conducted. The first one was for the current period (2008-2012) and the second one was for the next 15 years. Under a closed economy assumption, the benefits of the IPM cropping strategy were evaluated from 2008-2012 for the study area (Perambalur and Trichy districts). The net present value of the potential research is Rs. 6.23 crores and the internal rate of return (IRR) is 250% for an adoption rate of 8%.

The potential research benefits from 2008-2022 for the surveyed area generated by IPM in onion were projected to be about Rs. 41.11 crores for an adoption rate of 20% and increase proportionally with the adoption rate. The maximum benefits expected can reach Rs. 94 crores with an adoption rate of 60%. The internal rate of return (IRR) was also increase proportionally with the adoption rate. It varies from 256% for an adoption rate of 20% to 303% when the adoption rate reaches 60%. The potential research benefits generated by IPM from 2008-2022 for Tamil Nadu in onion were projected to be about Rs. 182.39 crores for an adoption rate of 40% and increases proportionally with the adoption rate. The maximum benefits expected can reach Rs. 260 crores with an adoption rate of 60%. The internal rate of return (IRR) varies from 677% for an adoption rate of 40% to 746% when the adoption rate reaches 60%. The results of economic surplus also indicated that the size of economic surplus for adopting the IPM strategy in onion was quite large and the consumers gain a larger share (77%) than producers (23%).

Policy Implications

1. The analysis on socio-economic characteristics revealed that onion production provides an important income source for poor and landless households in the rural part of the Tamil Nadu. Low literacy level and high dependence on agricultural production among the surveyed farmers indicate that they are more vulnerable into poverty. Investment in dissemination of integrated pest management (IPM) technologies could improve welfare conditions of vulnerable rural households.
2. Diffusion of information to farmers about the economic benefits of the technologies was essential to achieve high adoption rates. Our results support policies aimed at increasing the adoption rate of IPM technologies or helping producers to reach the potential expected change in yields. Moreover, the membership of producers in grassroot associations which is a platform, where information is diffused needs to be promoted to sustain the projected adoption path. Community participation is a key to successful adoption of IPM, and needs to be sustained by devising an appropriate policy.
3. Results showed that access to extension service positively and significantly influences the adoption of IPM in onion as well as the farmers getting more advice from pesticide dealers are less inclined to adopt IPM. Hence it is necessary that adequate training facilities should be made available and capacity building should be enhanced by training all the extension officials. The training facilities available at TNAU may be utilized by the Department of Agriculture.
4. The farmers have to be educated about the IPM technologies and encouraged to adopt Integrated Pest Management practices. The strategies should be focusing on highlighting the ill effects like environmental hazards of over use of plant protection chemicals and toxicity of the chemicals, besides being economical.
5. The farmers should be educated, particularly to follow safety norms while handling the pesticides. They should also be educated about timely application of pesticides and in using appropriate dosages in order to avoid the development of resistance.
6. Results on impact analysis indicated that a successful transfer of IPM technologies to farmers could increase onion yield and quality.

7. Results on economic surplus indicated that the benefits of onion IPM research were huge and the consumers also benefited. Hence to efficiently address pest and disease problems in onion and to obtain the successful development of IPM technologies, an interlocking virtual network between both public and private sectors is paramount. In this network the national research programs, international development institutions, input dealers, industrial experts and producers need to participate to take into account all aspects of the technology development in production, processing and marketing. Such a network brings all the players together and helps the national research institutions and international agencies to understand the complexity of the problem and design appropriate technologies, so that the producers aware of the technology under development, and input dealers to make available the technologies to the producers.

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Appendix I

Share of Area and Production of Vegetables of Tamil Nadu to India (2010-11)

Vegetables	Area (Share in %)	Production (Share in %)
Chilly	8.40	2.59
Onion	4.20	2.25
Brinjal	1.20	0.77
Okra	0.97	0.70
Tomato	4.42	3.00
Total Vegetables	3.59	6.74

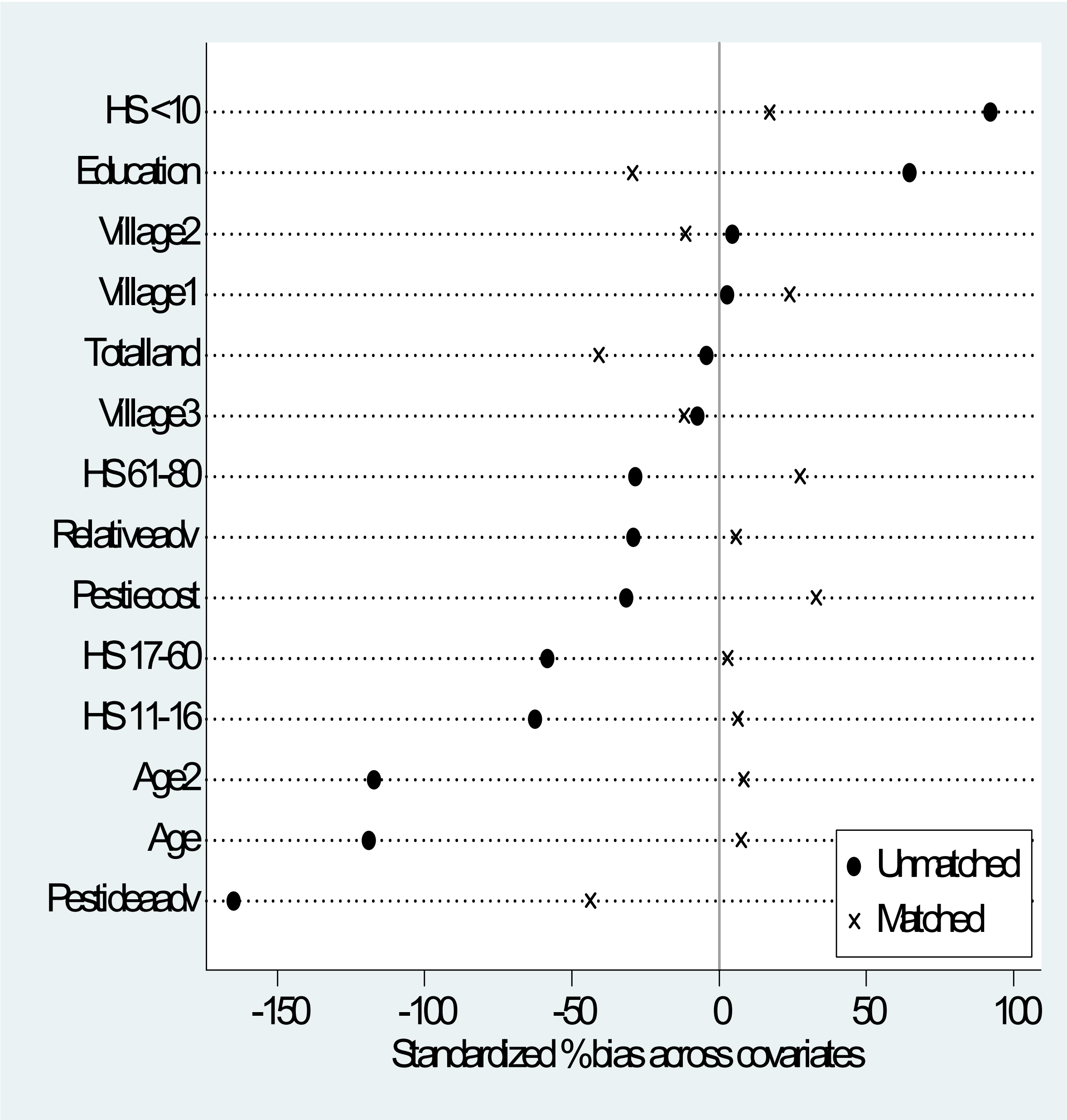
Share of selected vegetables to total vegetables in Tamil Nadu (2010-11)

Vegetable	**Area** (%)	**Production** (%)
Chilly	22.63	0.56
Onion	10.47	4.88
Tomato	7.87	5.06
Brinjal	2.52	0.99
Okra	1.75	0.66

(Source: Season and Crop Report Tamil Nadu, Department of Economics and Statistics, Chennai.)

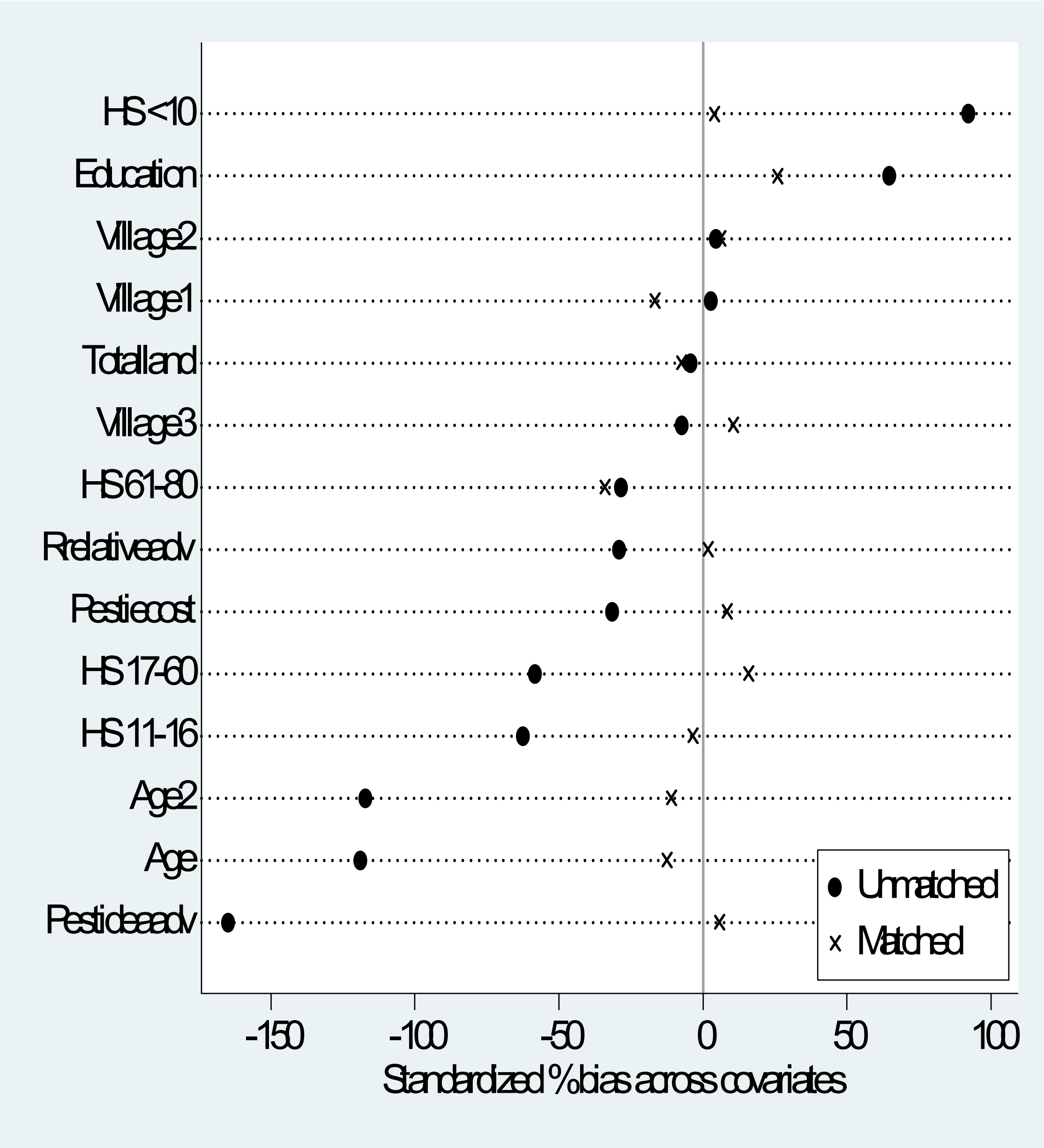
Appendix II

Standardised percentage bias reduction across covariates – Nearest Neighbor Matching



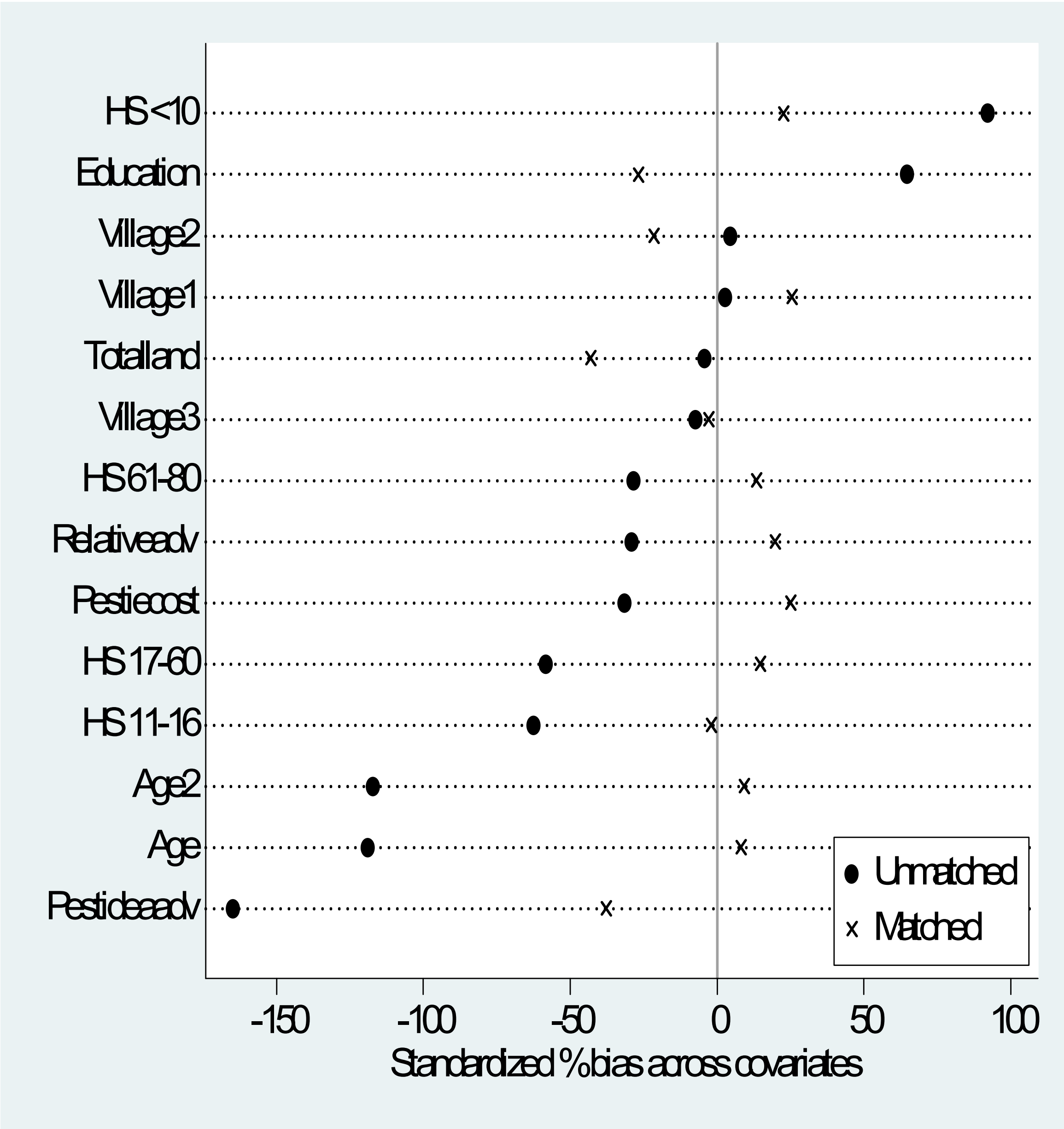
Appendix III

Standardised percentage bias reduction across covariates – Kernel based Matching



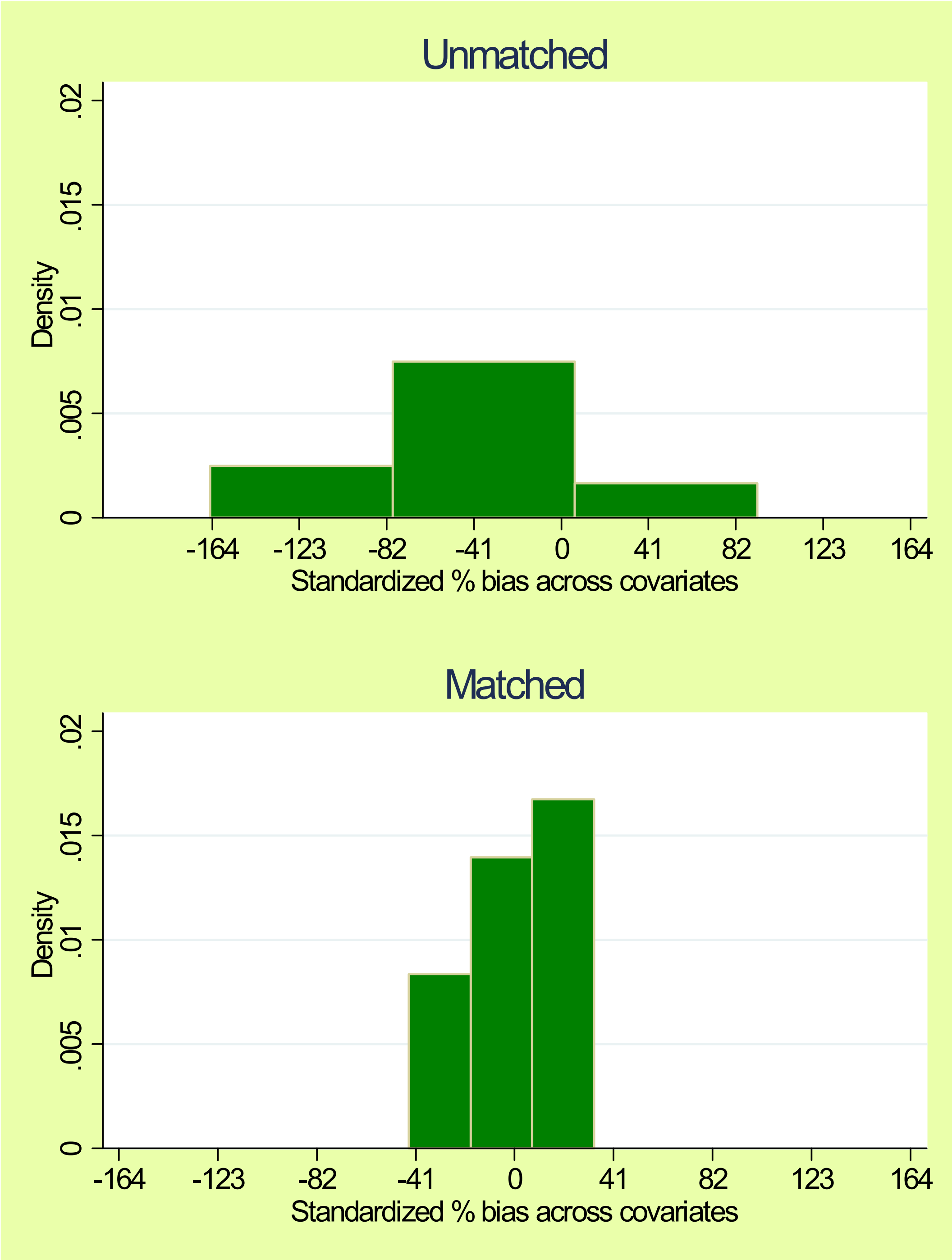
Appendix IV

Standardised percentage bias reduction across covariates – Caliper/Radius Matching



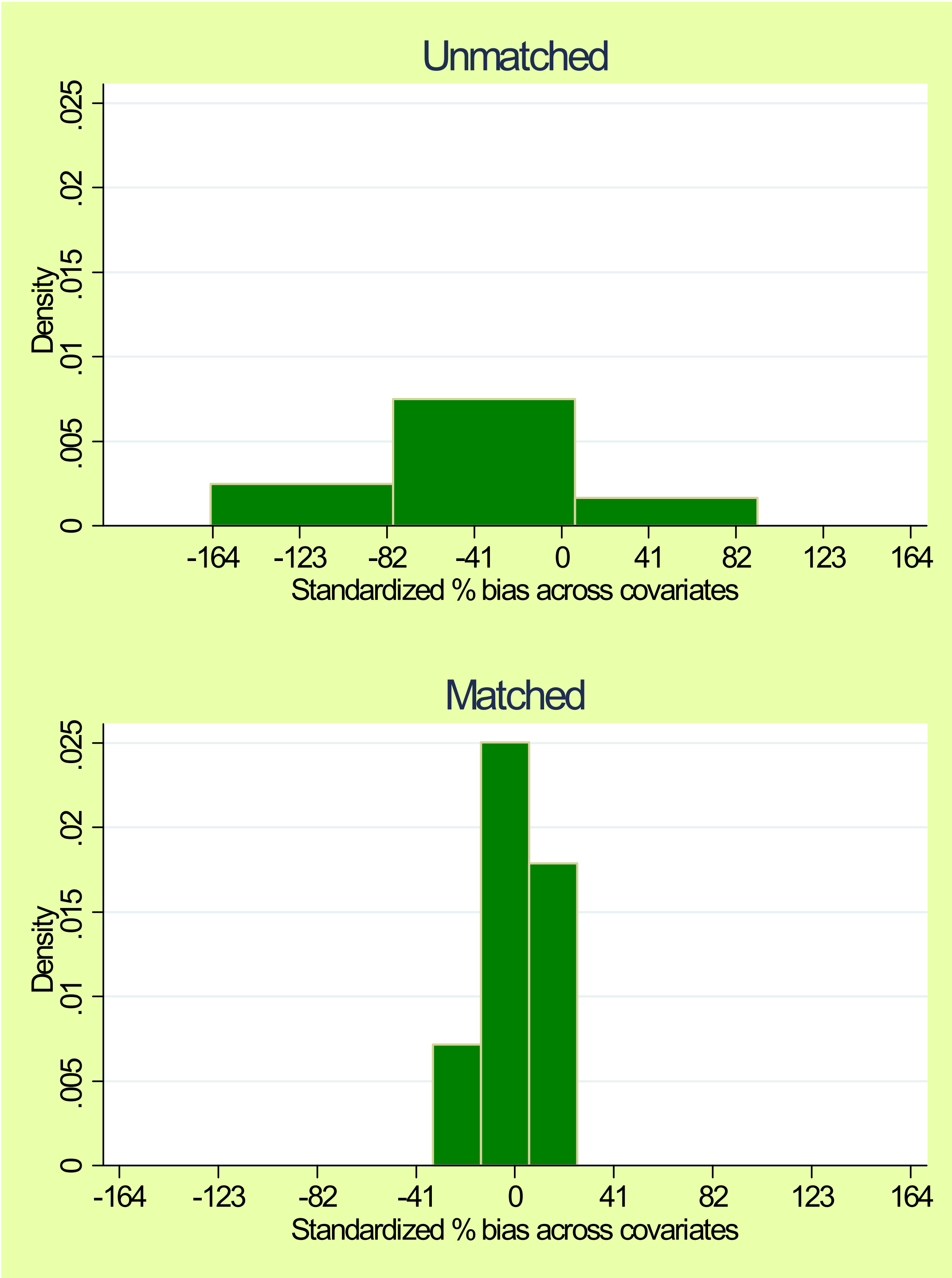
Appendix V

Standardised percentage bias reduction across covariates – Nearest Neighbor Matching



Appendix VI

Standardised percentage bias reduction across covariates – Kernel based matching



Appendix VII

Standardised percentage bias reduction across covariates – Caliper/Radius matching