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SOCIO-ECONOMIC ANALYSIS ON INTEGRATED PEST MANAGEMENT

TAE-JIN KWON*

I. Introduction

Pests cause significant damage to crops. Many countries including Korea heavily rely on pesticides to control a variety of pest species, which are difficult to manage by other means. The introduction of highly intensified production methods and mono-cultural practices has exacerbated pest problems. However, those production systems are inevitable to secure necessary foods in many countries.

On the other hand, an excessive use of pesticides may result in several problems regarding food safety, work force safety, environmental quality, and wildlife health risk. The direct effect associated with human health risk comes from the exposure of farmers in the field during application. The indirect effect results from their chronic accumulation in our bodies through intake of food crops such as vegetables, fruits, and others on which pesticides may have been applied recently and not yet degraded before consumption. Due to inappropriate use of pesticides, many pests have also developed resistance to them, resulting in pest resurgence. The effectiveness of certain chemicals may decline over time due to the development of resistance. The destruction of the natural enemies of pests also results in pest outbreaks, as well as in the emergence of secondary pest. Pesticide application levels have to be adjusted to slow or deter the development of resistance.

In many situations the effectiveness of pesticide use increases, and its side effects decline if pesticide application is based upon

* Senior Fellow, Korea Rural Economic Institute, Seoul, Korea.

continuous monitoring of pest populations. Headley (1972) introduced the notion of economic threshold, the minimal size of pest population that justifies pesticide application economically. Integrated Pest Management (IPM) is a system for accomplishing a specific goal, minimizing the impact of pests by using a variety of control procedures and attempting to decrease the overall chemical input into the environment. The IPM combines chemical, cultural, and biological control practices into one program to manage pest populations. The United States Department of Agriculture (USDA) has set a goal for the use of IPM on 75 percent of U.S. farmland by the year 2000(Jorge).

IPM in Korea has recently been given a boost with the funding and nation wide activities of the United Nations Development Programme (UNDP), Ministry of Science and Technology (MOST), Rural Development Administration (RDA) and the UN Food and Agriculture Organization (FAO) from 1993 to the present. The activities of this program have included training of IPM trainers, farmer IPM training, exchanges of technology and information with related foreign countries, and supporting IPM researches. The project has primarily focused on rice, but does have some activities related to apple IPM development through the Apple Research Institute. Korea is the third highest pesticide user per hectare next to Japan and Belgium. Currently, the third phase IPM program is under implementation.

To apply IPM, farmers need to accept a practice that is usually more management and labor-intensive than the use of chemical agents. Hence farmers will need to see a demonstrable economic payoff. Ultimately, the choice of pest management technology will be influenced by the costs, benefits, and availability of competing alternatives as well as by any rules or other social norms governing its use.

The IPM field data surveyed by the Korean IPM Program

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[1] IPM is defined by the FAO Code of Conduct as: a pest management system that, in the context 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 maintains the pest populations at levels below those causing economically unacceptable damage or loss.

[2] The current pesticide application rate in Korea, 11.8 kg a.i./ha, is third to Japan 19.4 kg a.i./ha (1990), and Belgium 12.1 kg a.i. (1993).

during 1995-96 were used to analyze income effects of IPM. The economic effects of IPM were figured out by the budgeting method. To find out socio-economic effects and farmer's perception on IPM, mail survey was carried out through monitors of the Korea Rural Economic Institute.

The purposes of this study are to review the overall IPM programs and to identify socio-economic effects of IPM in Korea. The paper proceeds as follows. First, the institutional and historical background of IPM is summarized. Then the socio-economic income effects of IPM in particular with regard to small farmers are analyzed by using farm survey data in the following section. The final section provides a summary and policy implications.

II. Progress of IPM in Korea

1. Plant Protection

Investigations of the designated pests are carried out periodically by the regional officers according to the established methods. There are 150 places for rice and 50 places for vegetables and fruits to forecast insect pests and diseases in the country. Besides these forecast plots, 1,341 farm fields were assigned to observe insect pests and diseases in 1997. The results of the investigations are delivered to the Plant Protection Office, Rural Development Administration (RDA).

The Plant Protection Office in RDA issues the national pest and disease occurrence forecast according to the result of discussion by experts of plant diseases and insect pests.[3] Information of 10 kinds of diseases and 11 kinds of insect pests is released for rice, and 17 kinds of diseases and 8 kinds of insect pests for vegetables and fruits. Agricultural pest information is released nationally through broadcastings, newspapers, and internet.

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[3] Agricultural pest information available at the national level consists of reports on occurrence forecasting, warning, and caution. The report on "occurrence forecasting" was released 17 times in 1996, and 18 times in 1997. The report for "warning" is released when a widespread outbreak of major diseases or insect pests is forecast and urgent control measures are required. The report for "caution"is released when a widespread outbreak of critical disease or insect pests is forecast but not to the extent that immediate control measures are required.

Korea belongs to the Asian monsoon region. Summer, which is growing season of rice and many other crops, is characterized by high temperature and high humidity. Such climatic characteristics attribute to the occurrence of diseases and insect pests and consequently bring damage to crop yields. In Korea, 46 diseases, 123 insect pests, and 111 weeds are recorded as potential pests for rice (NIAST).

Average yield losses of rice due to diseases and insect pests are estimated at 106 to 215 thousand tons annually and account for 2.3 to 4.0 percent of the average potential rice production in the 1990s (RDA 1998). However, the damage will be much higher when we consider the damage by weeds.[4] On average, insect pests damage is more serious than diseases in rice production. Plant hoppers reduced rice production by 1.9 percent annually from 1981 through 1990 (Table 1). Sheath blight reduced rice production by 1.2 percent annually from the same period. Besides these pests, important rice pests are rice blast, bacterial leaf blight, rice stripe disease, rice borers, etc.

TABLE 1 Yield Losses of Rice Due to Outbreak of Pests*

Unit: %

Pests	1987	1989	1991	1993	1995	1997	1981-1990
Diseases							
Rice blast	0.05	0.05	0.02	0.30	0.03	0.02	0.10
Sheath blight	1.10	0.80	0.73	0.80	0.62	0.52	1.20
Bacterial leaf blight	0.10	0.07	0.01	0.01	0.01	0.01	0.01
Rice stripe disease	0.01	0.01	0.01	0.01	-	-	0.03
Others	-	0.01	0.01	-	0.02	-	0.03
Total, Diseases	1.30	0.90	0.08	1.10	0.70	0.55	1.50
Insect Pests							
Rice borers	0.15	0.37	0.17	0.20	0.11	0.07	0.12
Plant hoppers	2.90	1.60	2.70	1.20	0.09	1.35	1.90
Rice water weevil	-	-	-	0.26	0.47	0.75	-
Others	0.20	0.62	0.30	0.44	0.13	0.08	0.30
Total, Insect pests	3.30	2.60	3.20	2.10	1.60	2.25	2.30
Total	4.60	3.50	4.00	3.20	2.30	2.80	3.80

* National average yield loss of the potential production was estimated from 1,341 observation fields.

Source: RDA (1998).

[4] The rate of yield reduction by weed infestation is estimated at 30.5 percent in rice when weeds are not controlled (NASTI).

If the agricultural chemicals were not applied at the time of pest outbreaks, yield losses would be greater. As shown in Table 2, rice yield loss due to outbreaks of sheath blight without fungicide application was 4.2 percent during 1981-90. Yield loss due to plant hoppers was 6.9 percent during the same period. The average yield loss due to diseases without fungicide application was 7.2 percent, while yield loss due to insect pests without insecticides was 9.2 percent.

The experimental results indicate that rice yield losses caused by diseases and insect pests were 16.4 percent during 1981-90, when no fungicides and insecticides were applied. The damage rate fluctuates greatly from year to year.

TABLE 2 Yield Losses Due to Pests When No Agricultural Chemicals Were Used*

Unit: %

Pests	1987	1989	1991	1993	1995	1997	1981-1990
Diseases							
Rice blast	0.80	0.90	0.50	7.90	1.60	1.57	1.40
Sheath blight	4.50	3.60	3.50	2.40	3.10	2.81	4.20
Bacterial leaf blight	0.60	0.10	0.06	0.07	0.11	0.01	1.07
Rice stripe disease	0.50	0.10	0.10	0.01	-	-	0.20
Others	0.30	0.40	0.05	0.14	0.07	0.01	0.33
Total, Diseases	7.7	5.1	4.2	10.5	4.9	4.4	7.2
Insect Pests							
Rice borers	2.80	1.90	1.90	1.60	0.80	1.77	2.00
Plant hoppers	7.10	2.50	6.60	1.90	4.50	8.03	6.90
Rice water weevil	-	-	-	0.54	2.10	2.09	-
Others	0.00	0.90	0.40	0.66	0.50	0.35	0.30
Total, Insect pests	9.9	5.3	8.9	4.7	7.9	12.2	9.2
Total	17.6	10.4	13.1	15.2	12.8	16.6	16.4

* National average yield loss of the potential production was estimated from 150 non-control plots in rice forecast fields.

Source: RDA (1998).

2. Changes in Pesticide Use

Synthetic chemical pesticides have been major agricultural inputs since the late 1940s. Approximately $750 million per year is spent in Korea on agricultural pesticides. Insecticides account for about 40 percent of the agricultural expenditures for pesticides while herbicides account for about 30 percent (Table 3).

Pesticides use has engendered concerns about health risks from residues on food and in drinking water and about the exposure to them of farm workers when mixing and applying or working in treated fields. Pesticides use has also raised concerns about impacts on wildlife and sensitive ecosystems.

Korean farmers apply 11.8 kg (in active ingredient) of pesticides, which is much higher than 1.3 kg in the United States, and 2.5 kg in Germany. However, the rate is lower than Japan (19.4 kg in 1990) or Belgium (12.1 kg in 1993). According to an analysis of chemical use in rice farming, 74 percent of farmers apply more pesticides than required, and 25 percent of farmers apply less in rice production (Kwon 1998). Therefore, only 1 percent of farmers apply an appropriate rate of pesticides.

TABLE 3 Overall Pesticide Use in Korea, 1980-97

Unit: ton(active ingredient)

Crop/Pesticide type	1980	1985	1990	1995	1997
Paddy-rice	9,058	7,038	10,964	7,195	8,863
	(56.1)	(38.6)	(43.7)	(27.9)	(35.7)
Horticulture & Others*	7,074	11,209	14,118	18,639	15,951
	(43.9)	(61.4)	(56.3)	(72.1)	(64.3)
By Pesticide Type					
Fungicides	5,448	5,955	7,778	7,909	7,332
	(33.8)	(32.6)	(31.0)	(30.6)	(29.5)
Insecticides	6,408	7,052	9,332	8,892	9,161
	(39.7)	(38.6)	(37.2)	(34.4)	(36.9)
Herbicides	3,374	3,994	5,509	5,817	6,043
	(20.9)	(21.9)	(22.0)	(22.5)	(24.4)
Others	902	1,246	2,463	3,216	2,278
	(5.6)	(6.8)	(9.8)	(12.5)	(9.2)
Total					
	16,132	18,247	25,082	25,834	24,814
	(100.0)	(100.0)	(100.0)	(100.0)	(100.0)

* Vegetables, fruits, and cereal crops excluding rice are included.
Source: Agricultural Chemicals Industrial Association (1981-98).

Since 1991, the total quantity of pesticides has generally decreased, but it continued to fluctuate with changes in planted acreage, infestation levels, and adoption of new products. An estimated 8,863 tons of pesticides were applied to paddy-rice, and 15,951 tons of pesticides were applied to major upland field crops including fruits and vegetables in 1997. Contributing to the decreased use was a shrunken use of fungicides and insecticides on paddy-rice; and decreased paddy-rice acres. During the same period, the total amount of pesticides applied to fruit and vegetables was either unchanged or increased. In 1997, fruit received pesticides more than double the amount of any other crops. Among the major crops exposed to severe pest infestation, however, pesticide quantity per hectare was by far greatest on vegetables.

Insecticides are the largest class of pesticide, accounting for 37 percent of the total quantity of pesticides applied in 1997 (Table 3). Damaging insect populations can vary annually depending on weather, pest cycles, cultural practices such as crop rotation and destruction of previous crop residues, and other factors. Insecticides use on rice has declined (with fewer acres treated) since 1991, but that on vegetables has increased (with expanded area and more intensive treatments per hectare).

Fungicides accounted for 30 percent of the total pesticide use in 1997 (Table 3). Fungicides are mostly used on rice and vegetables to control diseases that affect the health of the plant or quality and appearance of fruit. The 7,332 tons estimated for 1997 is down 23 percent since 1993. A large share of this decline is attributed to decreased diseases on fruits and vegetables. Most paddy-rice fields are treated for diseases, but these treatments account for one-third of the total fungicide use.

Herbicides account for 24 percent of the total active ingredients in 1997 (Table 3). However, farmers paid 31 percent of the total expenditure on pesticides in 1997. Herbicides use has increased while the other type of pesticides have decreased since 1990.

Pesticides designated as "other" which include soil fumigants, growth regulators, desiccants, and harvest aids, had the largest increase in use than any other pesticide classes (Table 3). The use of these pesticides, whose function is not necessarily to destroy a pest organism, increased about 20 percent each year since 1990 and accounts for about 15 percent of the total active ingredients applied to the surveyed crops.

3. Factors Affecting Pesticide Use

Prior to development of synthetic pesticides following World War II, farmers' solution to weeds, insects and diseases problems was primarily the use of physical and cultural practices. Weeds were controlled by tillage, mowing, site selection, crop rotation, use of weed-free seeds, and hoeing or pulling by hand. Insect pests and diseases were controlled through seed selection, crop rotations, adjustment of planting dates, and other cultural practices, but the risk of severe infestations, yield losses, and even abandoned production was still present.

Between 1970 and 1980, chemical pest control was widely adopted on most crops. Public and private research introduced new pesticides that could increase yields and substitute for some farm labor, machinery, and fuel. Higher prices for energy and other manufactured inputs along with rising wage rates promoted this trend. By 1980, herbicide use climbed toward 80 percent of the acreage of rice, vegetables, and many other crops. Insecticides and other pesticides were also widely used.

Although the adoption of pesticides as a crop production technology was nearly completed by the 1980s, many factors continue to affect the use of pesticides. Changes in planted acres or shifts in production between commodities and regions can affect the number of acres treated and quantities applied. Pest cycles and annual fluctuations caused by weather and other environmental conditions often determine whether infestation levels reach treatment thresholds. Changes in pesticide regulations, prices, new products, and pest resistance to pesticides also affect the producer's selection of active ingredients, application rates, and methods of treatment.

Despite the drastic decrease in labor force and arable land, Korean agriculture has achieved a high growth rate in the 1970s and 1980s. Productivity in rice production was markedly increased during the period. The increase in agricultural productivity is partly based on the use of new machinery, fertilizers, and agricultural chemicals. These technical inputs have been supplied at relatively decreased prices than the other inputs. Especially, increasing rate of pesticide price was lower than any other inputs during the 1970s and 1980s (Table 4). The increasing rate of pesticide price was relatively lower than that of wage rate or rice price in the 1990s, although real price of agricultural machinery decreased during the same period. As shown in Table 4, relatively lower increase in pesticide price was one of the main reasons pesticide use has fast increased during the 1970s and 1980s.

Government intervention in the agricultural sector has a significant impact on pesticide use. The dual pricing system provides incentive to produce more rice to the farmers. Under the dual pricing system, farmers use more fertilizers and pesticides to increase productivity under the limited farmland. Increased use of fertilizers makes plants susceptible to pest infestation. Increased pest infestation requires more pesticide application.

Input subsidies have a significant effect on pesticide use. There are several forms of input subsidies, including the financing of fertilizers and pesticides, loans of preferential rates, public funding of research and development, and support for storage facilities. Much of the support was given to the mechanization industry including a low loan rate, and joint utilization organization. Favorable loans were available to those buying tractors, power spraying, and the other farm machineries. As a result, the number of power spraying increased from 108,632 in 1980 to 557,459 in 1995 at annual increasing rate of 11.5 percent. Subsidies on pesticides, fertilizers, and farm machineries

TABLE 4 Comparison of Changing Rates in Agricultural Input and Output Prices

Unit: %

Year	Pesticides	Machinery	Agricultural labor	Price indexes of goods and service paid by farmers	Rice price	Price indexes of farm products received by farmers
1970-80	12.5	16.1	27.7	20.3	23.0	21.2
1980-90	2.0	3.6	10.8	6.6	6.2	6.5
1990-97	2.6	-2.7	11.1	5.1	5.8	4.8
1970-97	5.7	6.3	16.9	11.1	12.0	11.3

caused increased use of pesticides either directly or indirectly.

In many cases farmers may receive double subsidies that result in patterns of production that are intensive in chemical use. One example is rice in Korea where growers receive both output subsidy as well as input subsidy for fertilizers and pesticides.

One of the most important elements of government intervention in agriculture is a support for the public research and extension activities. Public researchers and extension specialists have helped to spread pesticides although they recognize the environmental side effects of pesticide use. However, reduction of the public research and extension infrastructure would not lead to reduced pesticide use.

In most cases, the impact of government policy on chemical use is revealed through its impacts on production. The wide array of government subsidies that increase agricultural production tends to increase chemical use with this production. Moving to more competitive markets, adopting efficient modes of production, and reducing subsidization of agriculture will entail less use of chemicals.

4. Emerging Issues and Problems as a Result of Pesticide Use

During the 1960s and 1970s, the agricultural development agenda was to increase food self-sufficiency and farm income. Within this context, the Green Revolution was launched to increase yields and production of stable foods. Green Revolution in fact led to higher farmers' incomes, food production, and development of national agricultural resources.

From the 1980s up to present, other aspects of the Green Revolution technology have become more apparent: reduction in genetic variability, overuse of agro-chemicals including fertilizers and pesticides, and farmer's dependence on extension staff and government are some of most obvious problems which have emerged.

The heavy use of pesticides in plant protection is known to be causing human health impact, and most likely causing environmental impact. Furthermore, endangered consumers are demanding higher quality food that has less fertilizers and pesticides used during production. In order to lessen the problems being caused by overuse of agro-chemicals, new approach of plant protection called "Integrated Pest Management" has been tested by researchers and farmers are currently testing the IPM methods in training programs throughout Korea.

The World Health Organization reports that roughly three million pesticide poisonings occur annually and result in 220,000 deaths worldwide (WHO). About 67,000 pesticides resulting in twenty-seven accidental fatalities are reported each year in the U.S. (Pimentel et al. 1996). Although it is impossible to place a precise monetary value on human life, the cost of human pesticide poisonings has been estimated. Insurance industry studies have computed monetary ranges between $1.6 and $8.5 million for the value of a "statistical life" in the U.S. Based on this figure and the available data, human pesticide poisonings and related illness in the U.S. are estimated to total about $993 million each year (Pimentel et al. 1996). Both economically and in terms of human life, these poisonings represent an enormous cost for society. A survey shows that around 500 peoples die from pesticide accidents every year (NIAST). The main cause of death from pesticide accidents was committing suicide by taking pesticides. Only 0.5 percent of the total death from pesticide accidents died from pesticide application.[5]

Pesticide accidents were quite common in the rural areas in the 1980s. According to a survey, 19 out of 50 farmers experienced pesticide poisoning during work over 3 years (Lee et al. 1980). Of the 19 farmers, 4 farmers had received treatment in the hospital because the symptom was very serious.

Korea has co-ordinate programs to reduce risk from pesticides on the national level. The Environmental Agriculture Division in the Ministry of Agriculture and Forestry (MAF) has the overall co-ordination responsibility in pesticide regulation.

According to a research, the residue levels were fairly safe ranging between 1/500 and 1/2 of the maximum residue level (MRL) of each crop established in Korea (RDA). One hundred and thirty nine samples of 9 representative agricultural products grown in a

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[5] According to the survey by Sunchunhyang Medical Center, only three persons died from poisoning during the pesticide application work out of the total of 255 persons who died from pesticide related accidents during 1983-87.

vinyl house were samples from cultivating sites and markets of the whole country. Fifteen pesticides were detected from the samples. The soil samples collected from nationwide farmlands were analyzed for monitoring of 51 pesticides for domestic use. Twenty-five pesticides were detected at very low residue level with low detection frequency.

5. Phases of IPM Program

IPM project was initiated in response to increasing cost and overuse of pesticides in Korea. While the current trend is to reduce amounts of pesticides, at the time of the project creation, pesticides use had been increasing.

IPM verification trials have been carried out in 1992 at three Provincial RDAs (PRDA) research stations (Cholla-buk, Cholla-nam, and Kyugsang-nam provinces) and in 1993 and 1994 at eight PRDAs (except Cheju province) to compare conventional control practices with IPM methods. Combined results of these validation trials show that at PRDAs the IPM could reduce pesticide use by 58.1% without significant yield differences.

In order to validate IPM methods as managed by guidance and farmers, IPM training was initiated. The first training of guidance officers was undertaken in 1993 at the Chollanam province PRDA. The training was based on intensive field practice of IPM decision making during each critical crop stage (roughly monthly) during the cropping period. The IPM methods currently being developed for rice in Korea have combined ecosystem management skills with basic production skills.

Since 1993, 92 IPM trainers have been trained in summer field programs, which emphasize hands on activities to manage rice production, pest insects, and disease. IPM training for farmers is conducted in "Farmer Field Meetings" (FFM) that take place in a farmer's field over the entire season.

The 2nd phase IPM program was initiated in 1995. The 1995 Training of Trainers (TOT) was undertaken in two provinces including Kyunggi and Kyungsangnam Provinces. The training was conducted using curriculum developed and tested in 1993 and 1994 TOTs and with the assistance of staff from RDA, and PRDA as well as graduates of the IPM TOTs from earlier years. Field activities and experiments were conducted as in past years with an overall emphasis on the following fields:

* Agronomic methods (fertilizers, irrigation, and varieties)
* Plant compensation (leaf and tiller damage)
* Field ecology (herbivores, natural enemies)
* Disease prediction (environmental and agronomic factors)
* Training methods (adults education, field training methods, and group dynamics)

The main idea taught was that in IPM we use pesticides only when necessary, and use only the low toxic compounds. Most extension officers like to use pesticides to avoid any damage, not just avoid economic damage. There is a need to put responsibility of plant protection on farmers and not on the extension staff so that they don't feel threatened by field injury.

The 3rd phase IPM program was initiated in 1997. It will be continued through at 1999. The basic directions of the 3rd phase IPM program currently being undertaken are:

* Human Resource Development
* Non-rice IPM development program
* Strengthening knowledge basis through exchange of experts and new research
* Establishment of Provincial IPM program

In the first year of the 3rd phase (1997), each province established a working group for the IPM project. The working group includes: PRDA extension director, PRDA research director, plant protection chief, validation team, one IPM trainer that finished the IPM TOT for rice, and a provincial government official. Based on the experience of developing IPM for rice, it is suggested that one specialized crop is chosen in each province. The specialized crops include tomato, cucumber, potatoes, watermelon, pear, apple, persimmon, and orange. Three to five study sites were established for each crop in each province to test IPM methods with weekly visits by IPM expert staff from each province to collect data and make decisions based on the field situation.

III. Socio-Economic Impacts of IPM in Paddy-Rice

1. Perception of Pest Management by Farmers

Field survey was carried out to figure out farmers'attitude of pesticide use and perception on environmental problems including pest management during July 1998. Total of 800 questionnaires were sent to the rice-growing monitors of the Korea Rural Economic Institute by mail, and 351 of them were responded.

Farmers feel that agricultural chemical such as pesticides and fertilizers are the main sources of farmland contamination. In addition, chemical is considered as an important pollutant to contaminating ground water. Farmers feel that plant hopper is the most destructive insect pest for rice. Then rice blast, sheath blight, rice borers, and rice water weevils are considered as major damaging pests. The results are similar to the survey result on the pest observation fields. However, farmers feel that rice blast is the most frequently infesting disease, while plant hopper is the most frequently infesting pest in rice production.

Most farmers thought that they could not produce agricultural product successfully without using pesticides. Pesticide demand is inelastic to the pesticide price. Rice growers answered that a half of them would not reduce the application rate although the pesticide price goes up by 50 percent.

Questions were given to the farmers as to how much they reduced the number of pesticides application compared to 5 years ago. A 50 percent of the total respondents reduced the number of pesticides application than 5 years ago, while 25 percent of them increased the number. The other 25 percent of them are keeping the same number of pesticides application.

Questions were given to the farmers as to how much they reduced the amount of pesticides applied compared to 5 years ago. A 54 percent of rice growers have reduced the amount of pesticides applied than 5 years ago, while 31 percent of them increased the pesticides use.

The timing of pesticide application is very important in pesticide management. Around 50 percent of farmers apply pesticides regardless of pest infestation. It is known that apple growers apply 14-16 fungicide treatments, 9-12 insecticide treatment, and 4-5 acaricide treatments (Lee 1995). The total number of applications per year is around 15-16, since fungicides, insecticides and acaricides are often applied together in a tank-mix. In general, sprays are applied according to the locally published 'spray calendar' which either gives the information on the developmental growth stage of apple tree or in some instances the exact calendar date for fungicide applications. The likelihood of infection based on weather conditions and disease development is not being considered during the time of applying fungicides (Riedl). The timing of insecticide and acaricide sprays also follows a fixed schedule. Growers apply pesticides according to the calendar on preset dates and at regular intervals. Few growers make observations on insect and mite pests in the orchard to establish the best time for spraying or determine the need for a control application by taking counts. Lack of adequately trained advisors and lack of reliable published information about monitoring procedures and treatment thresholds was often indicated as the principal reason why growers still follow the spray calendar instead of applying pesticides according to need.

Rice growers apply 7 different types of pesticides on 4 occasions. On average, 1.8 kinds of fungicides, 2.1 kinds of insecticides, 1.7 kinds of fungicides/insecticides, and 1.4 kinds of herbicides are applied in a season. Survey result shows that a half of them would not reduce current application rates even if pesticide price increases by 50 percent.

A 43.4% of the total respondents were familiar with IPM. A 34.3% of the total respondents had a chance to learn IPM through farmers training courses. Most of them acquired the knowledge from the regional extension offices. A total of 71 percent of rice growers were considering to adopt IPM in the future. It is expected that public or commercial IPM services would be provided in the future as in the U.S. or European countries.

2. Economic Effects of Integrated Pest Management

In the IPM program, pesticide applications are carefully timed and combined with other pest management practices to reduce the need for frequent applications. It is composed of a number of steps:

identifying the pest and its life history, establishing economic injury thresholds, monitoring, scouting and modeling populations, applying control tactics, and assessing the success of the program. It identifies the pests, determines pest populations and damage, and makes pesticide applications only when necessary, using the lowest rate necessary for adequate pest control. Minimizing the amount of pesticide use reduces costs and helps protect the environment. As with any system, IPM is impacted by the development of new technology. The degree of that impact depends on how much the technology affects the component steps of the system. Many of the steps in IPM depend heavily on accurate and timely information and so can greatly benefit from the development of improved methods of accessing and disseminating information.

Recent economic and environmental assessments of pesticides in North America have extended economic analysis to include social costs. One study (Pimentel et al.) estimated that in the United States, U.S. $4 billion is spent annually to prevent U.S. $16 billion in crop losses, yet the social (e.g. health, environment, etc.) costs the result from the use of these pesticides is U.S. $8 billion. Thus U.S. $12 billion is required to prevent U.S. $16 billion in losses. Such studies indicate that costs for pesticides in Korea are probably much higher if the social costs were taken into account.

The economic effect of pest control is calibrated by the difference between yield with control and yield without control in the experimental plots. According to the last 20-year survey data, the economic effect of pest control is estimated to be 14.1 percent of the total production of rice (Table 5). The effect ranges between 6.5 percent and 29.9 percent. The economic effect of pest control was 18.6 percent in the 1970s, 13.3 percent in the 1980s, and 9.3 percent in the 1990s. It was 1,278 billion won or U.S.$ 1.3 billion in 1997. Compared with the total pesticide costs, 275 billion won or U.S.$ 0.3 billion, pest control is beneficial to the farmers in economic aspect.

According to the survey of rice production costs, the share of pesticide cost was 3.6 percent in the 1990s, while it was 2.5 percent in the 1970s. Of course, the share of pest management costs including pesticide cost, labor cost for pesticide application and weeding, and machinery cost is estimated to be around 10 percent of the total rice production costs. However, there was no significant difference in pesticide cost among farm size though the cost was lowest in the largest farm group.

In economic theory, profits can be increased by three methods: output increase, output price increase, and cost reduction. In respect to pest management, it is hard to expect output increase by the adoption of IPM. First of all, let's consider the possibility of output price increase.

TABLE 5 Economic Effect of Pest Control in Rice Production

Year	Total production (thousand tons)	Effect of pest control (%)*	Price (won/80 kg)	Economic effect by pest control (billion won)
1976	5,215	16.5	23,200	261.0
1977	6,006	18.2	26,000	370.8
1978	5,797	22.1	30,000	536.8
1979	5,565	17.6	36,600	478.7
1980	3,550	14.7	45,750	324.1
1981	5,063	8.2	52,160	281.1
1982	5,175	8.2	55,970	309.8
1983	5,404	29.9	55,970	1,178.3
1984	5,682	17.9	57,650	757.6
1985	5,626	18.0	60,530	796.1
1986	5,607	10.2	64,160	476.3
1987	5,493	13.0	73,140	684.1
1988	6,053	6.5	84,840	431.9
1989	5,898	6.8	96,450	501.0
1990	5,606	7.0	105,343	536.7
1991	5,384	9.1	113,207	722.2
1992	5,331	7.0	120,670	576.9
1993	4,750	12.0	124,209	913.8
1994	5,060	8.2	126,700	673.0
1995	4,695	10.5	126,700	776.5
1996	5,323	6.9	131,770	618.8
1997	5,450	13.84	131,770	1,277.9

* Difference between the reduction rates of farm fields and those of non-control forecast plots.

Source: RDA (1998).

According to a survey, price premium of the organic products is ranged between 24 percent and 147 percent (Suh et al.). The rice price produced by organic farming is 24 percent higher in the supermarket as compared to the rice produced by the conventional farming. A 42.3 percent of respondents are willing to pay 20 percent more for the organic rice than the conventional products. The higher the income the higher the willingness to pay for the safer products. The willingness to pay for organic products is expected to increase as national income goes up. As income increases, demand for safer foods and social need for environment-friendly agricultural practices will increase.

A survey was carried out by the research team of the Farm Management Bureau at the Rural Development Administration to compare the production costs and income between the IPM and conventional pest management in rice production (Park et al.). Total of 50 farmers (30 for IPM, 20 for conventional) from 5 regions were selected for a face-to-face interview. The average age of IPM farmers was 44, which is younger than the average age of conventional farmers, 51. The IPM farmers have 2-year experience in IPM farming. The IPM farmers applied less pesticides than conventional farmers did. They did not use either biological method or cultivation of pest resistance varieties.

In respect to the production costs per 10a, the IPM farming was lower by 2.6 percent than tradition farming (Table 6). The IPM farming saved pesticide cost by 28 percent rather than conventional farming, because the average number of pesticide application in the IPM farming was around 60 percent of the conventional farming. And IPM saved labor cost over 10 percent than conventional farming. However, the IPM farming spent more fertilizers and energy than conventional farming. The yield per 10a from conventional farming was even higher by 18 kg or 3.6 percent than from the IPM farming. The income of the IPM farming was even lower by 2.6 percent than that of the conventional farming.

The IPM farming applied pesticides 2.2 times - fungicide 0.8, insecticide 1.1, and herbicide 1.1 - on average, while the conventional farming applied pesticides 3.6 times - fungicide 1.8, insecticide 1.9, and herbicide 1.1 times on average. In case of the IPM farming, 13 percent of respondents applied pesticides only one time, 47 percent applied 2 times, and 40 percent applied 3 times. In case of the

TABLE 6 Comparison of Production Costs and Income between IPM and Conventional Rice Farming

Unit: won/10a

Items	IPM(A)	Conventional(B)	A/B(%)
Gross value of production (a)	755,923	782,230	96.6
Management costs			
Seed	7,641	7,558	101.1
Fertilizers	19,729	18,439	107.0
(organic)	(8,851)	(6,063)	(146.0)
(inorganic)	(10,878)	(12,376)	(87.9)
Chemicals	12,213	16,971	72.0
Fuel, lube, and electricity	3,927	3,549	110.7
Machinery*	72,199	73,684	98.0
Repairs	5,343	4,979	107.3
Hired labor	16,245	18,530	87.7
Custom operations	74,862	75,896	98.5
Other materials	6,276	6,050	103.7
Total, management costs (b)	219,435	231,228	94.9
Residual returns to management and risk (c)	536,488	551,002	97.4
Unpaid labor (d)	100,482	111,689	90.0
Basic production costs per 10a (b+d)	319,917	342,917	93.3
Other costs**	156,287	145,758	107.2
Production costs per 10a	476,204	488,675	97.4
Basic production costs per kg	664	686	93.3
Yield (kg, polished)	482	500	96.4
No. of pesticide application	2.2	3.6	61.1

* Machinery costs include costs for capital replacement, repair, maintenance, and rent for machinery.

** Other costs include land cost, and capital service on fixed and operating capital.

Source: Park, J.S. et al. (1997, 330-338).

conventional farming, 50 percent of respondents applied at least 3 times, 40 percent applied 4 times, and 10 percent applied over 5 times. The survey results show that IPM farming is inferior to the conventional farming in respect to income under current pest management practices.

However, other surveys show different results than the above analysis. Two years survey data by the Korean IPM Program was used for the analysis. Data was collected by the IPM training participants from different regions. Total of 46 samples surveyed in 1995, and 93 samples surveyed in 1996 were used in this study.

In 1995, yield per 10a was 453 kg in the IPM farming, while it was 462 kg in the conventional farming (Table 7). However, management costs per 10a were 148 thousand won in the IPM, which is lower by 17 thousand won than that of the conventional farming. Therefore, the income of the IPM farming was higher by 7,000 won as compared to the conventional farming. The IPM farming saved

TABLE 7 Comparison of Income between IPM and Conventional Rice Production, 1995

Unit: 1,000 won/10a

Item	IPM (A)	Conventional (B)	A/B
Gross value of production	7.4	714	0.99
Management costs	148	165	0.90
Income	556	549	1.01
Yield (kg/10a)	453	462	0.98
Inorganic fertilizer application rate (kg/10a)			
Nitrogen	13.3	15.9	0.84
Phosphorus	7.3	8.3	0.88
Potash	8.8	9.4	0.94
Population of natural enemies (no./m^2)*	272	141	1.93
Population of pests (no./m^2)**	195	121	1.61
Number of pesticide application			
Fungicides	0.8	2.2	0.36
Insecticides	1.0	2.5	0.40
Herbicides	1.0	1.1	0.91
Total	2.7	5.7	0.47

* Includes predators, parasites, spiders, etc.

** Includes plant hoppers, rice stem borer, etc.

more production costs than the value of yield loss by reduction of pesticide application. The average number of pesticide application was 2.7 times in the IPM farming, which is a half of the conventional farming. And fertilizers were applied less in the IPM farming. The population of both natural enemies and pests was higher in the IPM farming than in the conventional farming.

In 1996, yield per 10a was 473 kg in the IPM farming, while it was 483 kg in the conventional farming (Table 8). However, management costs per 10a were 127 thousand won in the IPM, which is lower by 18 thousand won than that of the conventional farming. The IPM farms used less chemicals and fertilizers than the conventional farms. The IPM farms applied pesticides 2.2 times on average, while the conventional farms applied pesticides 4.1 times. Additionally, the rice produced by the IPM farming was sold at higher price compared to the conventional farming. Therefore, the income of the IPM farming was higher by 13,079 won per 10a or by 2 percent than that of the conventional farming. The IPM farming saved more production costs than the value of yield loss by reduction of pesticide

TABLE 8 Income Analysis on IPM and Conventional Rice Farming, 1996

Unit: 1,000 won/10a

Item	IPM (A)	Conventional (B)	A/B
Gross value of production (a)	841,160	846,551	0.99
Management costs			
Chemicals	11,213	22,103	0.51
Fertilizer	22,039	22,787	0.96
(Inorganic)	(10,556)	(12,201)	(0.87)
(Organic)	(11,483)	(10,586)	(1.08)
Others	93,979	100,182	0.93
Total, management costs (b)	127,231	145,702	0.87
Income (a - b)	713,928	700,849	1.02
Yield (kg/10a)	473	483	0.98
Unit rice price received by farmer (won/kg)	1,778	1,753	1.01
Population of natural enemies (no./m^2)	162	79	2.05
Population of insects (no./m^2)	45	26	1.73
Population of pests (no./m^2)	115	81	1.42
Number of pesticide application	2.2	4.1	0.54

application as in 1995. The population of natural enemies in the IPM farming was 2 times more than in the conventional farming. And the population of both insects and pests was higher in the IPM farming than in the conventional farming.

IV. Conclusions

Crop production and income losses due to pests are quite high in Korea. It might be difficult to keep stable crop productivity without pesticides. Since the early 1990s, pesticide risk reduction polices have been promoted, and consumers' demand for safer foods has been increased. As a result of these movements, pesticide use has reduced steadily.

The present status of pest and disease management in Korea can be characterized by the preventive use of broad spectrum of insecticides, fungicides, and herbicides. Often pesticide applications are made on a fixed schedule and not according to the need basis as established by monitoring of pest and disease activity. Due to the intensive use of pesticides, environmental problems became serious and the general publics are requiring less and safe use of pesticides.

The nation-wide pest occurrence forecast information system has contributed to damage reduction due to pests with lesser use of pesticides. In addition, public or co-operative pest control system was very effective in reducing damage from pests in the 1980s. These systems may play an important role in the future to minimize yield losses due to pests with minimum pesticide use by means of established control threshold of each disease or insect pests in every region. Furthermore, the establishment of Integrated Pest Management combined with these systems will give more benefits to the farmers.

IPM program is still in the primitive stage. The long-term goal of IPM is to reduce overall use of pesticides by 50% without yield loss by the year 2005 through changes in national and local policies, training for farmers and guidance officers, and research into new methods of pest management which are not dependent on pesticides.

To accomplish the goal of IPM, national and local government policy reform is necessary. IPM should be the basis of crop protection practices. IPM uses the means of biological, cultural, mechanical, and chemical control to reduce pest populations below economically damaging levels within the constraints of health environmental impact. Crop protection and losses due to pests will be sole responsibility of the farmers. Plant protection guidance officers only provide new technology, field based recommendation, and education. The role of national forecasting system should be confined to transforming collected data and reporting with no recommendation function. All recommendations are the responsibility of country guidance offices based on local field surveys.

The increased dependence on pesticides fostered by agricultural development strategies led over time to the entrenchment of a chemical node of pest control as the dominant paradigm in pest management. Today, many countries including Korea have incentive frameworks that favor pesticide use over the adoption of more environmentally benign IPM approaches. Subsidies and financial supports for pesticides by national, provincial, and local governments should be reduced. Instead, national, provincial, and local governments need to make funds available for research and training on IPM based on the local situation. Quarantine services have to be strengthened to reduce insect, disease, and weed pest introductions. The IPM training program for farmers and guidance have to be strengthened.

A Sustainable Agriculture Promotion Act was established in December 1997 to be implemented at the end of 1998. The law promotes marketing of organic products, low chemical products, and chemical-free products. If we consider the prices of organic products are 20-35 percent higher than the the general products, agricultural products using less chemicals can give more profits to the farmers.[6] However, the proportion of those environmentally safe products remain at less than one percent now.

Taking the need for safe foods in the 21st century into consideration, we should increase the production of environmentally

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[6] A researcher at South Dakota State University compared cash prices for conventional and certified organic commodities during the period 1995 through 1997. The average price premium was 73 percent for corn, 141 percent for soybeans, 74 percent for spring wheat, and 73 percent for oats in 1997.

safe agricultural products. IPM and alternative sustainable farming methods would play more important roles in the stable food production through minimizing crop losses due to pests. Research and development of pesticides and pest management methods, to develop more effective and more environment-friendly techniques, should be promoted.

Future collaboration and discussion will be very helpful for realizing our goals of securing food security and safety, improving farmers' income, producing safe food and reducing the environmental impact of farm practices. It is stressed that the beneficial effects of the IPM go beyond the saving of pesticides and income increasing. Pesticides contaminate agricultural lands, ground water, as well as rivers and reservoirs. The social costs to clean natural resources contaminated by pesticides are huge. It is recognized, however, that although these benefits were real they had not been quantified and that additional research is needed to assess the actual effects of cost saving and environmental protection.

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