A Comparative Study of "Three Reductions Three Gains" and Popular Rice Production Models in the Mekong Delta, Vietnam

Vo Thi Lang, Ngo Thi Thanh Truc, Huynh Thi Dan Xuan, Mai Van Nam

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Abstract

A comparative study of two rice production models being applied in the Mekong Delta, Vietnam, was reported. One was based on a modern approach to control the amount of seed, fertilizers and pesticides to be used. The other was based on a more historical approach, which has often resulted in the use of excess amounts. The results showed that the modern approach, often called "Three Reductions" provided greater economic as well as environmental benefits to society in the form of input savings, especially pollution-related inputs (nitrogen, pesticides) and of output gains (higher rice quality and net benefits).

Key words: Three reductions three gains; Seed rates; Fertilizers; Pesticide; Rice; Mekong Delta; Vietnam.

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1. Introduction

In the last three decades, Vietnam rice production has been increasing continuously, from 11.6 million tons in 1975 to 35.6 in 2004, and the cultivated area has been raised from 5.6 to 7.3 million hectares with average yields from 2.2 to 4.9 tons/ha (Xuan, 2005). This increase in rice quantity has turned Vietnam into one of the most rice exporting nations in the world. Of the areas of Vietnam that contributed to this achievement, the Mekong Delta (MD) has played the main part.

Together with rice production achievement, intensive farming patterns (two to three paddy crops per year) have replaced the traditional farming style (one paddy crop per year). When the planted area increases, input quantity also increases. Seeds, inorganic fertilizers and pesticides are the main material inputs in rice production. They help enormously to promote Vietnam rice production, thereby improving farmer living conditions and raising export rice quantity of Vietnam in general and the MD in particular.

However, intensive farming has caused many problems to the environment and human health when farmers have used a lot of agrochemicals to push up paddy productivity. At present, MD farmers rely completely on chemical fertilizers and plant protection chemicals. They believe that these inputs will help raise paddy yield per hectare, thereby increasing their paddy production and bring about high profit. To raise paddy yield, besides applying new paddy varieties, they increasingly use chemical fertilizers with quantities beyond paddy needs. This is both a wastage and cause of pest increase. When pest increases, they have to use more pesticides to cope with the situation. These two actions push up production costs and reduce profits. On the other hand, the increase in pesticides use implies threat to pesticide applicators', society's and ecology' s health.

In the MD, average inorganic fertilizers per hectare increased from 40 kg in the time of 1976-1981 to 120 kg during the period 1987-1988 and 140 kg in 1992. This figure has still been rising in recent years. Survey data of HCM City University of Economics and experimental data of the Cuulong Delta Rice Research Institute collected from 1996 to now showed that rice farmers have used an average pure nitrogen, phosphorus, potassium (N,P,K) rate of 180-190 kg/ha. The mix of N, P and K is not rational in which overuse of nitrogen fertilizer is an outstanding feature in fertilizer use practice of rice farmers today (Dung, 2000).

As for pesticides use, according to a 1997 survey by Dung, MD farmers used 75 kinds of pesticides, of which there were 28 kinds of insecticides, 17 herbicides and 30 fungicides. On average, each farmer used 1017 grams of active ingredient (a.i.) per hectare for the winter-spring crop, of which insecticides made up 43 % and most of which belonged to groups I and II which have high and moderate toxicity according to the World Health Organization (WHO) classification.

There have been several studies so far focusing on the impact of agrochemical use on productivity and human health as well as on the natural environment in the MD. Their conclusions have had a point in common; that is, pesticide use has had bad effects on farmer health and the environment, especially on water resources (Dung, 1997; Phuong, 2003). These are the external costs that farmers have not calculated in their production costs.

The externalities arising from using excess nitrogen and pesticides on plants can be seen through the effects such as deteriorated health of sprayers, health damage and loss of life of consumers, contaminating surface freshwater and groundwater sources, reducing quantities of useful organisms, etc.

To raise economic efficiency in rice production and reduce detrimental impact of using agrochemicals, a program previously called Integrated Crop Management (ICM) and now simply called “Three Reductions Three Gains” (3R3G) has been developed in some provinces in the MD since 2002. The term “3 Reductions” means reducing three input factors (seeds, inorganic fertilizers, and pesticides) and “3 Gains” obtaining three higher output results (yield, rice quality, and profits). In addition to technical contents, “three reductions”, which is the derivation from theories and practices from universal techniques like high-quality seed, high-yield rice farming technique, IPM method, ...the 3R3G is the association of many knowledge transfer techniques to rice farmers such as multimedia techniques and farmers’ participatory approach through demonstration activities. The program has been carried out in the MD by the local authorities with the help of the Plant Protection Department, the International Rice Research Institute (IRRI) and the Cuu Long Delta Rice Research Institute.

The 3R3G program began after the Plant Protection Department investigated the paddy farming practice of 600 farming households in O Mon and Vi Thuy districts of old Cantho province in 2000. The results showed that many farmers did not follow the recommendations of the Cuu long Delta Rice Research Institute when they applied fertilizers and pesticides in their paddy production, which caused nutrient imbalance in the soil thereby affecting paddy productivity. This practice neither brought farmers efficiency nor protected the environment. The Plant Protection Department therefore studied and proposed the 3R3G program to help farmers reduce production costs, increase rice quality and income. From the 2002-2003 winter-spring crop to 2003-2004 crop, some 82.000 households in O Mon and Vi Thuy districts were distributed instructional documents to carry out this program on an area of nearly 50.000 hectares. After a period of time, with the gained results, the Plant Protection Department associated with local government units to disseminate the program to other provinces in the MD. According to the assessment of the MD Services of Agriculture and Rural Development and the Plant Protection Department, the 3R3G area has so far amounted to 418.481 ha or 15% of the 2004 planted area. Up to now almost all of the MD provinces have more or less applied this model in paddy production.

The clear aim of the 3R3G program when initiated by the Ministry of Agriculture and Rural Development is to change rice-farming practices in the MD to cut costs, raise rice quality, increase farmers' income and protect farmer health and the environment. However, when MD local authorities reported the 3R3G program results, they have almost focused on economic results and with less attention to environmental aspects. In addition, the 3R3G program has not been extensively implemented and accepted throughout the MD yet. Quite a few farmers still hesitate to apply the new practice due to many reasons.

Based on those backgrounds, a comparative study of the 3R3G rice production model and the popular production model was conducted with both economic and environmental considerations. The overall objective of the study was to compare the 3R3G and non-3R3G rice production models with economic and environmental considerations.

Specific objectives:

- To compare quantitatively the two rice production models' results in terms of seed, fertilizers, and pesticides.
- To explore farmers' perception of pesticide effects on their health.
- To compare the economic results of the two rice-production models, especially three targets (yield, rice quality, profit).
- To propose some recommendations in order to improve the "3 reductions 3 gains" program' s outcomes in the MD.

2. Literature Review

This section consists of three main parts. The first part deals with key concepts relating to the subject. The second part is about empirical studies of rice production improvements concerning seed and nitrogen use. The third part mentions impacts of agrochemicals on farmer health and the environment.

2.1 **Some concepts**

Economics is fundamentally concerned about scarcity. Scarcity is generally defined as a limited supply of a good or services. People's needs are diverse and insatiable, but the resources for producing the things they want such as land, labor, raw materials, etc, are limited in supply. If something is scarce, there is not enough of it and it is difficult to obtain it (Curtis M. Jolly, Howard A. Clonts). Scarcity requires that choice must be made between the alternative uses of resources. This has led to the concept of efficiency. There are many terms of efficiency but in this paper we just mention some.

"Technical efficiency refers to the producer's ability to avoid wasting resources by producing as much output as input usage allows, or by using as little input as output production allows. Thus the concept of technical efficiency can have naturally an output orientation or an input conserving orientation" (Bent E. Roland).

"Economic efficiency requires gaining the greatest value of outputs for the given inputs. Economic efficiency requires technical efficiency, but technical efficiency does not automatically imply economic efficiency" [Applied Natural Resource Economics and Management, the University of Sydney].

"Social efficiency requires that all market and non-market values be incorporated into the marginal benefits and marginal costs of production, no matter to whom they accrue. Social efficiency is obtained when marginal benefits equal marginal costs of production. In many cases, when environmental values are concerned, there may be very substantial differences between market values and social values. If we are to have rates of output that are socially efficient, decisions about resource use must take into account both types of costs, the private costs plus whatever external costs arise from adverse environmental impacts" (Field and Olewiler, 2005).

From the above concepts, to raise social welfare, our society should aim at social efficiency, not efficiency in narrow sense.

2.2 **Empirical studies of rice production improvements relating to input reduction**

Today a great majority of rice farmers use modern rice varieties that are high-yield ones with the characteristics of high response to nitrogen fertilizer and high tiller ability. However, these varieties often have a dense canopy structure, which facilitates lodging and disease problems. Yield therefore is not stable and benefits may decline because of high inputs to prevent diseases. The dense canopy creates a humid microenvironment favorable for diseases; especially endogenous pathogens as sheath blight and stem rot that thrive in N-rich canopies (Mew,1991). To deal with this problem, farmers usually use fungicides to prevent yield loss. "It seems to be a fact that the more N fertilizer farmers apply, the more pesticide farmers have to use" (Nguyen et al, 2004). This practice reduces farmers' profit and increases risks to the environment. Facing this problem, rice scientists have given the concept of "healthy rice canopy". This is a newly developing concept. It refers to an idealized canopy with critical physiological features deemed favorable for growth, grain yield, and disease resistance. Nguyen et al. has reviewed some traits like plant architecture, tiller number and leaf area index, and plant nutrients and disease. Past studies showed that a higher plant density as well as higher nitrogen application usually leads to a higher plant height because of the competition for light. Short stature reduces the susceptibility to lodging and increases the harvest index (Tsunoda, 1962). Besides, tillering plays an important role in determining rice grain yield, as it is closely related to panicle number per unit ground area. Moderate tillering facilitates synchronous flowering and maturity, more uniform panicle size, efficient use of horizontal space (Janoria 1989), and reduces disease pressure (Mew, 1991). Nutrient management is very important to high yield but it may affect response of rice to pests as well as development pattern of pest populations due to the change of environments within rice canopy. Among the nutritional factors that influence the level of pest damage in a crop, total nitrogen has been considered to be the most critical (Nguyen et al., 2004).

Based on that concept, Cuulong Delta Rice Research Institute, Vietnam, has tested integrated effects of different seeding rates and N application levels on rice production and disease. Results showed that precise N application (80 kg/ha) with the help of Leaf Color Chart and reduced seeding rate (100 kg/ha or even 75 kg/ha) produced a more healthy rice canopy and more grain yield (Nguyen et al., 2004).

Huan, et al., 2004, in an experiment on farmers' participatory evaluation of reducing pesticides, fertilizers and seed rates in rice farming in the Mekong Delta, Vietnam, in 2001-2002, showed that seed, fertilizers, insecticides and fungicides can be reduced with little effect on yield, thereby allowing higher gross margins. These results provided the basis for launching a national mass media campaign, "Three Reductions", to push up the adoption of these practices in several provinces in the Mekong Delta.

Another study carried out by Phung, Son, and Thuan, 2003, with experiments on various soil types in Cantho, Angiang, and Dongthap provinces, showed that to maintain high yields, levels of 100-120 kg of seed/ha and 80-100 kg of nitrogen/ha in the dry season were recommended. Under the condition of good land leveling, seeding rates can be reduced to 60 kg/ha with no loss of rice yield.

According to technical instructions by agricultural experts, in order to gain better outcomes in rice production, some basic procedures in the 3R3G technique involve (1) Careful land preparation, good seed selection and proper seed treatment; (2) Sparsely sowing by row seeder or by hand at the densities of 80-120kg/ha; (3) Good irrigation control; (4) Pest prevention by the IPM method: only use plant protection chemicals when necessary; (5) Proper fertilizer application. Associating organic and inorganic fertilizers if possible. Applying nitrogen fertilizer using the Leaf Color Chart; (6) Timely harvesting, adequate paddy drying (Angiang Plant Protection Sub-Department, 2005).

2.3 Agrochemical use and its impacts on farmer health and the environment

One of the major types of external costs is the cost inflicted on people through environmental degradation. In rice production, the use of agrochemicals has caused significant impacts on farmer health and the environment. Indiscriminate pesticide use can result in one or more of the following: (1) health impairment due to direct or indirect exposure to hazardous chemicals; (2) contamination of ground and surface waters through runoff and seepage; (3) the transmittal of pesticide residues through the food chain to the farm family and urban consumers; (4) an increase in the resistance of pest populations to pesticides, thereby reducing their efficacy and consequently causing pest outbreaks; (5) the reduction of beneficial insects like parasites and predators, thereby reducing the effectiveness of pest control strategies that attempt to minimize pesticide use. The incidence and magnitude of each of this effect depend on the type of chemicals, frequency and quantities applied and their persistence (Pingali, 1995).

Long-term exposure to pesticides may lead to health problems like eye effects (Morgan, 1977), skin effects (Hamilton, 1982; Bainova, 1982), respiratory tract effects (Hock, 1987; Morgan, 1982; Nemary, 1987; Pingali, Marquez, Palis, and Rola, 1995), cardiovascular effects (Morgan, 1977), gastrointestinal tract effects (Morgan, 1977; Pingali, Marquez, Palis, and Rola, 1995), neurological effects (Morgan, 1977). The pesticide health problems can lower productivity because of the farmer's absence from work during treatment and recuperation and impaired capacity to work.

In addition to pesticides application, rice farmers usually apply great quantities of inorganic fertilizers to ensure or raise rice yields. Nitrogen (N), phosphorus (P), potassium (K) are essential for achieving optimum crop yields. However, applying too much nitrogen or phosphorus to cropland can have adverse effects on the environment. Excess nitrogen and phosphorus in surface waters and nitrogen in groundwater cause eutrophication (excess algae growth) in surface waters and health problems in humans and livestock as a result of high intake of nitrogen in its nitrate form. Eutrophication is the slow, natural nutrient enrichment of streams and lakes. As algae grow and then decompose they deplete the dissolved oxygen in the water. This condition usually results in fish kills, offensive odors, unsightliness, and reduced attractiveness of the water for recreation and other public uses (Baird, 1997).

3. Methodology

3.1 Methods of analyzing data

Hypotheses to be tested**:**

a. The 3R3G farmers use less seed, fertilizers, and pesticides than non-3R3G ones.
b. The 3R3G farmers obtain higher yield, rice quality, and profits than non-3R3G ones.

For the first research objective, 3 main material inputs (seed, fertilizers, and pesticides) were compared quantitatively to see the difference level between the two models. Fertilizers and pesticides quantities were calculated based on their pure matters, that is, N, P, K content in inorganic fertilizers or active ingredients in pesticides. To test the differences between the two models, Mann-Whitney test was used (when the variables are not normally distributed) to compare the means of major variables.

For the second objective, information gathered from the survey about the perception of farmers of pesticide impacts on their health were used for the analysis.

For the third objective, costs and returns analysis was used to compare the economic results of the two models, using Mann-Whitney test. At this stage, yield, net returns, and rice quality were also compared to see if the 3R3G model obtained its aims (3 Gains). Rice quality evaluation was done by means of seed and paddy price. In addition, to explore how input factors affected the profitability of the two rice-production models the profit function was used.

3.2 Method of data collection

The stratified sampling method was used to choose the survey sites. Three provinces in the MD (Cantho City, Angiang, and Soctrang province) that have intensive paddy farming practices were chosen for a survey to gather information for the research. Cantho City was chosen because it was the first province to be selected as a pilot site for testing the 3R3G program by the Plant Protection Department. Angiang was chosen as a study site because it is the province that is now the most dramatically pushing the 3R3G model. Soctrang is a coastal province, selected as a representative for coastal provinces with rice production. In each locality one district was chosen from which one commune was selected. Therefore three communes were sorted out: Thoi Thanh (O Mon district, Cantho City), An Hoa (Chau Thanh district, Angiang province), Truong Khanh (Long Phu district, Soctrang province). Thoi Thanh was the pilot site to test the 3R3G program. An Hoa and Truong Khanh are two communes that have received the direct guidance from local governments to conduct the 3R3G program. The survey was conducted in October 2005 in collaboration with the officers from the local Economic Divisions and Plant Protection Stations in three districts. These officers helped the research team identify which farmers are practicing the 3R3G model and which not. Then the random sampling method was used to choose farmers for interviewing belonging to two separate farmer groups: 3R3G and non-3R3G farmers. The expected number of observations was 240, with 80 for each province consisting of two groups of farmers.

An actual number of 238 farmers were interviewed, of whom there were 146 3R3G farmers (An Giang (57), Can Tho (40), Soc Trang (49)); and 91 non-3R3G ones (An Giang (22), Can Tho (36), Soc Trang (33)). The interviews with questionnaires were conducted at farmers' houses. The interviewers were young lecturers from the School of Economics and Business Administration, Cantho University.

Primary data source:

- Information about the implementation of the 3R3G program in each locality was collected from local authorities such as the Agricultural Extension and the Plant Protection Stations.

- Data were collected by means of a structured questionnaire containing the following information relating to two groups of farmers (3R3G and non-3R3G): rice farming household characteristics, items of rice production costs, input uses, output prices, and farmers' perceptions of impact of pesticides on their health.

Time for each interview was about 45 minutes to 1 hour. Respondents were willing to answer questions but some items took more time to answer than other ones such as detailed information about kinds and quantities of pesticides used in their crops. Some people had their records while other people resorted to their memory as well as their relatives' in the house, so some cases did not reach high-quality pesticide information.

Secondary data source:

Secondary data were drawn from statistical yearbooks, previous studies relating to rice cultivation, input uses and environmental consequences on human health and the environment in Vietnam and Southeast Asia, articles, official reports, government policies on rice production.

4. Results and discussion

4.1 General socio-economic characteristics of the study sites

In general, the characteristics between non-3R3G and 3R3G farmers in the study sites did not differ much, except the number of years of residence, years of rice farming, and household females. Years of residence of sample farmers were considerably different between the non-3R3G and 3R3G models (40 and 42, respectively). Years of rice farming were also different and from this data it seemed that 3R3G farmers had more experience in rice farming than non-3R3G ones. Both types of farmers had a lot of experience in rice growing (over 20 years of experience).

The education level of the surveyed farmers in the study sites was low for both types of farmers. Most of them left school after grade 7. This is common in the MD because of poor conditions and other causes such as bad transportation due to the complicated system of waterways, inefficient state investment in building schools, lack of school teachers, lack of study time due to having to help their parents in cultivating work, etc. This limited their learning capacity in receiving scientific and technological knowledge, hence, reducing the opportunities to improve their income, since farmer education plays an important role in the allocative and technical efficiency of farmers (Welch, 1970; Schultz, 1975).

The household size for the two models averaged 5 persons. Female members made up about 50% of the total. On average, the number of females in the 3R3G model was greater than that of the non-3R3G one, which might suggest that females were more interested in the benefits of the new technique through the effects of cutting inputs costs, reducing pesticides use and exposure thereby protecting their relatives' health.

Table 1: **Characteristics of surveyed farmers in the study sites**

Characteristics	Mean		Std. Dev.		Z statistic
	Non-3R3G	3R3G	Non-3R3G	3R3G	
Years of residence	40.36	42.44	10.48	11.75	-1.80*
Years of rice farming	23.01	26.81	11.82	11.31	-2.29**
Age of respondents ((years)	45.61	47.06	11.52	10.87	-1.55
Education level (schooling years)	6.74	7.10	3.12	3.11	-0.83
Household size ((persons)	5.32	5.45	2.01	1.96	-1.20
Of which: female	2.30	2.82	1.31	1.41	-3.38***
Labor (persons)	4.12	4.28	1.76	1.90	-0.59
Farm size (ha)	2.02	2.27	1.90	3.34	-0.11
Of which: paddy land area (ha)	1.92	2.10	1.77	3.15	-0.36

*,**, ***: Significance level at 0.10, 0.05 and 0.01, respectively.

Source: 2005 survey

Household workers were, on average, 4 persons. This number usually consisted of the father, mother, two adult children, but not all of the children work in the agricultural field. They can work in other fields such as industrial, commercial or educational sectors. We could see later that because of this reason, lack of workers on rice fields, some households could not apply the 3R3G model, as this one required their frequent visits to paddy fields in order to get good results in rice quality and productivity.

4.2 Paddy varieties use in the study sites

Survey statistics showed that rice varieties popular in the study sites were: IR 50404, OM 1490, OM2517, OM2717, OM2718, OMCS2000, OM3238, Tai Nguyen, ST3, ST5, Jasmine 85, etc. Today, most MD farmers have realized the importance of paddy seed for good results in cultivation. They shifted to grow high yielding rice varieties, usually nitrogen-response varieties. These have short growth duration, ranging from 85-110 days.

Table 2: **Seed quantity used in the study sites, 04-05 Winter-Spring crop, kg/ha**

	Mean		Std. Dev.		Z statistic
	Non-3R3G	3R3G	Non-3R3G	3R3G	
Seed quantity	180	142	83	43	-5.29***

***: Significance level at 0.01.

Source: 2005 survey

Survey results indicated that non-3R3G farmers used far more seed quantity than 3R3G farmers. According to the recommendations given by the agricultural extension agency, seed quantities necessary for 1 ha are about 100-120 kg/ha for hand sowing and 70-100 kg/ha for machine sowing (row seeders). Comparing the figures in Table 2 with recommended rates, we could see that seed quantities used by the two groups of farmers were still greater than recommended rates. This was because MD farmers have been familiar with the traditional practice of densely sowing, usually over 200 kg of seed per ha, and changing a long-established practice has not been an easy task for agricultural agencies. However, seed quantities used by the two groups considerably decreased compared with the traditional practice. These figures could reflect part of success of the propaganda effect of the mass media on the 3R3G program in various forms so farmers living outside the demonstration sites (usually consisting of about 30 hectares per site) also absorbed something from this program and applied it to their fields. So it was not easy to separate who completely applied the 3R3G model and who did not.

According to technical instructions by agricultural agencies, to get good results in terms of yield, 3R3G farmers should use row seeders to sow seed. This practice empirically helped reduce seed quantity per ha to recommended rates without reducing rice yields and helped farmers easily take care of their paddy fields. Paddy grown in rows will have enough space for the paddy to develop well and this airy space helps reduce insects density (e.g. brown plant hoppers), thus reducing pesticide needs. It may also reduce nitrogen fertilizer need. However, due to financial difficulties, not many farmers could purchase row seeders although their prices are not expensive and farmers did know the distinct advantages of row seeding compared to hand sowing. In fact, machine sowing takes more sowing time and labor than hand seeding in addition to having a flat land surface. Survey statistics showed that the percentage of farmers using row seeders was much smaller than that of the ones practicing hand sowing. (Appendix, Table A1). That was the reason why surveyed seed quantities did not decline to the expected rates.

The choice of varieties depends on individual farmers. Table 3 reveals some farmers' reasons for choosing a certain variety. High yields, being suitable to local conditions and easy sale were the most common reasons.

Table 3: **Reasons for farmers to choose paddy varieties in the study sites, %**

Reasons	Non-3R3G	3R3G
Agricultural extension	1.0	2.0
High yields	12.0	18.5
Pest-resistance	5.9	6.3
Good rice quality	3.8	2.0
Being suitable to local conditions	10.0	9.6
Easy sale	6.5	14.9

Source: 2005 Survey

As for sources of supplying seeds, data collected showed that non-3R3G farmers usually propagated seeds themselves or bought seeds from other local farmers while 3R3G farmers tended to buy seeds from Seed Stations or local farmers (Appendix, Table A2).

4.3 Fertilizer use in the study sites

The kinds of common inorganic fertilizers in the study sites were: Urea, Phosphate, DAP, Kali, NPK 20-20-0, 20-20-15, 16-16-8, 30-20-5, Con co 1, Con co 2, Con co 3, Con co MTU, Con co cai tao. These fertilizers had different nutrient contents so the amount of pure nutrients in each kind applied per hectare was calculated to get the nitrogen, phosphorus, and potassium quantity/ha.

Table 4: **Comparison of inorganic fertilizer use between the two models, 04-05 Winter-Spring**

Nutrients	Mean		Std. Dev.		Z statistic
	Non-3R3G	3R3G	Non-3R3G	3R3G	
N (kg/ha)	122.30	99.78	89.67	42.10	-3.40***
P_2O_5 (kg/ha)	74.06	63.19	63.31	32.15	-1.41
K_2O (kg/ha)	37.11	46.93	30.75	34.73	-2.41 **.

Source: 2005 Survey

, *: Significance level at 0.05 and 0.01, respectively

Table 4 shows the quantities of N, P_2O_5, K_2O used by non-3R3G and 3R3G farmers in the study sites for the 2004-2005 winter-spring crop. 3G3G farmers used less nitrogen but more potassium than non-3R3G ones. The rising trend of applying potassium was also reflected in a study conducted by Huan et al. (2004). The mean difference of P_2O_5 was not significant. This meant that the 3R3G program had good effect on the quantity of nitrogen fertilizers but less effect on phosphorus used in growing paddy. As we mentioned earlier, MD farmers tend to overuse nitrogen fertilizers compared to recommended rates proposed by agricultural institutions such as Cantho University or the Cuu Long Delta Rice Research Institute so one of the aims of the program was to reduce nitrogen fertilizers to the recommended rates. The inorganic fertilizer rates for the dry and wet seasons recommended by Cantho University were as follows:

Table 5: Recommended inorganic fertilizer quantities in rice production in the MD, kg/ha.

Nutrients	Alluvial Soil		Acid sulphate Soil	
	Dry season	Wet season	Dry season	Wet season
N	120	100	100	80
P_2O_5	30	50	50	80
K_2O	30	30	30	30

Source: Seminar document: Measures to raise summer-autumn yields in the MD. 2003. School of Agriculture, Cantho University.

Most of rice land in the MD belongs to the first category (Alluvial Soil). Non-3R3G farmers tended to use much more nitrogen fertilizers than 3R3G farmers and they did not reduce N to recommended rates while 3R3G farmers cut down N better. Both types of farmers used much more phosphorus than recommended rates. For K_2O, the amount used in the 3R3G model was higher than the non-3R3G model and much higher than the recommended rate. This data shows that rice farmers still use inorganic fertilizers wastefully. According to instructional documents given in training courses, to reduce nitrogen fertilizer quantity to recommended rates, farmers can compare the color of paddy leaves with the colors in The Leaf Color Chart supplied to farmers by local agricultural agencies to choose appropriate nitrogen amount. For P_2O_5 and K_2O, there were no concrete instructions like that.

Information from the survey showed that MD farmers usually relied on their experience to choose rates of fertilizers applied on their fields (Appendix, Table A3). A considerable number of 3R3G farmers also applied fertilizers according to agricultural experts' advice and the Leaf Color Chart and a smaller number of non-3R3G farmers did too. Here the results showed that the two groups of farmers used the Leaf Color Chart to determine necessary nitrogen quantity to be applied, as this tool was usually free given to them.

To analyze more concretely (Table 6), in O Mon district, Cantho City and Long Phu district, Soctrang province, fertilizer quantities of the 3R3G model were much smaller than those of the non-3R3G model. But in Angiang province, total fertilizers did not differ between the two groups. This could be due to the impact of the strong propagation of 3R3G program in Chau Thanh district, Angiang province, non-3R3G farmers also reduced their quantity of fertilizers themselves. If comparing the nitrogen rate used by Angiang farmers with the recommended rates of Cantho University, we could see that the An Giang rate was within the recommended rates. For example, recommended rates of nitrogen fertilizer in the MD by Cantho University was 100-120 kg of N per ha in Winter-Spring crop while Angiang farmers used some 104 kg of N. This meant that An Giang farmers absorbed technological advances more actively than other localities' farmers, which reflected the strong effort of An Giang government in pushing its agricultural economy. Up to now, Angiang has been considered as the most rice-producing province in Vietnam. This may be due to the dynamics of Angiang government in propagating agricultural scientific and technological advances to its farmers.

Table 6: **Inorganic fertilizer use in the study sites, 04-05 Winter-Spring crop, kg/ha**

Nutrients	Cantho		Angiang		Soctrang	
	Non-3R3G	3R3G	Non-3R3G	3R3G	Non-3R3G	3R3G
N	134.53	96.52	105.10	102.22	120.42	99.60
P2O5	77.03	48.83	66.67	67.32	75.73	70.41
K2O	46.27	45.03	49.48	60.52	18.85	32.07

Source: 2005 Survey

The choice of types of fertilizers also depends on farmers' experience. The data collected indicates that a great percentage of respondents chose kinds of fertilizers to buy based on the knowledge of fertilizer usage left to them from their parents or combined with what they learned from the media. But this data also showed that a considerable percentage of 3R3G farmers chose types of inorganic fertilizers through lessons learned from 3R3G training classes, organized by local agricultural extension or plant protection stations (Appendix, Table A4).

4.4 Pesticide use in the study sites

Rice farmers usually apply various kinds of pesticides to cope with pests. Table 7 indicates the quantity of pesticides used in the 04/05 winter-spring paddy crop. There was no significant difference in total as well as individual kind of pesticide use between the two models. In fact, non-3R3G farmers could use pesticides much more than 3R3G ones since when interviewing non-3R3G farmers, we noticed that although these people said they had applied many kinds of pesticides, especially insecticides, they could not well remember some of the names of kinds of pesticides they had used for the crop. Most farmers did not usually keep their records adequately due to low education so they could not fully recall their pesticide use.

Table 7: **Quantity of pesticides used in the 2004-2005 winter-spring crop (gram a.i./ha)**

Kinds of pesticides	Mean		Std. Dev.		Z statistic
	Non-3R3G	3R3G	Non-3R3G	3R3G	
Herbicide	202.37	228.97	338.15	347.64	-1.59 NS
Insecticide	240.11	213.90	319.81	392.23	-0.51 NS
Fungicide	521.61	423.40	684.10	683.35	-1.43 NS
Total pesticides	971.10	886.27	842.40	816.89	-0.80 NS

NS: non-significance

Source: 2005 Survey

Frequency of pesticide applications

Table 8 shows that the number of insecticides and fungicides applications was significantly different between the two groups of farmers in 3 provinces. However, there was no significant difference in the number of spraying herbicides and mixed pesticides. In this survey, the two groups of farmers used fungicides the most times, as in the 04-05 winter-spring crop, blast disease developed heavily.

Table 8: **Number of Pesticide Applications of MD farmers (04-05 winter-spring crop) (times**)

	Mean		Std. Dev.		Z statistic
	Non-3R3G	**3R3G**	**Non-3R3G**	**3R3G**	
Herbicide	1.18	1.07	0.54	0.62	-1.51
Insecticide	2.32	1.69	1.65	1.30	-2.77***
Fungicide	2.90	2.13	1.68	1.28	-3.45***
Mixed	0.69	0.74	1.49	1.36	-0.76
Total	6.07	5.21	2.91	2.93	-2.27**

, *: Significance level at 0.05 and 0.01, respectively.
Source: 2005 Survey

Data on the number of pesticide applications by province are shown in Table 9. At the study site in Omon district, Cantho City, 3R3G farmers applied more times of spraying insecticides and fungicides than non-3R3G ones. This result did not reflect the expectation of agricultural officers when they launched the 3R3G program in this site. This site was one of the first pilot sites of the program in Cantho province in 2002, but now, when reviewing the results of that program, we saw that some of the farmers that had attended 3R3G classes at that time did not apply the program any more. These farmers gave some reasons for that, for example lacking direct family workers to frequently take care of their paddy fields by applying the knowledge of integrated pest management transferred in IPM training classes. The 3R3G program is partly based on IPM knowledge to reduce pesticide applications, apart from seed reducing method. This requires frequent visits to paddy fields to monitor pest development to have timely intervention. If farmers cannot do that, they usually take preventive measures by spraying insecticides when they see some insects appearing on their fields. Besides, the distinction between the two groups of farmers here is not clear, since in Omon district, when the "3 reductions" program was launched, all of rice farmers were transferred 3R3G techniques. We chose farmers to be 3R3G or non-3R3G to interview based on their answers that they are applying the former technique or not. This could be the appropriate explanation for Cantho's paradoxical case of heavy pesticide application between the two groups of farmers.

Table 9: Pesticide Applications by province, 04-05 winter-spring crop, times

	Cantho			Angiang			Soctrang		
	Non-3R3G	**3R3G**	**Z statistic**	**Non-3R3G**	**3R3G**	**Z statistic**	**Non-3R3G**	**3R3G**	**Z statistic**
Herbicides	1.25	1.28	-1.05	1.18	1.23	-0.45	1.31	1.24	-2.07**
Insecticides	1.72	2.50	-3.67***	2.79	2.44	-1.53	3.67	1.27	-2.96***
Fungicides	2.26	3.03	-2.89***	3.60	2.71	-2.97***	3.70	1.69	-2.26**
Mixed	1.75	3.11	-0.77	2.50	2.60	-2.33**	3.56	1.43	-0.73
Total	4.64	5.97	-4.51***	7.32	6.61	-1.03	8.68	3.21	-2.74***

, *: Significance level at 0.05 and 0.01, respectively.
Source: 2005 Survey

At the study sites in Angiang and Soctrang, the number of applications of almost all kinds of pesticides of sample 3R3G groups was smaller than that of non-3R3G groups. This could be due to these two survey sites were the areas that received strong support from the local governments such as training, seed grant, technical advice from agricultural extension officers or plant protection officers, leaflets, etc. Especially in the study site in Soctrang province (Truong Khanh commune), the number of pesticide applications dropped sharply from 8.68 to 3.21 times. Up to now, Soctrang has not yet developed the 3R3G program on large scale like Angiang province. To push up the 3R3G model in the whole province, the provincial authorities chose Truong Khanh commune as a focus point to concentrate their effort of directing the program to get good results in order to use it as a good example for the rest of farmers in the province to follow. Therefore, they provided fund and necessary personnel to this site. This drastic reduction in pesticide applications was the result of that strong guidance.

Farmers' Perception and Behavior in Pesticide Application

The survey results showed that the perception of the two farmer groups of the impact of pesticide on their health was different. The non-3R3G group did not pay much attention to adverse effects of pesticide use on their health. The percentage of the "No Effect" response of the first group (14.3%) was greater than the second group (8.2%) while that of "Much Effect" response of the first group (25.3%) was much smaller than the second group (40.4%). The symptoms that farmers usually suffered were eye and skin irritation, headache, dizziness, fatigue and sleeping trouble (Appendix, Table A5). This helped explain why 3R3G farmers chose the 3R3G technique to improve their health conditions.

Table 10: **Farmers' perception of their health with prolonged pesticide use, %**

Degree of effect	Non-3R3G	3R3G
No effect	14.3	8.2
Very little effect	4.4	2.7
Little effect	17.6	21.2
Moderate	36.3	25.3
Much effect	25.3	40.4
Extremely large effect	2.2	2.1

Source: 2005 Survey

From that perception, actions to protect their health also differed between the two groups. Table 11 shows that among those who used protective equipment when spraying, the number of 3R3G farmers was greater than that of non-3R3G farmers. And within each group, the number of users was much greater than that of non-users. For non-users belonging to the non-3R3G group, two common reasons for not wearing protective equipment were no necessity and no information about protective equipment while for non-users within 3R3G group, no comfort and no necessity were the main reasons.

Table 11: **Farmers' use of protective equipment when spraying pesticides, %**

Equipment Users/Non Users	Non-3R3G	3R3G
Users	64.8	80.8
Non-users: due to	35.2	19.2
- No money to buy	1.1	-
- Discomfort	-	5.5
- No necessity	5.5	3.4
- No knowledge of pesticide impacts	-	0.7
- No information about protective equipment	6.6	0.7

Source: 2005 Survey

During pesticide spraying, farmers usually wore a protective kit consisting of: protective helmets, mouth & nose covers, trousers and shirts with long sleeves, of which mouth covers and full clothing were the most used. 3R3G farmers tended to wear more protective components than non-3R3G farmers. This showed that 3R3G farmers' awareness of harmful effects of pesticides was greater than that of non-3R3G farmers. (Appendix, Table A6).

As for choosing kinds of pesticides, MD farmers relied on some sources of information besides their experience, of which information from agricultural extension officers, television and input sellers were the main bases. Next was the radio. Newspapers and seminars had the least impact on farmers, as these means could not compete with television that is very popular in rural areas (Appendix, Table A7).

4.5 Farmers' Perception in choosing rice production models

To explore farmers' thoughts about the 3R3G program, the questionnaire had a section relating to farmers' behaviors toward the program. Following were some reasons for farmers to adopt or not adopt the program.

For 3R3G farmers, they paid first attention to cutting costs, then to increasing their income, and then protecting health. A considerable number of respondents also said that they adopted the program partly because there was encouragement from local authorities (Appendix, Table A10).

As for non-3R3G farmers, when asked about why they did not apply the program, farmers of this group gave many reasons. The most common reason was that they did not receive help from the local government. This help was usually represented in the form of training classes, technical advice from agricultural extension officers, free leaf color charts, subsidized row seeders and seed. In fact, to carry out the 3R3G program throughout the country, the state agencies and research institutes have provided financial as well as technical support to farmers involving in pilot projects. Then, from these farmers, the outcomes would be spread to other farmers living outside the project areas. Because of the budget limitations of each locality and the determination level of its local government, the impact of the 3R3G program differed in different provinces. It seemed that freshwater provinces carried out this program more strongly than brackish water ones. Soctrang province was a typical example. Truong Khanh commune of Long Phu district in Soctrang is now a pilot site where Soctrang government has directed the 3R3G program. Only farmers in the project area received special technical and material help from local authorities to engage in the 3R3G model. Hence, farmers outside the project area continue to keep their traditional model _ dense sowing, nitrogen and pesticide overuse.

Besides the above reason, there were many other reasons for which farmers refused to adopt the new model, for example, lack of family labor, fear of yellow snails, inappropriate land conditions, being unable to control irrigation, being familiar with the old model, not trusting the new model, etc. Lack of family labor was a cause that some households could not follow the new model because the pursuit of it required a lot commitment to the field. Fear of yellow snails was also a farmers' concern as they were afraid that these snails would eat young seedlings in case of sparsely sowing, which would lead to yield loss (Appendix, Table A11).

4.6 Comparative analysis of the two rice production models

4.6.1 Costs and returns analysis

By means of costs and returns analysis, the analytical results of the economic indicators of the two models were shown in Table 13. It was hypothesized that the 3R3G model brought higher yields to 3R3G farmers but in this paper the results show that the mean yield difference is not statistically significant. It is known that paddy yields depend on many factors besides physical inputs. Pest outbreak, bad irrigation, drought, flood, lack of monitoring, etc. can cause yield loss. So farmers may not obtain high yields if their paddy fields fall into disadvantageous conditions. Although there were no clear differences in yield, rice returns were higher for 3R3G farmers.

Table 12: Rice Production Results in the study sites, 04-05 Winter-Spring Crop

Items	Mean		Std. Dev.		Z statistic
	Non-3R3G	3R3G	Non-3R3G	3R3G	
Yields (kg/ha)	7,840	7,700	948.88	1,063.67	-1.08
Returns (VND)	16,279,000	17,137,000	2,767,753.60	3,861,523.29	-1.82*
Seed cost (VND)	461,000	438,000	265,802.92	205,510.41	-0.90
Pesticide cost (VND)	676,000	573,000	426,085.94	337,599.77	-1.41
Fertilizer cost (VND)	2,288,000	1,898,000	1,611,864.77	808,751.93	-2.53**
Labor cost (VND)	1,158,000	1,267,000	436,276.17	521,789.03	-1.50
Other cost (VND)	620,000	766,000	591,000.62	702,068.09	-1.29
Total cost (VND)	5,206,000	4,941,000	1,861,335.02	1,338,787.61	-1.08
Net returns (VND)	11,073,000	12,196,000	2,928,151.51	3,894,827.71	-2.35**
Cost/kg of paddy (VND)	670	650	237,22	195.66	-0.56
Net returns/Cost ratio (times)	2.46	2.72	1.70	1.45	-2.28**
Net returns/Return ratio (times)	0.67	0.70	0.11	0.11	-2.28**

Source: 2005 Survey

*, **: Significance level at 0.10, 0.05, respectively.

Notes:

Returns = Yields in kg * price per kg

Total costs = seed, pesticide, fertilizer, labor and other costs

Net returns = Returns – Total costs

This could be explained that the 3R3G technique has brought better-quality rice so its output got higher price than that of non-3R3G technique, which leads to greater returns. Rice quality is also reflected in seed price. Good eating rice varieties sell higher price. Table 14 shows the statistically significant differences in seed and paddy price between the two models. From this table, we can say that, in general, 3R3G farmers used better-quality seed and produced better-quality rice than non-3R3G ones.

Table 13: Seed and paddy price in the study sites, 04-05 Winter-Spring Crop, VND/kg

	Mean		Std.Dev.		Z statistic
	Non-3R3G	3R3G	Non-3R3G	3R3G	
Seed price	2612.7	3197.94	743.03	1201.91	-3.75***
Paddy price	2076.67	2244.14	250.37	364.85	-4.23***

***: Significance level at 0.01

Source: 2005 Survey

In Table 13, seed cost between the two models is not significantly different since 3R3G farmers used lesser seed rate but their seed price was higher so these two factors offset each other, thus narrowing the gap between the two models' seed cost.

As for fertilizer cost, since 3R3G farmers used much less nitrogen fertilizer than non-3R3G ones, they endured less fertilizer cost. The remaining costs like pesticide cost, labor cost, other cost, total cost and cost per kg of paddy were not significantly different between the two models.

Since 3R3G farmers obtained higher return and endured similar total costs, they got higher net returns, net return/cost ratio, and net return/return ratio. Therefore, generally speaking, the 3R3G model has saved material input cost, raised rice quality, and increased returns, net returns, compared to the non-3R3G model.

In fact, when analyzing data results by province (Appendix, Table A14), we saw that the outcomes were not similar for each province. The survey site in Soctrang province seemed to reach the most targets set by the program advocates. These targets were formulated based on the experimental results of the new techniques tried by volunteer farmers at demonstration sites in Cantho and some other provinces. During testing stages, farmers usually received lots of support under various forms from extension workers and their fields were well monitored so the results were quite convincible. But when the program was launched extensively, due to lack of continued support for larger areas, farmers have not stuck to initial advice from experts and they applied the techniques arbitrarily. That may be one of the reasons why cost and return analysis results for Cantho did not follow the general trend when pooling data from 3 provinces.

As for Angiang, the analysis results did not show clear differences between the two models. As said earlier, this might be due to no clear boundaries between people who completely apply 3R3G technique and those who apply the traditional practice, as the guidance and propaganda work of local agencies in Angiang was relatively good so farmers that did not officially join the 3R3G group in receiving technical advice from and reporting results to extension workers also imitated similar techniques applied by the 3R3G group.

Some environmental benefits from the 3R3G model

As said in the literature review, social efficiency requires the balance between marginal benefit and marginal cost of the use of resources but it is a challenge to calculate all benefits and all costs relating to producing goods. So in this paper we just mentioned some benefits arising from savings of material inputs as well as from reducing pesticide applications in the 3R3G model.

Through the 3R3G model, farmers saved a considerable amount of seed (38kg/ha) and nitrogen fertilizer (22.5 kg of nitrogen/ha), compared to the non-3R3G model. With the MD paddy land area of 1,500,000 ha and 2 paddy crops/year we have 3,000,000 ha of paddy/year. If we multiply this figure by the above input savings, we will save 114,000 tons of seed, 67,500 tons of pure nitrogen per year for the MD. These are socially and environmentally significant numbers. With seed savings, we can use this bulk for other purposes such as for hungry people, for husbandry, etc. With nitrogen fertilizer savings, if we did not produce this quantity, our society would save a lot of inputs for turning out this product and the environment would be less polluted. In addition, reducing the number of pesticide applications will improve health conditions of sprayers as well as the surrounding environment. So the 3R3G model can help MD farmers as well as society to reduce economic and environmental cost, thus bring considerable benefits to society.

4.4.2 **Regression analysis of the two rice production models**

Making good profit is one of the most important goals of any business entity. To explore which rice-production model brought more profits to rice farmers and how input factors influenced the profitability of each model, the following profit function was used:

$$net = a_0 + a_1 seedc + a_2 laborc + a_3\, ferc + a_4\, pestc + a_5\, otherc + a_6\, yield + a_7\, RG$$

where:

net = net returns of the 04-05 winter-spring crop, VND/ha

seedc = seed cost, VND/ha

laborc = labor cost, VND/ha

ferc = fertilizer cost, VND/ha

pesc = pesticide cost, VND/ha

otherc = other cost, VND/ha

yield = paddy yield, kg/ha

RG = dummy variable for the 3R3G model (RG =1 if 3R3G model, = 0 if non-3R3G)

a_0, a_1, a_2, = regression coefficients indicating the impact of each independent variable on the dependent variable, net.

The results of the regression analysis were:

1. **Model 1**: including all observations of the 3R3G and non-3R3G models in the three provinces (n=235)

Net = -845757.4 + 1.2841seedc – 1.1313***laborc – 0.7376***ferc – 0.7049pesc

(-0.5066) (1.6076) (-2.9530) (-4.6584) (-1.4483)

- 0.8193***otherc + 1957.6130***yield + 1269465.0469***RG

(-2.9285) (10.6118) (3.3040)

$Adj.R^2 = 0.4021$

Note: Values in parentheses are t-value

***: Significant at 0.01 level

The variables with significant coefficients were laborc, ferc, otherc, yield, and RG. Labor cost, fertilizer cost, and other cost had negative impacts on net returns. Meanwhile, yield and 3R3G practice had positive impacts on net returns.

2. **Model 2**: non-3R3G model (n = 91)

Net = -832573.4422 + 0.4914seedc – 1.0039**laborc – 0.7944***ferc

(-0.4339) (0.6119) (-2.0560) (-6.0333)

-1.1641**pesc – 0.3429otherc + 2002.0077***yield

(-2.3335) (-0.9580) (8.9822)

$Adj.R^2 = 0.5750$

, *: Significant at 0.05 and 0.01 level, respectively.

In this model, the variables of laborc, ferc, pesc, and yield had significant coefficients. Labor cost, fertilizer cost, and pesticide cost had negative impacts on net returns while yield had positive impact on net returns.

3. **Model 3**: 3R3G model (n = 144)

Net = -265498.4262 + 2.0905seedc – 1.0218*laborc – 0.6175*ferc

(-0.1087) (1.5490) (-1.8220) (-1.7818)

-0.3532pesc – 1.0003**otherc + 1945.2751***yield

(-0.4420) (-2.5474) (7.3050)

Adj.R^2 = 0.3193

*, **, ***: Significant at 0.10, 0.05 and 0.01 level, respectively.

In the 3R3G model, laborc, ferc, otherc, and yield are the variables with significant coefficients. Labor cost, fertilizer cost, and other cost had negative impacts but yield had positive impact on net returns.

In summary, the 3R3G model has brought better profits to rice farmers. In both models, yield and seed cost had positive impacts on net returns although seed cost' s impact was insignificant. On the other hand, if the significant level of 15% is accepted in agricultural areas, seed cost' s impact in the 3R3G model on net returns is more significant than in the non-3R3G model. This could be inferred that 3R3G farmers used better-quality seed thereby producing better-quality rice and gained better price, which more positively affected the profitability of the 3R3G model.

Limitations of the study:

This study only compared the results of the two rice production models in terms of 3 input factors and 3 output outcomes with cost and return analysis, not covered all the cost farmers have endured during production process such as costs generated from spraying pesticides that have had adverse effect on farmers' health. This study also could not evaluate social cost and benefit of the two rice production models due to lack of data and specialized knowledge.

5. Conclusions and recommendations

5.1 **Conclusions**

Through the comparative analysis of the two rice production models in the study sites in the MD in terms of 3 input factors (seed rate, fertilizers, and pesticides) and 3 output outcomes (yield, rice quality, and profit), the survey results indicated that the 3R3G model used less seed rate, nitrogen quantity, pesticide applications, and obtained higher rice quality and profit than the non-3R3G one. However, potassium quantity was more and the aims of reducing pesticides quantity and raising yield were not reached although the number of pesticides applications reduced. This could be explained by some arguments. First, there could be some inexact data during data collection.

Second, perhaps there was a gap between conducting demonstration sites and applying the new model on a large scale in the MD. In demonstration stages, there was often close monitoring of responsible agencies on technical processes to be implemented, but in extensive application stage, these agencies could not afford the cost of monitoring as well as cost of supporting, so the outcomes were not as good as in demonstration stages. However, with the input savings and rice quality and profit obtained, the 3R3G model has brought considerable economic and environmental benefits to MD farmers.

5.2 **Recommendations**

Although the 3R3G program has been applied in the MD for about 3 years, the level of reaching its 3R3G targets has not been very high, especially seed rates. The recommended seed rates ranged from 70-120 kgs/ha depending on machine sowing or hand sowing, while average surveyed seed rates were 142 for the 3R3G model and 180 for non-3R3G. To reduce the gap between recommended rates and actual rates, row seeders need to be improved so that it could be technically and economically accepted by farmers. As for fertilizers, technical experts should study whether the trend of using more potassium is rational and whether it affects environmental quality, thereby offering the right N-P-K formula for rice production in specific regions. To reduce the use of pesticides, pest-resistant rice varieties need studying to be put into use besides propagating the adverse impacts of pesticide use on farmers' health and the environment. For more farmers to wear protective equipment while spraying pesticides, this needs to be improved in terms of convenience as well as price. To convince more farmers to adopt the new model, more demonstration sites need to be established (like Truong Khanh commune, Soctrang province, case).

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APPENDICES

Table A1: **Ways of paddy sowing in the study sites, 2004-2005, %**

	Cantho		Angiang		Soctrang	
	Non-3R3G	**3R3G**	**Non-3R3G**	**3R3G**	**Non-3R3G**	**3R3G**
Hand sowing	100.0	92.5	87.0	56.1	78.8	83.7
Machine sowing	0	7.5	13.0	42.1	21.2	10.2

Source: 2005 Survey

Table A2: **Sources of seed, %**

Sources	**Cantho**		**Angiang**		**Soctrang**	
	Non-3R3G	**3R3G**	**Non-3R3G**	**3R3G**	**Non-3R3G**	**3R3G**
Self-seed propagating	25.0	27.5	15.8	30.3	12.2	17.8
Seed Stations	19.4	7.5	61.4	18.2	34.7	37.7
Local farmers	55.6	52.5	19.3	57.6	42.9	36.3
Seed Production Companies	-	12.5	7.0	-	-6.1	8.2

Source: 2005 Survey

Table A3: **Farmers' bases to choose rates of fertilizers, %**

	Cantho		**Angiang**		**Soctrang**		**Region**	
	Non-3R3G	**3R3G**	**Non-3R3G**	**3R3G**	**Non-3R3G**	**3R3G**	**Non-3R3G**	**3R3G**
Experience	91.43	70.00	90.48	78.57	93.75	74.42	92.05	74.82
Other farmers	17.14	-	-	7.14	3.13	2.33	7.95	3.6
Agricultural extension	8.57	65	28.57	51.79	9.38	60.47	13.64	58.27
Leaf Color Chart	11.43	45	19.05	37.5	15.63	25.56	14.77	35.97

Source: 2005 Survey

Table A4**: Farmers' Bases to choose kinds of fertilizers, %**

Reasons	Can Tho		An Giang		Soc Trang		Region	
	Non-3R3G	**3R3G**	**Non-3R3G**	**3R3G**	**Non-3R3G**	**3R3G**	**Non-3R3G**	**3R3G**
Experience	100.0	80.0	90.9	82.5	87.9	65.3	93.4	79.0
Other farmers	16.7	2.5	22.7	5.3	9.1	10.2	15.4	6.2
Agricultural extension	11.1	55.0	27.3	56.1	15.2	49.0	16.5	53.4
Low price	2.8	5.0	4.5	5.3	3.0		3.3	3.4
Family budget	-	-	4.5	-	-	-	1.1	-

Source: 2005 Survey

Table A5**: Symptoms experienced after farmers' pesticides application, %**

	Cantho		**Angiang**		**Soctrang**		**Region**	
	Non-3R3G	**3R3G**	**Non-3R3G**	**3R3G**	**Non-3R3G**	**3R3G**	**Non-3R3G**	**3R3G**
Without symptoms	62	52.78	46.15	42.86	61.54	54.76	58.9	50

With symptoms:	38.24	47.22	53.85	57.14	38.46	45.24	41.1	50
- Eye irritation	23.08	50	11.11	59.09	22.22	44.44	20	51.2
- Skin irritation	23.08	19.44	22.22	31.82	22.22	33.33	22.5	28.8
- Headache	7.69	5.56	33.33	9.09	11.11	13.33	15	9.6
- Dizziness	30.77	11.11	22.22	13.64	16.67	11.11	22.5	12
- Vomit	-	11.11	11.11	4.55	11.11	x	7.5	4.8
- Fever	-	-	-	2.27	-	-	-	0.8
- Convulsion	-	-	-	2.27	-	-	-	0.8
- Hard breath	23.08	8.33	11.11	4.55	5.56	x	12.5	4
- Heart trouble	7.69	5.56	x	2.27	5.56	4.44	5	4
- Sleep trouble	30.77	13.89	11.11	15.91	11.11	6.67	17.5	12

Source: 2005 Survey

Table A6: **Kinds of equipment used when spraying pesticides, %**

Items	Cantho		Angiang		Soctrang		Region	
	Non-3R3G	**3R3G**	**Non-3R3G**	**3R3G**	**Non-3R3G**	**3R3G**	**Non-3R3G**	**3R3G**
Protective helmets	11.1	12.5	31.8	22.8	12.1	12.2	16.5	16.4
Mouth and nose covers	63.9	72.5	54.5	70.2	54.5	85.7	58.5	76.0
Clothes (long sleeves +trousers)	61.1	67.5	36.4	54.4	48.5	77.6	50.5	65.8
Raincoats	2.8	-	-	1.8	12.1	8.2	5.5	3.4
Eye glasses	2.8	20.0	13.6	5.3	6.1	4.1	6.6	8.9
Gloves	2.8	7.5	13.6	5.3	9.1	6.1	7.7	6.2

Source: 2005 Survey

Table A7: **Information sources for MD farmers to choose pesticide application, %**

Information Source	**Can Tho**		**An Giang**		**Soc Trang**		**Region**	
	Non-3R3G	**3R3G**	**Non-3R3G**	**3R3G**	**Non-3R3G**	**3R3G**	**Non-3R3G**	**3R3G**
Experience	83.3	67.5	81.8	70.2	72.7	67.3	79.1	68.5
Agricultural extension	8.3	47.5	31.8	52.6	12.1	44.9	15.4	48.6
Input sellers	25.0	15.0	22.7	8.8	21.2	10.2	23.1	11.0
Other farmers	11.1	2.5	9.1	12.3	12.1	6.1	11.0	7.5
Radio	2.8	5.0	13.6	10.5	6.1		6.6	5.5
Television	30.6	22.5	59.1	36.8	30.3	22.4	37.4	28.1
Newspapers	-	-	-	1.8	3.0	2.0	1.1	1.4
Seminars	11.1	-	4.5	-	12.1	-	9.9	-

Source: 2005 Survey

Table A8: **Farmers' perception of their health with prolonged pesticide use, %**

	Can Tho		An Giang		Soc Trang		Region	
Degree of effect	**Non-3R3G**	**3R3G**	**Non-3R3G**	**3R3G**	**Non-3R3G**	**3R3G**	**Non-3R3G**	**3R3G**
No effect	5.6	10.0	22.7	8.8	18.2	6.1	14.3	8.2
Very little effect	8.3	5.0	4.5	3.5	-	-	4.4	2.7
Little effect	30.6	17.5	9.1	26.3	9.1	18.4	17.6	21.2
Moderate	25.0	17.5	36.4	24.6	45.5	32.7	35.2	25.3
Much effect	25.0	47.5	27.3	36.8	27.3	38.8	26.4	40.4
Extremely large effect	5.6	2.5	-	-	-	4.1	2.2	2.1

Source: 2005 Survey

Table A9: **Farmers' reasons for not using protective equipment when spraying pesticides, by province, %**

Reasons	Can Tho		An Giang		Soc Trang		Region	
	Non-3R3G	3R3G	Non-3R3G	3R3G	Non-3R3G	3R3G	Non-3R3G	3R3G
No money to buy	1,0	-	0,0	-	0,0	-	1,1	-
Discomfort	7,0	7,5	13,6	7,0	9,1	2,0	14,3	5,5
No necessity	3,0	2,5	9,1	5,3	0,0	2,0	5,5	3,4
No knowledge of pesticide impact	-	0,0	-	1,8	-	0,0	-	0,7
No information about protective equipment	3,0	0,0	1,0	1,8	6,1	0,0	6,6	0,7

Source: 2005 Survey

Table A10: **Farmers' Reasons for choosing the 3R3G production model, %**

Reasons	Cantho	Angiang	Soctrang	Region
To increase income	57.5	73.7	63.3	65.8
To cut costs	92.5	89.5	91.8	91.1
Local encouragement	35.0	36.8	42.9	38.4
To protect health	30.0	24.6	30.6	28.1
To imitate other people	20.0	14.0	6.1	13.0
Being given some material support	-	1.8	2.0	1.4

Source: 2005 Survey

Table A11: **Farmers' Reasons for choosing the traditional production model, %**

Reasons	Cantho	AnGiang	Soctrang	Region
No help from the state	38.9	40.9	24.2	34.1
Lack of family labor	8.3	18.2	12.1	12.1
Fear of yellow snails	38.9	9.1	9.1	20.9
Inappropriate land conditions	22.2	4.5	21.2	17.6
Unable to control irrigation	2.8	9.1	9.1	6.6
Familiar with the old model	11.1	9.1	12.1	11.0
Not to trust 3R3G model	-	22.7	12.1	9.9

Source: 2005 Survey

Table A12: **Comparison of seed and paddy price in 04-05 winter-spring crop by province, kg/ha**

	Seed price			Paddy price		
	Mean			Mean		
	Non-3R3G	**3R3G**	**Z statistic**	**Non-3R3G**	**3R3G**	**Z statistic**
Cantho	2308.57	2417.5	-0.25	2164.36	2113.25	-1.01
Angiang	3112.73	3922.11	-2.45**	2280.45	2456.25	-3.79***
Soctrang	2601.56	2969.32	-2.37**	1845.15	2102.81	-3.56***

Source: 2005 Survey

***: Significance level at 0.01

Table A13**: Rice production economics in the study sites**

Items	**An Giang**			**Can Tho**			**Soc Trang**			**Region**		
	Non 3R3G	**3R3G**	**Z statistic**	**Non 3R3G**	**3R3G**	**Z statistic**	**Non 3R3G**	**3R3G**	**Z statistic**	**Non 3R3G**	**3R3G**	**Z statistic**
Yields (kg/ha)	7,760	7,400	-1.42	7,330	7,880	-2.64***	7,870	8,370	-1.77	7,840	7,700	-1.08
Returns (VND/ha)	17,697,000	17,851,000	-0.67	15,529,000	17,112,000	-2.62***	14,358,000	17,622,000	-3.56***	16,279,000	17,137,000	-1.82*
Seed cost (VND/ha)	522,000	545,000	-0.18	376,000	461,000	-3.03***	420,000	363,000	-0.26	461,000	438,000	-0.90
Pesticide (VND/ha)	803,000	704,000	-0.54	349,000	543,000	-3.35***	734,000	603,000	-0.98	676,000	573,000	-1.41
Fertilizer (VND/ha)	1,775,000	2,019,000	-1.22	1,684,000	2,674,000	-3,43***	2,228,000	1,927,000	-2.52**	2,288,000	1,898,000	-2.53**
Labor cost (VND/ha)	1,201,850	1,154,000	-0.31	1,505,000	1,128,000	-2.81***	1,162,000	1,206,000	-0.32	1,158,000	1,267,000	-1.50
Other cost (VND/ha)	715,000	635,000	-0.77	558,000	657,000	-0.83	513,000	1,094,000	-3.40***	620,000	766,000	-1.29
Total cost (VND/ha)	5,017,000	5,057,000	-0.81	4,471,000	5,463,000	-2.86***	5,058,000	5,194,000	-0.53	5,206,000	4,941,000	-1.08
Net Returns (VND/ha)	12,679,000	12,794,000	-0.30	11,058,000	11,649,000	-1.04	9,300,000	12,428,000	-3.70***	11,073,000	12,196,000	-2.35**
Cost/kg of paddy (VND)	651	670	-0.30	617	691	-1.54	663	624	-0.27	670	650	-0.56
Net Returns/Cost ratio (times)	3,17	2.75	-0.37	2.66	2.37	-1.13	2,05	2,74	-2.18**	2.46	2.72	-2.28**
Net Returns/Return ratio (times)	0,71	0,70	-0.37	0.71	0.68	-1.13	0,63	0,70	-2.18**	0.67	0.70	-2.28**

Source: Calculated from the 2005 survey data
, *: Significance level at 0.05, 0.01, respectively.

Correlation matrix

cor yield seedrate larate ferrate pesrate if RG==0
(obs=90)

	yield	seedrate	larate	ferrate	pesrate
yield	1.0000				
seedrate	-0.0716	1.0000			
larate	-0.0096	0.3276	1.0000		
ferrate	0.0719	0.0331	-0.0371	1.0000	
pesrate	0.0286	0.0590	0.0909	0.0784	1.0000.

or yield seedrate larate ferrate pesrate if RG==1
(obs=142)

	yield	seedrate	larate	ferrate	pesrate
yield	1.0000				
seedrate	-0.0371	1.0000			
larate	-0.2361	-0.1327	1.0000		
ferrate	0.0723	-0.0801	0.1092	1.0000	
pesrate	0.0940	-0.0525	-0.0766	0.1568	1.0000

cor yield net seedc laborc ferc pesc otherc if RG==0
(obs=91)

	yield	net	seedc	laborc	ferc	pesc	otherc
yield	1.0000						
net	0.6002	1.0000					
seedc	0.0088	0.0198	1.0000				
laborc	-0.0413	-0.1997	0.1805	1.0000			
ferc	0.1281	-0.3521	-0.0319	0.0759	1.0000		
pesc	-0.1232	-0.2667	0.0784	0.0455	0.0172	1.0000	
otherc	0.0358	-0.0488	0.0452	-0.0390	-0.0488	0.1932	1.0000

cor yield net seedc laborc ferc pesc otherc if RG==1
(obs=144)

	yield	net	seedc	laborc	ferc	pesc	otherc
yield	1.0000						
net	0.4994	1.0000					
seedc	-0.0201	0.1305	1.0000				
laborc	-0.1745	-0.2836	-0.2178	1.0000			
ferc	0.1503	-0.0794	0.0250	0.1360	1.0000		

```
        pesc |   0.0309  -0.0057  -0.0014  -0.1518   0.1219   1.0000
      otherc |   0.1993  -0.0984  -0.0258   0.0961   0.0671  -0.0223   1.0000
```

Note:
Yield (kg/ha), seedrate= seed rate (kg/ha), larate = labor rate (man-day/ha), ferrate = fertilizer rate (kg/ha), pesrate = pesticide rate (kg/ha)

Regression results

1. **3R3G and non-3R3G model**

```
. reg net seedc laborc ferc pesc otherc yield  RG

      Source |       SS       df       MS              Number of obs =     235
-------------+------------------------------           F(  7,   227) =   23.48
       Model |  1.2664e+15     7  1.8092e+14           Prob > F      =  0.0000
    Residual |  1.7487e+15   227  7.7036e+12           R-squared     =  0.4200
-------------+------------------------------           Adj R-squared =  0.4021
       Total |  3.0151e+15   234  1.2885e+13           Root MSE      =  2.8e+0
> 6

------------------------------------------------------------------------------
         net |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       seedc |   1.284054   .7987574     1.61   0.109    -.2898725    2.857981
      laborc |  -1.131281   .3830966    -2.95   0.003    -1.886162   -.3764013
        ferc |  -.7376227   .1583419    -4.66   0.000     -1.04963   -.4256149
        pesc |  -.7049394   .4867205    -1.45   0.149    -1.664007    .2541285
      otherc |  -.8193078   .2797677    -2.93   0.004    -1.370582    -.268034
       yield |   1957.613   184.4755    10.61   0.000      1594.11    2321.116
          RG |    1269465   384226.1     3.30   0.001     512359.2     2026571
       _cons |  -845757.4    1669502    -0.51   0.613     -4135461     2443946
------------------------------------------------------------------------------
```

2. **Non-3R3G model**

```
 reg net seedc laborc ferc pesc otherc yield  if RG==0

      Source |       SS       df       MS              Number of obs =      91
-------------+------------------------------           F(  6,    84) =   21.30
       Model |  4.8572e+14     6  8.0953e+13           Prob > F      =  0.0000
    Residual |  3.1932e+14    84  3.8014e+12           R-squared     =  0.6033
-------------+------------------------------           Adj R-squared =  0.5750
       Total |  8.0504e+14    90  8.9449e+12           Root MSE      =  1.9e+0
> 6

------------------------------------------------------------------------------
         net |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
```

```
     seedc |   .4913603   .8030549     0.61   0.542    -1.105602    2.088323
    laborc |  -1.003888   .4882682    -2.06   0.043    -1.974863   -.0329131
      ferc |  -.7943623    .131662    -6.03   0.000    -1.056187   -.5325379
      pesc |  -1.164146   .4988939    -2.33   0.022    -2.156252   -.1720411
    otherc |  -.3428628   .3578981    -0.96   0.341    -1.054582    .3688568
     yield |   2002.008   222.8852     8.98   0.000     1558.776    2445.239
     _cons |  -832573.4    1918811    -0.43   0.665     -4648340     2983193


. ovtest, rhs

Ramsey RESET test using powers of the independent variables
       Ho:  model has no omitted variables
                  F(18, 66) =      1.12
                   Prob > F =      0.3544


. vif

    Variable |       VIF       1/VIF
-------------+----------------------
        pesc |      1.07    0.937572
      otherc |      1.05    0.952492
      laborc |      1.05    0.955121
       seedc |      1.04    0.958071
       yield |      1.04    0.960586
        ferc |      1.03    0.970407
-------------+----------------------
    Mean VIF |      1.05


. hettest, rhs

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
         Ho: Constant variance
         Variables: seedc laborc ferc pesc otherc yield

         chi2(6)      =     5.90
         Prob > chi2  =   0.4350
```

3. **3R3G model**

```
 reg net seedc laborc ferc pesc otherc yield  if RG==1

      Source |       SS       df       MS              Number of obs =     144
-------------+------------------------------           F(  6,   137) =   12.18
       Model |  7.5017e+14     6  1.2503e+14           Prob > F      =  0.0000
    Residual |  1.4062e+15   137  1.0264e+13           R-squared     =  0.3479
```

```
-------------+------------------------------           Adj R-squared =  0.3193
       Total |  2.1563e+15   143  1.5079e+13           Root MSE      =  3.2e+0
> 6

------------------------------------------------------------------------------
         net |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       seedc |   2.090534   1.349591     1.55   0.124    -.5781888    4.759257
      laborc |  -1.021794   .5608093    -1.82   0.071    -2.130756    .0871678
        ferc |   -.617501   .3465655    -1.78   0.077     -1.30281    .0678084
        pesc |   -.353227   .7992242    -0.44   0.659    -1.933638    1.227184
      otherc |  -1.000253   .3926553    -2.55   0.012    -1.776702   -.2238043
       yield |   1945.275   266.2946     7.30   0.000     1418.696    2471.854
       _cons |  -265498.4    2441814    -0.11   0.914     -5094018     4563021

 ovtest, rhs

Ramsey RESET test using powers of the independent variables
       Ho:  model has no omitted variables
                F(18, 119) =      0.55
                  Prob > F =      0.9266


. vif

    Variable |       VIF       1/VIF  
-------------+----------------------
      laborc |      1.18    0.849722
       yield |      1.12    0.890491
        ferc |      1.08    0.924265
      otherc |      1.06    0.942199
       seedc |      1.06    0.942581
        pesc |      1.05    0.953621
-------------+----------------------
    Mean VIF |      1.09

hettest, rhs

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity 
         Ho: Constant variance
         Variables: seedc laborc ferc pesc otherc yield

         chi2(6)      =    74.92
         Prob > chi2  =   0.0000
```