タイ雑草研究計画
短期専門家
報告書

—The National Weed Science Research Institute Project in Thailand—

1985年9月

国際協力事業団

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はじめに

国際協力事業団は，タイ国との間でとりかわした討議議事録（R/D）に基づき，昭和55年4月18日から5年間，同国の雑草問題の解決を図ることを目的として，雑草の制御，管理に関する基礎及び応用研究のための技術協力を実施してきた。また，5年間の協力期間終了に伴ない，タイ国側の要請に基づき，本年度より2年間のフォローアップ協力を実施している。

これまでに日本から長期専門家3名，短期専門家16名を派遣しており，現在は3名の長期専門家が研究・指導を続けている。

本報告書は昭和59年5月10日から昭和60年3月31日までに派遣された短期専門家5名の研究報告書をとりまとめたものであり，先に印刷された本計画に係る各種報告書とあわせて広くご利用いただければ幸いである。

昭和60年9月

国際協力事業団
農業開発協力部長
田内　尭

昭和59年5月10日から昭和60年3月31日までに派遣された
短期専門家（農業研究分野のみ）一覧

分野	氏名	派遣期間	赴任時現職
除草剤残留	重川弘宣	1984. 5. 10 ~1984. 8. 9	宇都宮大学農学部 付属雑草防除研究施設
雑草生理	秋田重誠	1984. 8. 10 ~1984. 8. 31	農林水産省農業生物資源研究所 機能開発部研究室長
雑草生理生態	村田吉男	1984. 9. 21 ~1984. 9. 30	東京農業大学総合研究所
農業機械	石原修二	1984. 10. 29 ~1984. 12. 28	農林水産省東北農業試験場 農業技術部機械化作業第1研究室
農業経済評価	門間敏幸	1985. 2. 14 ~1985. 3. 31	農林水産省農業研究センター プロジェクト研究第2チーム

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ANALYSIS OF PARAQUAT

Reduction and Gaschromatography

HIROYOSHI OMOKAWA

Short-term Expert of JICA

National Weed Science Research Institute (NWSRI) Project

in Thailand

Assistant Professor

Organic Synthesis of Herbicide,

Weed Control Research Institute, Faculty of Agriculture,

UTSUNOMIYA UNIVERSITY

UTSUNOMIYA, JAPAN 9th August, 1984

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Preface

This study work was performed through the National Weed Science Research Institute Project by Department of Agriculture, Ministry of Agriculture and Cooperatives, Thailand and Japan International Cooperation Agency, Japan. The study was carried out smoothly under cooperation by Dr. Prateep Krasaesin, Miss Patcharin Wanichanatakul and Mrs. Orasa Wongkasem. Without their earnest and self-sacrificial works, this work would not be proceeded.

This study work is a first step. Then, it seems probable that there are some questionary parts in this works. The author hopes some additional studies are made plan and examined, and many reports about the relationship of paraquat and environment are made public.

9th August, 1984

Hiroyoshi OMOKAWA

I. Analytical Studies on Herbicide in Hydrosphere

Introduction

Herbicide is a facinating instrument. Weed control system using herbicide in Thailand will be settled in the near future. An utilization of herbicide has two opposite sites: economical merits and environmental demerits. We have to reach the consensus of herbicide introduction to agriculture from the view points of environmental factors and economical state of the country. Furthermore, it is necessary to study environmental science for human.

Paraquat is one of the most useful herbicide and its amount of import goes on increasing in recent years in Thailand. Relationship of residual content of paraquat in water (river and/or pond) and toxicity to aquatic biotics especially a fish and a shell-fish has been coming into social problem.

For environmental science and agriculture, it is important to establish analytical method of paraquat in hydrosphere. Several methods have been used for determining paraquat content of soil, plant, fish, water and others. Free radical reduction product of paraquat can be determined spectrophotometrically, but it is necessary to concentrate of paraquat by ion-exchange chromatography and difficult to separate another quartanary ammonium compounds. Thin layer chromatography is available for the analysis of paraquat. This method is more rapid and less tedious, but is difficult to quantity. Gas chromatography has been used to determine paraquat contents after conversion to volatile compounds which prepared by reduction with $NaBH_4$, $PtO_2 - H_2$, $NaBH_4 - NiCl_2$ or other reducing agents. The reduction method is rapid and sensitive. Furthermore, HPLC (High Performance Liquid Chromatography) is useful method for determination of paraquat content without complicated separation and/or purification.

In this study, I described the analysis of paraquat in hydrosphere using reduction method and gas chromatography, and the synthesis of perhydroparaquat

(1,1'-dimethyl-4,4'-bipiperidine) as an authentic sample.

I-1. Synthesis of Perhydroparaquat as an Authentic Compound

To analyze quantitatively, an existence of an authentic compound is necessary. In generally, paraquat is converted to a volatile compound by reduction. There have been several procedures to afford volatile compounds until now. Catalytic hydrogenation of paraquat with platinum (IV) oxide (PtO_2) affords perhydroparaquat (1,1'-dimethyl-4,4'-bipiperidine), and there are many reports using PtO_2-H_2 condition. Sodium borohydride ($NaBH_4$) reduction of paraquat affords some volatile compounds, which was reported by S.Ukai et al. Furthermore, they reported sodium borohydride-transition metal salt system to afford perhydroparaquat in 1977.

In this section, I tried to synthesize an authentic compound by two methods: (1) Calatylic hydrogenation with Rh/B-H_2 system under normal pressure and (2) Sodium borohydride-transition metal cellite system (Ni/B-$NaBH_4$-cellite).

Method 1. Ni/B-$NaBH_4$-Cellite system

Placed 500 mg of paraquat in 20 ml water, 1 gr of $NiCl_2$-$6H_2O$ and 10 mg of cellite in 100 ml of reaction vessel and added 1.0 gr of $NaBH_4$ at room temperature. A mixture was vigorously stirred for 1 hr (Note-1), added NaCl for salting-out, made basic with NaOH solution, and extracted with benzene (20 ml) x 3 times). Benzene layer was dried with Na_2SO_4, and concentrated in vacuo. Crystalline product was obtained and checked its purity by GLC. Further, purification was carried out by sublimation.

Note-1. The end point of reaction is checked by GLC. An aliquot of reaction mixture is extracted with hexane or benzene, and then anlyzed by GLC.

Method 2. Rh/H-H_2 system

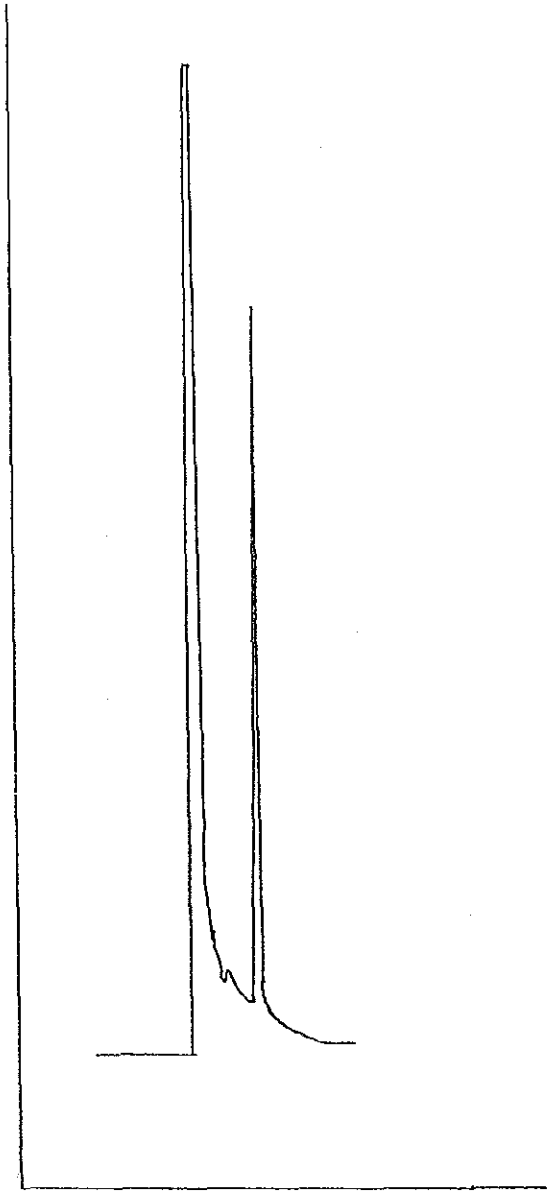
To a mixture of 30 mg of rhodium chloride trihydrate ($RhCl_2.3H_2O$) in 70% ethanol (150 ml), a solution of sodium borohydride (20 mg) in 10 ml of water

was added dropwise under vigorously stirring. While allowing 10 minutes for formation of the catalyst, 500 mg of paraquat was dissolved in 20 ml of 0.1 N-HCL solution. The paraquat solution was added to the catalyst containing solution, and then hydrogenation was started at 30°C. (Note-1). After the reaction was completed (Note-2), the reaction vessel was reduced by aspirator in order to remove hydrogen, and the reaction mixture was filtered by suction. The filtrate was made alkaline with 1 N NaOH solution and extraction with benzene. Separation and purification was made by the same manner as method 1.

Note-1. Before the hydrogenation is started, an atmosphere in reaction vessel must be exchanged to hydrogen three times.

Result :

After sublimation, a pure crystal was obtained gas chromatogram is shown in Fig.1.



FID- detector

5% Thermon-1000 on Shinchrom B

Glass column 1,0 m x 3 mm Ø

Column temp. 140°C

Detector/Injection Temp. 230°C

H_2 0.5 kg/cm^2. $N_2$60 ml/min. Air 0.5 kg/cm^2

Fig.1. Gas chromatogram of perhydroparaquat synthesized by Ni/B-$NaBH_4$-cellite system.

I-2. Gas Chromatography of Perhydroparaquat

Gas chromatography of reduction product of quartanaly ammonium compounds such as paraquat and diquat is reported by S.U. Kan and K.S. Lee, S.U. Khan, and S. Ukai et al. The Carbowax 20 M + 1% KOH colum give a sharper peak and a high sensitivity. But a column support contained KOH has a tendency to be shortlived.

I tried a new type of support "Shinchrom B" employed by Chromato Packing Center in Japan.

(1) colum condition

5% Thermon-1000 on shinchrom B (80/100), glass-column (1.6 m x 3 mm, 1.0 m x 3 mm)

(2) GC condition

Carrier Gas (N_2) : 50 ml/min

H_2 : 3.5 ml/min

Air : 150 ml/min

Attenation : 16

Power : 7.5 - 8.0

Range : 1.0

Column Temperature : 185°C (1.6 m column)

170°C (2.0 m column)

Injection Temperature : 230°C

(3) Calibration curve of perhydroparaquat

Prepared 0.01 ppm to 1 ppm benzene solution of perhydroparaquat and injected 5 µl. Calibration curve was made by log relationship of peak hight and content per injection (g/Inj).

The curve was linear over the concentration range examined, with a calculated lower limit of determination of 2.5×10^{-10} g per injection (0.05 ppm, 5 µl Injection) Fig.2..

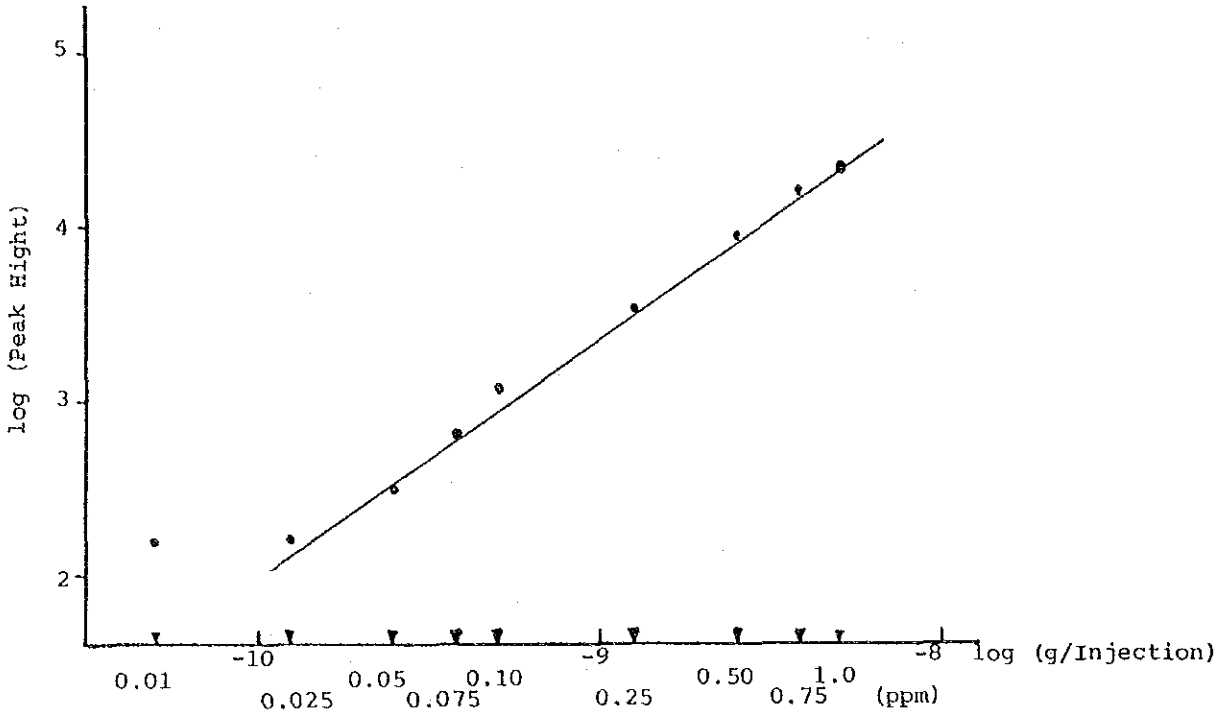


Fig.2. Calibration curve of perhydroparaquat

I-3. Analysis of Paraquat in Pure Water

This section was described determination of reaction condition to pure-water-paraquat system. S. Ukai et al reported that sodium borohydride-transition metal salt system afford perhydroparaquat in 1977. However, it was seem to be lower recovery of perhydroparaquat at low concentration of paraquat.

As the result of my study, addition of cellite affords higher recovery of perhydroparaquat than Ukai's condition at low concentration of paraquat.

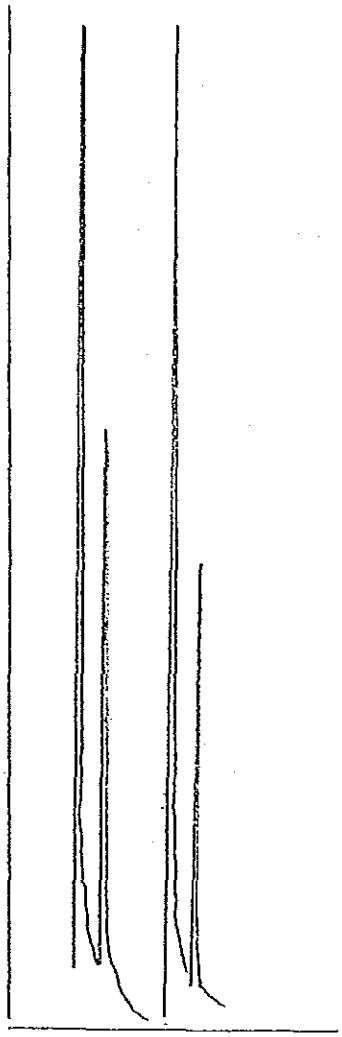
Method

Placed 2 ml of test solution (concentration of paraquat 1.0 ppm and 0.05 ppm), 1.5 ml of 0.02 M nickel chloride solution and about 0.5 mg of cellite in 20 ml of test tube, and added 1.5 ml of 2.6 M sodium borohydride solution at room temperature. A mixture was vigorously stirred for 1 hr at 30-35°C, added sodium chloride (NaCl) for salting-out, and extracted with benzene (2 ml x 4 times). Benzene layer was dried with Na_2SO_4 and concentrated in vacuo. The residue was justified at 2.0 ml with benzene, followed by drying with KOH/K_2CO_3 in order to remove moisture completely (Note-1). A content of perhydroparaquat was calculated by peak high with a calibration curve.

Note-1. If a drying is no sufficiently, a peak of water appears at almost the same retaintion time as perhydroparaquat under GLC column condition (5% Thermon-1000 on Shinchrom B).

Result:

Under the experimental conditions described paraquat yielded perhydroparaquat in almost quantitative yield. On absence of cellite, yield of the reaction was a little lower than one of cellite-presence condition (Fig.3).



Cellite, No cellite

Fig.3. Gas chromatogram of perhydroparaquat 1.0 ppm paraquat solution Ni/B-$NaBH_4$ system FTD-detector

I-4. Analysis of Paraquat in Natural Water

A natural water contains soil colloid and many kinds of organic materials. On analysis of paraquat by hydrogenation, organic materials must be removed from a test water. Furthermore, paraquat in natural water exists in the two forms of a free type and a combined type adsorbed to soil colloid and other organic substances. To determine its content, it is necessary to analyze a free type paraquat and a combinded type one respectively. In this section, I tried to establish to analyze of paraquat in natural water system.

Analyses of paraquat in supernatant and whole water

A water of creek in Thailand contains some soil-colloids and organism such as algae, plankton, microbe and other. On treatment of paraquat to aquatic field in order to control water hyacince and other aquatic weeds, it seems that paraquat is adsorbed to soil-colloid and/or organizm rapidly. I tried to analyze paraquat in supernatant and whole-water.

Experiment 1. Analysis of paraquat from fortified natural water after 30 mm.

Material and Method

A natural water was collected from creek without experience with paraquat around NWSRI. A content of paraquat was adjust to 1.0 ppm using above natural water. After 30 min., placed 2 ml of the fortified natural water sample, 0.02 M nickel chloride solution and cellite in 20 ml test tube and added 2.6 M sodium borohydride at 30-35°C. A mixture was vigorously stirred for 1 hr, added NaCl for salting out, and extracted with benzene (2ml x 4 times). Benzene layer was dried over Na_2SO_4 and concentrated in vocuo. The residue was filled up to 2.0 ml by benzene, added dry KOH/K_2CO_3 and stood over night at refrigerator. Perhydroparaquat was analyzed by GLC.

Table 1. Reaction conditions for analysis of paraquat in natural water

	Content of paraquat (1.0 ppm) ml	0.02 M $NaCl_2.6H_2O$ (ml)	2.6 M $NaBH_4$ (ml)	Cellite
Run-1	Absence (*1)	1.0	1.0	Presence
Run-2	2.0	0.5	0.5	Absence
Run-3	2.0	0.5	0.5	Presence
Run-4	2.0 (*2)	0.5	0.5	Presence
Run-5	2.0	1.5	1.5	Presence
Run-6	2.0 (*3)	0.5	0.5	Presence
Run-7	Absence (*4)	1.0	1.0	Presence

*1. 2 ml of natural water without paraquat of creek around NWSRI

*2. Filtrate of natural water contained 1.0 ppm paraquat with filter paper

*3. Supernatant of the filtrate (Run-4) under 3,500 rpm for 20 min.

*4. Distrilled water (2 ml) without paraquat

Result and Discussion

Retaintion time (2.6 min) is assigned to perhydroparaquat and 3.6 min is hydroparaquat contained double bond. The fractions without paraquat (Run-1 and Run-7) showed peak hight of reaction product below limit of detactable amounts. It indicates that the creek water doesn't contain paraquat. From the result of Run-2 and Run-3, addition of cellite give good reaction yield and recoverity (about 2 times).

It was very interesting result that an addition of cellite showed a high reaction yield and recovery. On addition of cellite, activity of the catalyst (Na/B) is seem to be strong than one of no-cellite condition.

From Run-2 and Run-5, increasing of reducting agent ($NiCl_2$, $6H_2O$ and $NaBH_4$) comes with higher peak hights (Rt 2.6) and lower peak hight of hy-product (Rt 3.6). Recovery of Run-5 was about 98% on perhydroparaquat. A natural

water in Thailand has many kind of soil colloid and others. From the result of Run-6, a supernatant has no perhydroparaquat. It indicates that paraquat is rapidly adsorbed to soil-colloid and other at low concentration, and separation of soil colloid from natural water is able to be carried out by centrifugation under 3,500 rpm for 20 min. Result of Run-4 suggested that it could not separate soil colloid from natural water by filter paper completely.

Table 2. Peak hight of perhydroparaquat (Rt. 2.6 min) and hydroparaquat (Rt. 3.6 min)

Run	Height of Peak	
	Rt. (2.6 min)	Rt. (3.6 min)
1	137	67
2	2835	1439
3	5949	2678
4	1518	696
5	7598	2519
6	23	369
7	0	199

Experiment 2. Analysis of paraquat from fortified natural water after 7 days.

Material and Method

A fortified natural water sample was kept into refrigerator for 7 days. Placed 2 ml of the sample in 20 ml of test tube, and hydrogenation and extraction were carried out by the same manner as Exp. 1. A content of perhydroparaquat was determined by GLC under a calibration curve of pure perhydroparaquat.

Result and Discussion

Recovery of paraquat was about 61%. Paraquat was strongly adsorbed soil colloid and other during the keeping, and could not react with the reducing reagent perfectly. This reaction system was carried out without treatment such

as sulfuric acid. Then, it seems that the recovery is made better by a treatment with sulfuric acid which step is essentially to remove the conbined paraquat with soil colloid and others.

I-5. Effect of Paraquat to Fish

Paraquat is an useful herbicide to control aquatic weeds such as water hyacinth (Eichhornia crassipes) and water lettuce (Pistia stratistes) in creek.

In Thailand, a fish died in the pond treated with paraquat to control aquatic weeds. However, we have taken no answer yet, why the fish died. TLM of paraquat was already reported to carp (40 ppm). In this section, I discussed the effect of paraquat to fish under different kind of water.

I-5-1. Effect of paraquat to fish under different kind of water

Material and Method

Fish (Porcilia reticulata) was collected from a creek and kept into glass-vessel put a natural water (NW) which was collected from creek around NWSRI and a tap water (TW). Each 10 l of NW and TW were respectively poured into glass-vessel (25 cm x 37 cm) and kept 10 fishes per pot under air-bubling. Concentration of paraquat was adjusted to 0 ppm, 6 ppm, 13.8 ppm, 27.6 ppm and 55.2 ppm per pot. After 24 hr, 2 ml of water was collected from each of glass-vessels and analyzed paraquat under Ni/B-cellite system. A number of alived fish was counted at 24 hr, and 48 hr. Temperature of examined water was 29.0°C.

Table 3. Residue of paraquat in NW and TW, and number of died fish

		Concentration of paraquat (ppm)	Number of died fish		Analyzed concentration of paraquat (ppm)
			24	48 hr	
	Run-1	0	-	-	0
TW	Run-2	6.9	4	6	3.6
	Run-3	13.8	10	10	6.7
	Run-4	0	-	-	0
	Run-5	13.8	-	-	4.9
NW	Run-6	27.6	8	9	11.7
	Run-7	55.2	10	10	29.4
	Run-8	SPT of Run-5			6.6
	Run-9	SPT of Run-6			9.9
	Run-10	SPT of Run-7			23.4

SPT : Supernatant obtained by centrifugation (3,500 rpm, 20 min.)

Result and Discussion

Contents of paraquat in NW and TW indicated about half to initial concentration. However, a recovery of NW system showed a tendency of lower than one of TW system. It is widely noted that soil is suspended in a solution of paraquat, some of the paraquat is adsorbed on to the suspended particles. A creek water in Thailand contains many kinds of soil colloids and water-soluble humine. It is guesses that a difference of the paraquat contents between NW and TW is based on presence or not of soil colloid. In TW, a fish died perfectly at 13.8 ppm of paraquat and 60% at 6.9 ppm of one. But in NW, alived all of fish in the paraquat solution at 13.8 ppm and died at 27.6 ppm after 48 hr (Table 3). These result showed many interesting ideas to us. In NW, it is guessed that molecule of paraquat combines to water-soluble humine, and active form of it decreases. As a result, difference of TLM volue was shown (Fig.4). It is seem that a fish does not killed by paraquat under ordinaly handling to control of

aquatic weeds. However, we have to take a correct answer on interaction of fish and paraquat in future.

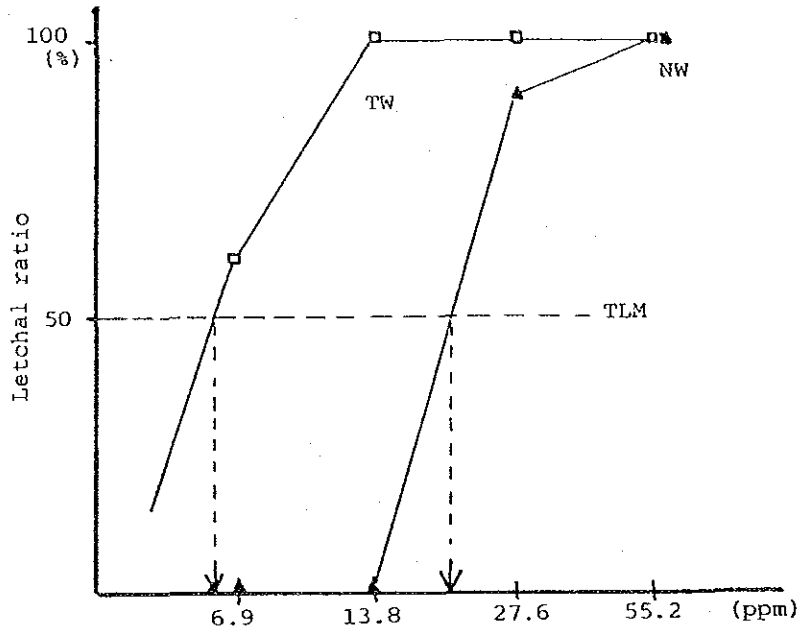


Fig.3. Effect of paraquat to fish

TW: Tap water, NW: Natural Water

I-6. Analytical Method of Chemicals in Hydrosphere

In hydrosphere, there are many kind of chemicals such as industrial chemicals, medicines, agricultural chemicals and food appendixes. These chemicals are classified into two types; soluble and insoluble compounds to organic solvent.

The flow-sheet shows the separation and anlysis of chemicals in hydrosphere. An adsorptive separation by SEP-PAK c18 is effective method than solvent extraction in many respects; cartridge method require only a few mililiters of organic solvent, eliminate cross contamination, reduce clean up time, and show high recovery and reproducibility.

I showed the flow-sheet of an analytical method as follows (Fig.5).

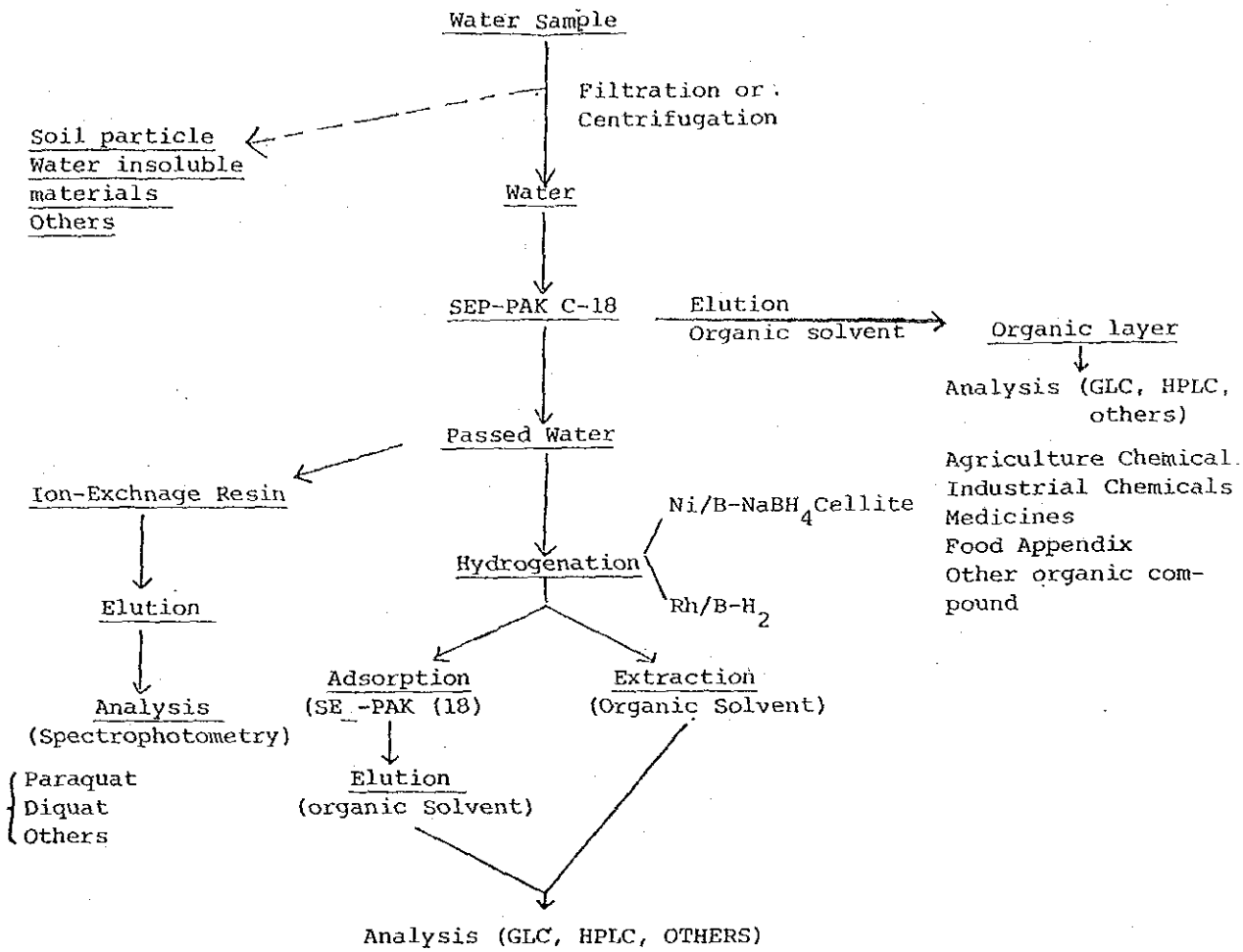


Fig.5. Analytical Method of Chemicals in Hydrosphere

II. Remaining Problems and Proposal

This study work is the first step to analyze paraquat in hydrosphere. I recognize that there are many controversial points in this system. The recovery is no satisfactory (about 61%). But the analysis was carried out no treatment with sulfuric acid which made free-type paraquat. Our result showed that paraquat in natural water consisted in three type conditions; free type, losely adsorbed type and strongly adsorbed type. A sulfuric acid treatment is essentially for determination of adsorbed paraquat. Then, we have to examine under some reaction conditions using sulfuric acid treatment. So, Ni/B-$NaBH_4$-Cellite system is seem to be one of analysis of paraquat having suitably accurate, rapid, selective, and sensitive properties. It should be applicable to a wide variety of soil, plant, water and other sample. I am looking foward NWSRI researchers to plan, to examine and to report on an analysis of paraquat using H_2SO_4-treatment, Ni/B-$BaBH_4$-Cellite system and gas chromatography.

III. Main Schedules During Stay in Thailand

I stayed in Thailand for three months. My stay in NWSRI was two short to do a satisfactory research study. However, I had investigation trips three times throughout the stay. These trips gave me an opportunity to know about nature of Thailand and agriculture.

It showed the main schedule as follows :

10th May, 1984 - Arrival at Bangkok

17th-19th May - The Annual Research Symposium of Department of Agriculture in Pattaya

- Rayong Field Crop Research Center, Field Crop Institute, DOA, the Ministry of Agriculture and Co-operatives in Rayong

16th-20th July - MUSOR, Horticulture Experiment Station in Muang, Tak Province

	- Sanpatong Rice Experiment Station in Sanpatong Chiangmai
	- Tea Plantation in Mae Tang, Chiangmai
26th-27th July	- Agricultural Machinery Center (KURDI) in Kamphangsaen Campus, Nakorn Pathom
	- Mae Klong Pilot Project, Royal Irrigation Department, Ministry of Agriculture and Cooperatives (MOAC), Amphur Tha Muang, Kanchanaburi
	- Chao Phya Pilot Project, Agricultural Land Reform Office, MOAC, Amphur Lad Bua Luang, Ayutthaya
	- Central Laboratory, Kasetsart University Kamphaeng-saen Campus, Nakorn Pathom
31st July	- NWSRI Seminar (Analysis of Paraquat in Hydrosphere)
9th August	- Departure

Acknowledgements

It has been a greatly honored for me to have a chance of staying and studying in National Weed Science Research Institute Project. I would like to express my sincere appreciation to the Authority of the Department of Agriculture concerned, Mr. Yookti Sarikaphuti, Director-General, Dr. Risk Syamanonda, the Deputy Director-General, Dr. Tanongchit Wongsiri, the Deputy Director-General, Dr. Umpol Senanarong, the Deputy Director-General and Mr. Visut Chandrangsu, Director of Botany and Weed Science Division, who gave much arrangement and convernience to do cooperative works.

I wish to thank Dr. Paitoon Kittipong, Chief of Weed Science Branch and all researchers and secretariates in NWSRI for their heartfelt acceptance and much helps to me.

I have to express my appreciation to Dr. Kenji Noda, the leader of NWSRI Project, Mr. Kiyoshi Kojima, the expert of NWSRI Project of JICA, Mr. Teruhiko Nibe, the expert/coordinator of NWSRI Project of JICA and Dr. Jiro Harada, the expert of NWSRI Project of JICA for their useful advices and suggestions.

Further, I wish to thank Dr. Tadao Yamada for valuable suggestions.

ACTIVITY REPORT

JICA Short-Term Expert
Shigemi Akita
(National Institute of
Agrobiological Resources,
Tsukuba Science City,
Ibaraki, Japan)

1. Objectives of cooperation.

   (1) Checking and improvement of the system to measure the rates of photosynthesis and some related physiological reactions

   (2) To conduct some demonstrative experiments using the established system

2. Period of cooperation.

   August 10 - August 31, 1984

3. Counterparts.

   Mrs. Cha-um Premasthira

   Miss Siriporn Zungsontiporn

4. Performance

   (1) The measuring system of the rate of photosynthesis was improved and tuned perfectly and the measurements of some additional physiological reactions have been established.

   (2) Some demonstrative experiments using this system have been conducted. Through this experiments, the precise techniques to handle this system and basic knowledge to apply this system for the analysis of physiological phenomena have been delivered.

5. Desirable instruments for further improvement of the system

The system has been established almost completely but it is necessary to improve this system further by getting following apparatus :

	Name of apparatus	Quantity
i	Electric bulbs	4
ii	Stabilizer for bulb	2
iii	Recording output unit for hygrometer	1
iv	Assimilation chamber	2
v	Electric compensating unit for cold points of thermocouples	1
vi	Anemometer	1

出　張　報　告　書

昭和 59 年 10 月 15 日

専門家　東京農業大学総合研究所
教授　　村　田　吉　男

1. 業　務　目　的　　雑草生理生態（学位論文指導）

2. 期　　間　　昭和59年9月21日　同9月30日（10日間）

3. 日　　程

9月 21 日(金)　TG741　16:20 成田発　20:30 バンコック着

22 日(土)　休　養

23 日(日)　Khon Khaen 大学 Dr. Chaitat 招介の Mr Nawarat (Department of Agriculture, Field Crops Research Institute Fiber Crops 科長）に会い研究業績を聞く。

24 日(月)　ＪＩＣＡバンコック事務所を訪問
Departmennt of Agriculture 局長を表敬訪問。
Kasetsart 大学　Sorasith 教授に面会。

25 日(火)　NWSRI にてＪＩＣＡ-SAEDA システムによる Ph. D. 取得制度説明会並びに個別面接。
DOA 次長　Dr. Tanongchait に面会。

26 日(水)
27 日(木)　Field trip (Kasetsart 大学　Kamphaengsaen キャンパス, Suphanburi 試験場および E. geniculata 試験圃場見学, 野田リーダーおよび Miss Maneesa 同行）。

28 日(金)　セミナー（生物学, 農学研究における原理・原則の適用について）。
あと全員とランチパーティ。
Miss Maneesa と討議。

29 日(土)　Miss Maneesa と今後の打合せ。

30 日(日)　TG740　10:30 バンコック発　18:30 成田着帰国

註　9月26日夜は Suphanburi のホテル泊, 他はバンコック Capital Mansion 泊。

4. 業務の概要

1) NWSRIスタッフとの個別面接結果について

現在NWSRIのスタッフのうちM.S.をもつ職員は表Iの7名であるが，休暇中の1名（Miss Patcharin）を除く6名と個別面接し，これまでの研究歴と業績および現在の仕事についてきいた。

その結果，6名の内Ph.D候補者として業績，能力いずれの点から見ても最も適格な者はMiss Maneesa であると判定された。その他の研究者については，Mr.Prasanは英国Burnell大学のM.S.と16年の研究歴をもつが，その内容はいろいろな除草剤の各種の雑草に対する散布効果をみた，普及の資料となるような実用試験が多く，学問的に興味あるものは少ない。M.S.論文はヒエ属植物の発芽生理を扱ったもので，各種の化学的，物理的処理が休眠覚醒に及ぼす効果を調べている。数年前岡山大学農生研において研修を受け，温度と雑草の発芽・生長の実験を行なっているが，短期間のためもあり，簡単な結果を得たに止まる。3年前チエンマイにおけるFAOのトレーニングコースにおいて雑草防除法について講義を行っているがこれも実用的なものが主体であり，総じてPh.D.論文の素材となる業績はあまりない。Ph.D.論文を書くためには，今後かなりの蓄積が必要である。その他の研究者の中では，Mrs.Chanpen（35才）が比較的将来有望と思われた。Kasetsart 大学で生物学を専攻し，貯水池の水草の同定と現存量を取り扱った。M.S.論文を見ても基礎が確りしている印象であった。しかしまだM.S.取得後3年で業績は少ない。現在水生雑草の研究を行っている。

以上のような実情のため，Ph.D候補者として現在直ちに取り上げるべき研究者はNWSRIではMiss Mancesa以外にはないように思われる。

なお，Botany and Weed Science Divisionの部長 Mr.Visut Chandrangsuは，農業気象の分野で既に約20年の研究歴をもち，1968年鴻巣の農事試験場稲作コースで6ケ月間の研修を受け，当時農技研生理第1科長であった村田の講義を受けたこともあることが判明した。また本年12月，日・タイ共催（JSPSとNRCT）のソンクラ大学における国際セミナーでのスピーカーの1人に選ばれており，Ph.D候補者となりうるかどうか今後検討に値する研究者であると思われる。

2) Miss Maneesaの現在までの進捗情況と今後の予定

一部に再試験や追加を必要とするものがあるが，全体として野田リーダーの立てた構想に従ってほぼ順調に試験が進んでいると見受けられた。一部の試験結果（全体の約30%）は本年4月の日本雑草学会において発表した。

今後次のような手順に従ってとりまとめを進めて行く必要がある。

(i) 過去にNWSRIにおいて行った試験結果と本年日本留学中およびNWSRIにおいて行

った試験結果を表2に示したような小テーマに分けて論文として取りまとめる。草稿ができ次第村田へ送ってその校閲とアドバイスを経て論文に仕上げ，1985年11月の国際雑草学会（10 th APWSS Conference）において発表する。

(ii) これらの論文を表3のような主題と構成に従い，一部未完成な部分は残したまま，とも角全体としてとりまとめ，大まかな考察を加えて本年末までに村田へ送る。表3は昨年野田リーダーの作成した原案に本年度得た結果と進捗情況を検討協議の上，必要な改訂を加えたものである。改訂の主な点はa）ワタと混合群落の生産構造調査の追加，b）トウモロコシおよびE. geniculataの要水量の比較，c）両者の根系の深度分布の再調査，およびd）除草剤の効果のモデル実験追加である。

(iii) これらの追加実験およびアレロパシー（Part V.）の実験結果は明年3月までには一応の結果がえられると考えられるので，これらの結果をもって4月上・中旬にMiss Maneesaが日本へ来て，村田指導の下に前の素稿と合せて学位論文に仕上げ，東京農業大学に提出し，本人発表を行なって6月上・中旬に帰国することができれば好都合である。

3）そ　の　他

DOAの担当次長Dr. TanongchitにはJICA-SAEDAシステムによるPh. D取得制度について改めて若干の説明を行ない，Miss Maneesaについての見透しについても意見を述べ，またMr. Nawaratの件も耳に入れたが，次長はこの制度を高く評価し，その成果に期待している旨の発言があった。

Miss Maneesaの場合には上述のように学位論文の材料となるような業績が順調に蓄積されつつあるが，これに直ちに続く研究者をNWSRIで見出すことは難しい。Miss Maneesaにしても，その研究の構想と試験設計はもとより，実施についても多くを野田リーダーの指導に仰いでいるのが実情である。NWSRI Projectによって手頃な実験室と最新の測器類がかなり整備され，中には日本でも滅多に見られないようなものまであるが，研究をいかに展開するか．その中で測定装置をどのように生かすか，それ以前に研究とは一体どういう風にやるものかという根本的な点に関しては，この国の現状はまことに前途遼遠の感を免れない。研究設備を整えることと，研究が行なわれることは全く別の問題である。自発的に研究が行なわれるようになるためには，科学的な考え方を植えつけ，人を育てるという地味な忍耐強い努力が永く継けられなければならない，その意味で本Project なども学位授与という問題を含めて事業全体を成功に導くためには，たとえ規模は縮小しても，今後息長く人と研究自体の援助を続けることが不可欠ではないかと考えられる。

Table 1. NWSRI Staff members qualified by M.S.

1. Miss Maneesa Teerawatsakul (born 1937), Level 7
   B.S.: Kasetsart U., 1968, Agronomy,
   M.S.: Univ. of Kentucky, U.S.A., 1970, weed control,
   Present field of research: Weed control in field crops.

2. Mr. Prasan Vongsaroj (1944), Level 7
   B.S.: Kasetsart U., 1968, Agronomy,
   M.S.: Burnel U., England, , Weed science,
   Present field of research: Weed control in rice.

3. Mrs. Cha-um Premathira (1948), Level 6
   B.S.: Kasetsart U., 1970, Agro-economy,
   M.S.: Kasetsart U., 1979, Agronomy,
   Pre ent field of research: Weed science (toxicology).

4. Miss Patcharin Wanichanantakul (1948), Level 6
   B.S.: Kasetsart U., 1971, Soil science,
   M.S.: Burnel U., England, 1975, Weed biology,
   Present field of research: Herbicide bio-chemistry.

5. Mrs. Chanpen Prakongrongs (194), Level 6
   B.S.: Kasetsart U., 1973, Botany,
   M.S.: Kasetsart U., 1981, Aquatic weeds,
   Present field of research: Weed science (aquatic weeds).

6. Mrs. Sermsiri Daengyeonyoung (1953), Level 5
   B.S.: Kasetsart U., 1977, Agronomy,
   M.S.: Kasetsart U., 1984, Weed physiology,
   Present field of research: Weed controlin horticulture crops.

7. Mrs. Kleopan Suwannarak (1948),
   B.S.: Kasetsart U., 1970, Horticulture,
   M.S.: Kasetsart U., 1973, Botany,
   Present field of research: Weed control in horticulture crops.

Table 2. Papers to be submitted at the 10th APWSS Conference (tentative)

1. Different seasonal response of growing pattern of Euphorbia geniculata and its significance in crop fields.
   Maneesa, Tawee and Assistant
2. Production damage due to E. geniculata in corn and cotton with reference to the change of production structure.
   Maneesa, Somchart, Tawee and Noda
3. Characteristics of E. geniculata in seed germination and dormancy.
   Maneesa, Noda and Lawan
4. Emergence aspects and root system of E. geniculata with reference to weeding technology.
   Maneesa, Tawee and Noda
5. Different plant-physiological responses of environments between E. geniculata and corn.
   Maneesa, Murata, Kusanagi et al.
6. Ecological response of shading.
   Maneesa, Kubota et al.
7. Morphological characteristics of leaves of E. geniculata.
   Chanpen, Maneesa, Lawan and Noda
8. Allelopathy and fish-toxicity of E. geniculata extracts as related to its weediness.
   Maneesa, Siripoon and Harada
9. Euphorbia geniculata control by herbicides in field crops.
   Maneesa, Somchart and Assistant

Table 3. Title and content of the Ph. D. thesis to be compiled by Miss Maneesa Teerawatsakul

A STUDY ON THE ECO-PHYSIOLOGY OF A NOXIOUS WEED, EUPHORBIA GENICULATA ORTEG. AND ITS CONTROL IN UPLAND FIELDS OF THAILAND

Content (tentative)	Performance
Part I. Introduction The reason and purpose of this study and its importance in Thailand with review of literature	compiled
Part II. Distribution and its relation to environment (soil, climate and rainfall)	compiling
Part III. Biological characteristics as associated with weed control technology	
1. Dormancy and germination of seeds Percent germination and germination velocity under different light and temperature conditions, comparing with other upland weed seeds.	compiling
2. Morphological and anatomical characteristics (Observed by means of light microscope and scanning e.m.) Note: Euphorbiaceae in Thailand includes C_3 and C_4 plants. E. geniculata is a C_3 and E. hirta is a C_4 plant.	compiling
3. Physiological characteristics Response to water stress in soil and photosynthetic activity etc.	1983-84
4. Ecological characteristics	
1) Life cycles under three kinds of soil in a year	compiling
2) Reproduction capacity (ibid.)	compiling
3) Emergence depth	compiling
4) Emergence pattern of seedlings	1984
5) Root system and early growth features	1983-84
Part IV. Population ecology and physiology	
1. Influence of E. geniculata on the growth and yield of corn in comparison with cotton	1983-84
2. Competition mode between E. geniculata and corn in comparison with cotton	1983-84

3. Influence of light intensity restriction on a mixed population of corn and E. geniculata.....1983-84

Part V. Allelopathy of E. geniculata on crop plants..... 1984
Note: Extracts of E. geniculata provides no influence on other weeds and crops in preliminary tests. However, as it has been reported that E. spinus provides serious allelopathy on many plants, the case of E. geniculata should be re-examined.

Part VI. Control of E. geniculata in upland fields

1. Effectiveness of pre-emergence herbicides (corn, cotton).....compiling
To be supplemented.....1984

2. Effectiveness of post-emergence herbicides (corn, cotton)..... "

3. Recommendation for integrated control methods (corn, cotton)..... "

Part VII. General discussion

Part VIII. Summary

Acknowledgement

References

Note: Euphorbia geniculata is the synonym of E. heterophylla L. in U.S., called "milkweed" or "painted spurge" in English.

Mechanical weed control in Thailand.
An Observation of general situations and the enumerative descriptions of problematic factors to be considered for further research.

Shuji Ishihara
Short term expert with NWSRI Project in Thailand.
Assigned tour of duty from 29th October to 28th December, 1984.
Chief of Lowland mechanization Engineering Laboratory, Tohoku National Agricultural Experiment Station, Morioka, Japan

January 7th, 1985

1. General scope of the problem

The mechanical or physical weed control is generally considered to play only a minor and supplementary role in the domain of general weed control technology, where the development and use or chemical herbicides advanced to such an extent that nowadays the weed control process itself is sometimes interpreted as synonymous with the herbicide application.

In fact, there are many instances in which farmers no more use mechanical means at all to deal with the weed infestation problem, as in most areas of transplanted rice with adequate irrigation or submergence facilities and mechanical means sufficient to prepare well puddled and leveled paddy field.

On the other hand, there are also many instances where people quote the complaints of severe weed infestation even under the conditions in which farmers have used on their crops widely approved, otherwise effective herbicides as recommended.

The failures in those cases lack no plausible explanation as to their inevitable causes and ensuing processes, like insufficient soil moisture available, improper seedbed preparation, etc.

There are also other instances where the economic consideration does not permit the use of either effective herbicides or mechanical means to control weeds. In this case the crop growers have to rely solely on the traditional labour consuming proceedure of hand hoeing or picking in order to secure the desired harvest.

Other factors, which make the mechanical means rather desirable as the practical solution to the weed problems, include the diversity of the crops grown in actual farming enterprises where there are some kinds of crops which await further development of effective pose-emergence herbicides. Another often quoted argument against the too casual dependence on herbicide use is the general public awareness about the chemical pollution of environment resulting from inadvertent use of harmful chemicals. The fatal instance of 2-4-5 T, dioxin, received such a magnitude of publicity as to make it political issues in many countries. Combining the environmental problems attributed to other kinds of pesticides, nowadays the general public considers the herbicides as potential risk factor to the human welfare, apart from their beneficial aspect of liberation from drudgery in crop cultivation.

Even without such somewhat emotional arguments against the chemical weed control technology, the mechanical weed control still retain substantial importance in the crop growing proceedures implicitly as well as explicity. For instance, the so-called primary tillage, such as plowing or sod-busting, is an important process in growing crop before planting. The process not only prepares land for good seeding condition, but it also functions as a critical process of eliminating weed vegetation and burying weed seeds or propagating plant organs, such as rhizomes, bulbs etc. They may not be killed completely, but they get incapacitated enough to the extent that they may cause little adverse effects on the subsequent crops.

It is quite an obvious procoss of cradicating weeds to carry out the proceedure of interrow cultivation in the existing crop. In a narrow sense, only this aspect of crop cultivation proceedure is generally considered to be the mechanical weed control. But the problem of weed control should be viewed with much broader perspective, encompassing the crop growing environment as a whole. It is a science to deal with the dynamic system of ecology where every physical as well as biological factor is interrelated closely to each other. It requires the so-called integrated approach to devise a truely effective weed control technology. In that sense, the mechanical weed control itself should be interpreted in that context and be incorporated into a system of factors which constitute the whole body of the intended technology.

To a larger degree, the mechanical weed control can also be considered as a special application of soil tillage technology because it more often as not involved many variations of soil working tools as technical elements, requiring similar methodology and procedures with the emphasis on higher degree of precision in the resulting work.

The following report is intended to identify the existing problems in mechanical weed control in Thailand and to specify certain points of interests for future research there, which may or may not be relevant to the above arguments to see the weed control as a comprehensive technology.

2. The problems related to the mechanical weed control in Thailand

2-1 Weed problem in rice

Rice is the single most important food crop in Thailand and it is receiving the highest degree of attention in every aspect related to its production.

Among the various ways of growing rice, the most serious case in respect to weed control is when it is grown direct-seeded on dry land condition anticipating later rain for germination. There are some preemergence herbicides applicable for this practice, but they are not conclusive in effectiveness and the failure results in uncontrollable infestation of weeds, reducing the rice yield considerably.

Some postemergence herbicides are effective but can not control all weed species present.

In the case of deep water rice area, the initial dominance of weed recedes as the water level increases with the advance of rainly season. It is therefore important to secure the early robust rice growth so that seedlings can survive the early submergence and catch up with the deepening water level ahead of weeds. Since almost all rice fields are broadcast, it is impossible to introduce any type of inter-row cultivator to these directly seeded rice field.

If some means are found to seed rice in rows at regular interrow spacing, existing inter-row cultivator may be of some use after submergence.

For the purpose of precision rice drilling, it may be necessary to improve the quality of seedbed by the introduction of more elaborate means of seedbed preparetion. Right now there seems to be almost complete absence of specialized form of secondary tillage equipment for upland condition in Thailand. Under the existing conditions, the mechanical weed control in upland direct seeded rice in Thailand has little prospect of finding relevancy.

Other transplanted rice has no significant problems requiring attention from mechanical view points, because of the availability of quite effective selective ferbicides applicable under irrigated condition.

2-2 Problems in Field Crops

Thailand has many kind of field crops on her upland field. Sugar Cane, Cassava, Maize, Soybean, Mung beans, and cotton are among the more important ones from the economic view point. Each crop has its own particular problems according to the unique way of growing practices and it is beyond the author's capacity to enumerate those problems for each of them. Only some of the outstanding cases are presented here in general terms.

Sugar cane, maize, and Cassava have common characteristic to grow tall and profusely in their later stage of growth, resulting shading effect giving enough competitive advantage over later growing less tall weed species. It is important to secure only enough plant population, and to control early weed growth by either chemical or mechanical means.

Soybean also has shading effect in later growing stage and relatively competitive against weed growth. Early weed control is crucial also in Soy bean. Among the economically important field crops, Cotton presents the most serious problem in weed control. The crop requires longer time before emergence, which situation gives more advantage to other weed species. Very few effective premergence herbicides seem to be available for cotton. In addition to the problem of competition for water, nutrients, sunlight, weeds complicate the problem as they become the intermediate hosts for lethal insect pests on cotton plants. Among the weed species difficult to control by herbicides in upland conditions are Euphorbia geniculata, cyperus spp., Trianthema portulacastrum, Ageratum conyzoides.

Growing field crops requires heavy equipment for land preparation and bigger power units are being employed in field crops growing areas. 5-7 bottom plows are common features in these areas. But there seem to be very few harrowing implements being used in Thailand. Only the primary tillage implements of disc plows are used also for secondary tillage, resulting in poorly pulverized seedbed with little facility for later soil working except in lighter soil texture areas. Some farmers use ridger or small version of mouldboard plow for interrow cultivation. Rotary cultivators which are widely used in developed countries are almost non existent in Thailand even for the walking type two wheel tractors. Even the sweep and shovel type cultivators are difficult to find there.

Soil conditions in Thai upland field are generally not amenable to ready use of mechanical equipment.

Soil surface gets quite hard as a result of the baking effect of intense sunlight coupled with the heavy soil texture. But in some areas there are fields of light soil texture decile enough for ordinary soil working tools.

It seems quite possible that more of upland fieled in Thailand can be worked with more number of cultivation implements available elsewhere, after certain amount of modifications appropriate for local conditions. They will greatly reduce the required amount of labour currently expended on weeding in field crops of Thailand.

3 Proposals for further research work on mechanical weed control in Thailand.

1) Extraction of specific problems in individual crops.

In order to identify the existing problems in succinct and relevant ways, further field surveys for representative crops should be carried out. Target-oriented investigation rather than general survey should be conducted.

2) The reassessment of primary and secondary tillage in terms of weed control.

The seedbed preparation should be reexamined as to their effects on improving soil tilth, stand establishment, as related to weed population control.

3) Improvement of hand tools for weeding.

The assessments of the effectiveness of the lighter hand hoes for field crops have to be carried out.

The hoes currently in use in Thailand are very heavy in construction. They are to be reexamined in relation to the circumstances in which they are used.

4) The development of animal drawn sweep and shovel type cultivator.

This type of cultivator is relatively simple in construction, needing very few high quality materials for its component parts.

The important soil working elements can be manufactured by local black smiths in accordance with the specific local conditions. The development procedure itself will provide valuable steps for further development of power driven implements.

5) The development of medium-size rotary tiller for interrow cultivation.

Adaptation of domestically produced power tiller with high speed tilling rotor. Development of suitable soil working elements is necessary.

6) The development of axle driven rotary tiller.

The development of small size power tiller for low speed, inter raw cultivation.

Axle driven rotary equipment has the advantage of getting maximum soil disturbance effects out of a relatively small and light power unit since the weight of whole unit is supported on the rotor, which will facilitate deeper penetration of soil working element on other-wise hard and in-accessible soil surface.

It also can make use of the characteristic of slower rotor speed by dispensing with the necessity of costly design considerations to obtain the dynamic balancing which is necessary in high speed rotary units. The selection of suitable shapes of tines or blades on rotor according to particular local conditions is necessary.

ACKNOWLEDGEMENTS

The author wishes to express his deep gratitude to-ward all the persons who have afforded many benefits and favours in assisting to complete his tour of duty in Thailand. Special thanks are due to Mr. Visut Chandrangsu, Director of Botany and weed Science Division, Dr. Paitoon Kittipong, chief of weed science Research Institute, Dr. Somchani Khomvila, assistant chief of the Institute. They took over-all responsibility for the general activities of this expert throughout his stay at the Institute. Special thanks are also due to Mr. Chack Chakkaphak, Director of Agricultural Engineering Division, who gave prodding to this branch of study in the NWSRI project and made it possible for the author to get the assignment there. He provided limitless opportunities for the expert to work in cooperation with the Outstanding agricultural engineers in his division.

The author is deeply indebted for the personal and professional assistance provided by Mr. Charanchai Rojanacardi, Mr. Anusorn, and Mr. Jaruwat Mongkoltanas, all from Agricultural Engineering Division.

Much heartfelt appreciations have to be expressed toward the selfless personal assistances volunteered by Miss Maneesa Teerawatsakul, Mrs Cha-um Premasthira, Mrs Chanpen Prakongvongs, Mr. Chaiyot Supatanakul, and Miss Siriporn Zungsontiporn.

Very fundamental gratefulness is due to Dr. K. Noda, the project leader and other Japanese staff members, Dr. J. Harada, Mr. T. Nibe, and Mr. K. Kojima.

The author would like to extend his sincere gratitude to the kind day-to-day services provided by Mrs. Yupin and other members of the project secretariat.

ECONOMICAL EFFECT AND POSSIBILITY OF CHEMICAL WEED CONTROL IN THAILAND

DR. TOSHIYUKI MOMMA*

Short-term Expert of JICA

National Weed Science Research Institute (NWSRI) Project

in Thailand

29 March, 1985

*Project Research Team, Agricultural Research Center,

Ministry of Agriculture, Forestry and Fisheries

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1. Preface

The main economic policy at present time in Thailand is under the fifth Neo-Economic and Social Development five years Plan which started from October, 1981. Neo-Economic and Social Development five years Plan which practiced four times until 1981 being kept 7 percent/year economic growth rate, and realized development of industry, expand of exports and improvement of living standard etc. On the other hand, however, rapid economic growth brought on such distortion as urbanization of big cities, the increase income gap between rural and urban and the scarcity of land, water and forest resources. Furthermore, oil crises which extended over two times bring on a fall in primary product prices and a rise the rate of foreign interest, therefore, Thai economy falled into large confusion. The fifth Neo-Economic and Social Development Plan which have been made in such situations select the improvement of living standard, repletion of social service in the rural, an increase productivity on agriculture and industry, and reorganization of economic structure as major subjects. Especially on agricultural development, an increase of productivity have been emphasised, due to a expansion of Agricultural land is nearly limited in Thailand. Practically, the targets of annual ratio of yield increase were decided as follows ;
rice 3.0%, rubber 9.7%, maize 6.3%, sugar cane 2.5%, tobacco 2.5%, mungbeen 5.4%, sorghum 4.7%, soybean 2.9%, cotton 5.6%. Especially to improve productivity on upland field crops are emphasized in the plan.

These crops are main export commodities, intensification of international competition base upon the elevation of productivity is requested. Generally field crops production in Thailand are undeveloped as a plantation, a great part of field crops production are supported by small scale farmers. Therefore, farm mechanization has not been established, farms which depend upon family labour and hired labour are a majority at present. Moreover field crops production which does not have irrigation is largely fluctuated on yield by the state of rainfall. For rising up field crops productivity, equipment of irri-

gation facility, introduction of high yield varieties, practice of fertilization, control of plant disease and insects, weed control and effective machine utilize technique will be needed. Especially, weed control in Thailand under the condition of high temperature and humidity requires a large quantity of labour to manage, and affects yield level, therefore the development of appropriate technique for weed control become necessary. At present, weed control by herbicides are carried out only a part of rice production, large scale plantation of rubber and pineapple production and vegetable production in the suburbs of large city. The great part of a weed control are carried out by man-power.

The author carried out an series of investigation on the actual condition of weed control and economical evaluation of weed control by herbicides from February 14 to March 31, 1985 in Thailand as the short term expert of Thai-Japan Weed Science Research Project. Since the investigation term is very short as one month and half, we forcused to three subjects as follows ;

1) Possibility of chemical weed control examined through the movement of agriculture in Thailand.

2) Possibility of chemical weed control examined through the actual farming practice of major crops

3) Examination of economical evaluation method of weed control

In subject 1), we consider the possibility of introduction and practice of chemical weed control by analysing time sequent data concerning the movement of agriculture in Thailand. In subject 2), we report the actual condition of rice and field crops farming, and furthermore, study the effect of chemical weed control by agro-economical stand point. In subject 3), we examined method of economical evaluation for weed control technology.

2. Possibility of Chemical Weed control Examined through the Movement of Agriculture in Thailand

In this chapter, we consider the possibility of chemical weed control by studying movement of agriculture from the following standpoint;

(1) The movement of three essencial factors of agricultural production; land, labour and capital

(2) The movement of use and price of fertilizer, agricultural chemicals and herbicide

(3) The movement of production cost of major agricultural products and farm management

(4) The movement of price of agricultural product and its demand

1) The Movement of Essencial Factors of Production

A. Land

Table 1 shows a number of farms and farm size by regions. A number of farms in all regions are clearly increased every year. Usually it is said that a number of farms decrease according to the economic development, however, this negative phenomernon occured due to equal inheritance. On the other hand, farm size tend to decrease in all regions. Average farm size of whole Kingdom in 1981 was 26.76 rai, while that of Central Plain was the largest as 32.29 rai, followed by Northeast as 28.1 rai, South as 22.91 and North as 22.85 rai. The percentage of paddy field for agricultural land of South was the smallest as 35%, followed by Central Plain as 54.2%, North as 63%, and Northeast as 70%. As we have seen, farm size was decreasing by the increase of number of farm, such tendency is unfavorable for the development of agricultural mechanization and chemical weed control.

Next, looking the situation of land hold and land tunured. The percentage of owner ship land in the whole Kingdom was over 80% in every year, it shows that a great part of farm in Thailand are landed farmers. Moreover, the percentage of owner ship land tend to increase after 1978. Looking the percentage

Table 1. Farm Holding Land of Thailabd by Region

Unit : rai/household.

Regions	Year	Number of farm	Farm size	Paddy land	Under field crops	Under fruit tree & tree crop	Under Vegetable & flower	Other land
Whole Kingdom	1975	4,120,046	27.24	17.29	4.84	2.53	0.09	2.49
	1978	4,377,613	26.60	16.74	5.43	2.38	0.08	1.97
	1981	4,532,351	26.76	16.22	6.04	2.52	0.07	1.85
Northern	1975	1,054,521	22.72	15.01	5.75	0.59	0.07	1.39
	1978	1,147,130	21.27	13.88	5.74	0.65	0.07	0.93
	1981	1,181,594	22.55	14.21	6.54	0.67	0.06	1.07
North-Eastern	1975	1,675,650	28.35	20.34	4.49	0.28	0.05	3.19
	1978	1,754,760	28.10	20.26	5.28	0.26	0.05	2.31
	1981	1,840,184	28.10	19.66	5.83	0.30	0.04	2.27
Central Plain	1975	826,505	33.30	20.60	7.66	2.61	0.22	2.72
	1978	868,463	33.71	19.51	8.98	2.45	0.18	3.45
	1981	887,930	32.29	17.52	9.92	2.57	0.15	2.85
Southern	1975	563,370	23.50	7.98	0.19	12.77	0.05	2.51
	1978	607,260	22.17	7.98	0.19	11.68	0.05	2.27
	1981	622,643	22.91	8.01	0.19	12.50	0.04	2.17

Source : Agricultural Statistics of Thailand

Table 2. Total Agricultural Land Holding and Land Tenured Classification by Year and Region

Unit : Percentage

Year		Owner ship				Rented				
		Owner	Mortgaged out (period unspecity)	Mortgaged out (period specify)	Total	Rented from	Mortgaged in (period unspecity)	Mortgaged in (period specify)	Free of charge	Total
	1975	83.3	1.1	0.1	84.5	12.1	-	0.2	3.2	15.5
	1976	85.1	0.5	0.03	85.7	11.5	0.2	0.03	2.6	14.3
	1977	82.6	0.6	0.04	83.2	12.4	0.2	0.02	4.2	16.8
	1978	81.6	1.3	0.03	82.9	12.7	0.3	0.06	4.1	17.1
	1979	83.7	0.67	0.2	84.6	11.6	0.3	0.04	3.5	15.4
	1980	84.0	0.52	0.02	84.5	11.6	0.3	0.04	3.6	15.5
1979	North	78.9	0.3	0.02	79.2	14.6	0.2	0.08	6.0	20.8
	North-east	92.0	0.57	0.05	92.6	3.5	0.37	0.05	3.1	7.2
	Central plain	69.9	1.35	0.06	71.8	26.3	0.05	0.22	2.2	28.2
	South	91.7	0.02	0.08	92.0	4.6	0.67	0.02	2.8	8.1

Source : Agricultural Statistics of Thailand

of owner ship land by regions, that of Central Plain was the lowest as 67.7%, North is second as 78.9%, Northeast and South were both high as 92%. Large land holder born in Central Plain by the boom of land speculation after 1880's,

it was a time when export of Thai rice had started. Consequently, the number of tenant farmers in Central Plain have increased. A farm rent at that time was 1/3 - 1/2 of the products. It is said that, this rate is not changed till now. Rice production looked from cropping season in Thailand can be divided into major rice and second rice. Moreover, cultivation practice in the major or second rice can be classified as follows : (1) transplanting rice, (2) deep water rice and (3) germinated seed rice. Weed control of deep water rice and germinated seed rice are especially important. Germinated seed (direct sown) rice is rapidly spreading in second rice region of Central Plain. The yields of second rice is double of major rice, moreover, annual fluctuation of yields per rai is small. Therefore, the farmers of double cropping areas are interested in weed control by herbicides and new technology. The planting area of double cropping rice in Thailand was 2,038 thousand rai in 1974, then it is increasing every year, it raised to 3,963 thousand rai in 1983. But

Table 3. Planted Area, Irrigated Area and Non-Irrigated Area of Major Rice

unit : thousand rai

Year	Whole Kingdom	Irrigated area	Non-Irrigated area
1970	46840	11487	35353
1971	47043	11703	35340
1972	44620	11301	33319
1973	50232	11386	38846
1974	47821	11602	36219
1975	53244	11761	41483
1976	50859	11962	38897
1977	53465	12131	41334
1978	58409	12717	45693
1979	56868	12691	44177
1980	56882	13113	43769

Source : Agricultural Statistics of Thailand

percentage of double cropping rice is still very low as 6.6% in 1983. Moreover, 80% of the area in concentrated in Central Plain. Irrigated area of major rice was 11,487 thousand rai in 1970, after it is increasing every year, it became 13,113 thousand rai in 1980. The rate of increasing is very small as 14% per 11 years (Table 3). Irrigated area for major rice was 23% in 1980. Although a part of the irrigation area of major rice and second rice are already using herbicides, a full scale of extension to all of the area is espected in future. Major rice production in other area is dominated by transplanting and weed control by man power.

B. Labour

One of major factors supported to the development of agricultural production in Thailand is the existence of enough family labours, tenant farmers and agricultural labour who don't have agricultural land. Wage level for these labour have been kept very low, this contributed as one of the factor to provide a competitive power in the world market on such products as rice, maize, cassava etc. Future movement of these labour is very important for the diffusion of agricultural mecanization and weed control by herbicides.

The percentage of agricultural population to total population was 77% in 1970, and then this percentage had decreased 1% every year, it became 65% in 1983. The same tendency is recognized for the movement of agricultural labour, that percentage had decreased from 74.8% in 1970 to 61.9% in 1983. The percentage of farm population for total population decreased from 59.26% in 1970 to 55.76% in 1983. However, decreased rate of farm population in very small as 3.5% per 14 years in comparison with agricultural population and agricultural labours. It may be say from above facts that a great part of agricultural labours decreasing was due to the migration of landless people from village to big city, family labour of ownership farmers are scarcely change. A number of agricultural labors per farm is almost not changed as 3.7 - 3.8 man, this figure may be support above fact (Table 4).

Table 4. Economically Active Population Between 15-64 Years of Age in Agriculture

Year	Percentage of workers in agricultural sector	Percentage of Agricultural population	Percentage of farm family	Workers in agricultural sector per farm household	Agricultural population per farm household
1970	74.81	77.25	59.26	3.76	7.45
1971	73.09	75.81	58.04	3.78	7.43
1972	71.39	74.34	56.85	3.80	7.42
1973	68.58	71.75	54.64	3.81	7.40
1974	67.78	70.99	54.84	3.83	7.37
1975	67.03	70.24	54.89	3.84	7.35
1976	66.34	69.52	58.58	3.85	7.32
1977	65.70	68.83	58.90	3.85	7.29
1978	65.08	68.16	58.74	3.76	7.02
1979	64.49	67.51	57.58	3.82	7.11
1980	63.92	66.89	57.70	3.86	7.15
1981	63.38	66.29	56.57	3.89	7.18
1982	62.84	65.72	56.80	3.84	7.01
1983	61.9	65.18	55.76	3.78	6.94

Source : Selected Economic Indicators Relating to Agriculture, Division of Agriculture Economic, Ministry of Agriculture and Co-operatives, Thailand

If we assume that the decrease of agricultural labour who don't have agricultural land will continue from now on, the group of large scale farmers who conducted transplanting, weed control and harvesting by employing cheaply hired labour will be some short of labour, then mechanization and weed control by herbicides will be extend. But looking at the movement of employment, a number of unemployment persons are increasing rapidly in every year, estimated figure in 1984 show that it will be 1410 thousand man and 5.6% as the rate of unemployment. . Under these condition, it is hard to say that decrease rate of agricultural labour is going to continue for future. The future movement of agricultural labour who don't have agricultural land will be dominated by the poliey of regional despension of economic activity which is promoted by the fifth 5 years plan, but it may not absorb many labour because at present time this policy is not performed in whole Kingdom.

C. Capital

It may be said that recently agricultural mechanization in Thailand is progressing. Especially, extension of power tiller and tractor are progressing.

Table 5. Farm labor - saving equipments, whole country

Unit : Units

Years	2 wheel working tractor	4 wheel tractor	Big tractor	Sprayer	Water wheel engine	Water pump	Cleaning machine
1976	113,286	16,427	17,569	1,379,436	68,219	277,084	47,423
1978	192,004	26,984	28,984	1,528,461	89,775	359,308	59,488
1980	280,591	36,158	37,177	131,645	125,811	317,975	74,782
1981	284,351	39,158	50,044	138,504	146,927	603,548	83,801
1982	323,846	45,688	61,840	169,089	148,396	780,610	84,073

Source : Agricultural Statistics of Thailand

Especially, extension of power tiller and tractor are remarkable. Diffusion rate of power tiller to farm in 1975 was one machine to 37 farm, that of tractor was one machine to 124 farm. Diffusion rate of power tiller in 1982 was one machine to 14 farm, that of tractor was one machine per 43 farm. On the other hand, number of sprayers is few, moreover rate of increase is small too. Diffusion rate of sprayer in 1982 was one machine to 25 farm. The diffusion of water pump is recognized, but that of harvester and thresher are not recognized at farmer level.

2) Movement of Price of Agricultural Products and Consumer's Demand

A) Movement of Price of Agricultural Products

Table 6. Average Farm Price Index of Agricultural Product

Unit = Baht
Unit = Percentage

	Unit	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Nonglutinous paddy first grade	Kwein	1414	2121	2210	2008	2045	2403	2501	2994	3435	2871	2985
	%	70.4	105.6	110.0	100.0	101.8	119.7	124.5	149.1	171.1	143.0	145.9
Glutinous paddy first grade	Kwein	1284	1876	2104	1918	1874	2778	2194	2477	2889	2711	3131
	%	67.0	97.8	109.7	100.0	97.7	114.8	114.4	129.2	150.7	141.4	166.4
Maize	Kg	1.44	2.10	1.86	1.66	1.60	1.63	2.04	2.40	2.23	2.25	2.37
	%	86.7	126.5	112.0	100.0	96.4	98.2	122.9	144.6	134.3	135.5	137.8
Sorghum	Kg	1.14	1.78	1.50	1.37	1.42	1.51	1.93	2.28	2.65	2.10	2.3
	%	83.2	129.9	109.5	100.0	103.6	110.2	140.9	166.4	193.4	153.3	162.0
Mung been	Kg	2.75	3.28	3.78	4.92	5.67	6.41	5.52	7.02	8.30	8.17	8.26
	%	55.9	66.7	76.8	100.0	115.2	130.3	112.2	142.7	168.7	166.1	133.4
Cassava root	Kg	0.29	0.29	0.40	0.46	0.48	0.36	0.74	0.75	0.54	0.54	0.73
	%	63.0	63.0	87.0	100.0	104.4	78.3	160.9	163.0	117.4	117.4	155.3
Sugar cane	Kg	141.4	195.1	255.0	285.7	283.1	281.0	295.6	406.0	613.0	399.0	325
	%	49.5	68.3	89.3	100.0	99.1	98.3	103.5	142.1	214.6	139.6	115.6
Soybean	Kg	4.10	4.39	4.36	5.10	6.27	5.56	5.67	6.58	6.68	6.30	6.77
	%	80.4	86.1	85.5	100.0	122.9	109.0	111.2	129.0	131.0	123.5	133.0
Ground nuts in shell (dry)	Kg	2.98	3.62	3.74	4.29	4.59	5.11	5.44	7.57	6.65	6.27	8.57
	%	69.5	84.4	87.2	100.0	107.0	119.1	126.8	176.4	155.0	146.2	199.8
Coconut (large)	Hundred	214	314	224	208	268	338	383	479	444	274	372
	%	102.9	150.9	107.4	100.0	128.5	162.0	183.8	229.8	213.0	131.2	178.7
Cotton	Kg	5.46	6.75	6.39	6.07	7.57	8.12	10.25	10.50	11.48	9.77	11.71
	%	90.0	111.2	105.3	100.0	124.7	133.8	168.9	173.0	189.1	161.0	188.9
Kenaf	Kg	2.01	1.81	1.73	2.09	2.79	2.68	2.67	3.26	3.57	4.01	3.6
	%	96.2	86.6	82.8	100.0	133.5	128.2	127.8	156.0	170.8	191.9	175.6
Rubber	Kg	8.72	8.52	7.60	10.17	10.97	12.99	16.20	17.50	14.49	13.12	16.73
	%	85.7	54.3	74.7	100.0	107.9	127.7	159.3	172.1	142.5	129.0	164.5
Tobacco leaf dried virginia	Kg	17.49	25.28	25.95	29.55	33.82	29.05	36.38	44.79	36.20	38.04	48.89
	%	59.2	85.5	87.8	100.0	114.4	98.3	123.1	151.6	122.5	128.7	142.2

Source : Selected Economic Indicators Relating to Agricultural, Division of Agricultural Economics, Ministry of Agriculture and Co-operatives, Thailand

Not to speak of rice which is staple food for Thai people, prices of agricultural products in Thailand are very low. Looking at the movement of price of agricultural products from 1973 to 1983, every prices became about twice. Looking at the movement of index of consumer prices in the same period, it was raising exceed the prices of agricultural products as 74.2 in 1973, 100 in 1976, 155.9 in 1980, 193 in 1983. At the present time, it may be said that none of agricultural products which exceeded the consumer price.

On the other hand, annual fluctuation of prices on all the agricultural products are large. Especially, fluctuation of sorghum, cassava, sugar cane and coconut are larger consideration from the movement of annual fluctuation of prices (on agricultural product), and the movement of index of consumer prices, we can not say that profitability of farmers improve every year. It may be become worst. To extent weed control by herbicides under these situation, the movement of the price of herbicides and hired labour in future will become a critical factor.

B) The Movement of Demand of Agricultural Product

To grasp correctly the movement of demand : of agricultural products in Thailand is very difficult, because household survey data is not yet enough. Therefore, we consider the movement of demand of agricultural products base on the results of income elasticities of demand for food by Agricultural Economic Research Bulletin 1974.

Income elasticity of demand is the important economical index to show the demand fluctuation when income change. If income elasticity of demand is 0.1, it means that demand increase 0.1% when income increase 1%, when income elasticity is larger, we can think that potencial demand is larger and prices are going up.

Average of income elasticity of rice in Thailand is 0.047, looking at by region, North-Eastern Thai is 0.07 and other region are below 0.05. Domestic demand for rice is satisfied, therefore rice price will not drastically rise. On the other hand, income elasticity of all food average in

Table 7. INCOME ELASTICITY OF DEMAND FOR FOOD 1972/73

รายการ Items	ภาคกลาง Central	ภาคใต้ South	ภาคตะวันออกเฉียงเหนือ North–East	ภาคเหนือ North	เฉลี่ยทั้งประเทศ Average
ข้าว Rice	.050	–.038	.073	.014	.047
อาหารแป้งอื่น Other flour	.314	.331	.195	.674	.388
รวมอาหารแป้ง Total	.058	–.002	.082	.040	.063
เนื้อหมู Pork	.155	.506	.234	.469	.386
เนื้อโค กระบือ Beef	.323	.346	.198	.083	.142
เนื้อสัตว์ปีก Poultry	.896	1.591	.170	.164	.216
รวมเนื้อสัตว์ Total	.246	.736	.179	.262	.233
ไข่ Egg	.190	1.042	.262	.680	.462
ปลา Fish	.379	.422	.203	.496	.242
สัตว์น้ำอื่น ๆ Other fish	.595	1.09	.255	.302	.505
รวมสัตว์น้ำทุกชนิด Total	.292	.531	.203	.468	.280
ผัก Vegetable	.374	.453	.127	.371	.216
ผลไม้ Fruit	.248	.253	.085	.577	.267
เมล็ดถั่วและพืชน้ำมัน Oil seed	.258	.260	.174	.460	.388
น้ำมันและผลิตภัณฑ์ Oil andfats	.704	1.602	.608	1.381	.706
น้ำตาล Sugar	.083	.816	.006	.819	.337
ขนม Sweet	.163	.995	.146	.496	.259
เครื่องดื่ม Beverage	–.302	.426	.326	.861	.406
น้ำมันปรุงอาหาร Cooking oil	.375	.784	.177	.831	.578
เครื่องชูรส Flavour	.215	.153	.230	.433	.277
อาหารอื่น ๆ Other	.557	.462	.444	.417	.451
อาหารทุกประเภท All food	.062	.293	.130	.052	.189

ที่มา : รายงานผล"การศึกษาความยืดหยุ่นของความต้องการอาหารต่อรายได้" ของครัวเรือนเกษตรกร
เอกสารเศรษฐกิจการเกษตร, กองเศรษฐกิจการเกษตรปี 2517

Source : Income Elasticity of Demand
Agricultural Economic Research Bulletin 1974

หมายเหตุ : ความยืดหยุ่นในการเสนอซื้ออาหาร เมื่อรายได้เปลี่ยนไปคือเปอร์เซ็นต์การเปลี่ยนแปลงของรายจ่ายเดิม เมื่อรายได้เพิ่มขึ้น 1 เปอร์เซ็นต์

Note : Income Elasticity of Demand for food is percent changing expenditure when income increasing one percent.

Thailand is small as 0.189, it show that demand for food comparatively is satified. Income elasticities differ from by regions, but demands for meet, oil and fat, vegetable, fish and sugar in Thailand will increase because income elasticities of these foods are comparatively large. As far as cassava which is main export field crop, frame of export for decrease export for future is established between Thai and EC, the adjustment of production is performed. As far as maize, demand of Singapore, Malaysia and Hongkong are large and that are stable, but demand of Japan exist many factors for being unstable.

It may be clear from the movement of demand for foods that prices of rice and main field crops in future could not be increased so much. Therefore, increasing yield per rai and decreasing production cost are the most important profitable farming.

3) The Movement of Production Cost of Major Agricultural Products and Farm Economy

A) Production Cost

Table 8. shows the movement of production cost of major agricultural products from 1971/76 - 1980/81. The rate of fixed cost to total cost of these crops are very low in comparison with variable cost, moreover that did not increase each year. If considering the increasing of prices, it seems to be constant or decline. The rates of fixed cost to total cost in 1980/81 are as follows; major rice 19.1%, maize 16.7%, cassava 12.4%, second rice 9.1% and cotton 6.0%. Therefore, increasing of production cost of all crops are due to the increasing of such variable cost as hired labour, cultivation charge, fertilizer, insecticides, seed and fuel. Annual increasing rate of variable cost of all crops are the same as the increasing rate of prices. Looking at the movement of income per rai, major rice which is lower yield level become minus, moreover it's amount is increasing every year. On the other hand, income per rai of second rice realize high profit by higher yield per rai. Cassava

Table 8. Cost Production Per Rai and Per Kilogram

Year	Cost item		Major rice	Second rice	Cassava	Maize	Cotton
1975/76	Yield	Kg/rai	265	512	2197	374	150
	Variable Cost	Baht/rai	352.28	731.58	465.13	410.18	1023.18
	Fixed cost	Baht/rai	126.59	126.03	99.39	112.21	80.37
	Total cost	Baht/rai	478.77	857.61	564.52	522.39	1103.55
	Total cost	Baht/rai	1.81	1.67	0.26	1.40	7.36
1977/78	Yield	Kg/rai	257	500	2068	223	144
	Variable cost	Baht/rai	448.5	733.76	522.36	314.72	838.52
	Fixed cost	Baht/rai	122.66	67.67	82.68	82.81	93.97
	Total cost	Baht/rai	571.21	801.43	609.87	397.53	934.49
	Total cost	Baht/rai	2.22	1.60	0.29	1.78	6.49
1979/80	Yield	Kg/rai	258	528	1693	299	190
	Varaible cost	Baht/rai	591.83	1274.53	677.80	430.56	1479.58
	Fixed cost	Baht/rai	147.24	158.12	111.61	93.71	112.03
	Total cost	Baht/rai	739.07	1432.65	779.41	524.27	1591.61
	Total cost	Baht/rai	2.86	2.71	0.46	1.75	8.38
1980/81	Yield	Kg/rai	270	608	2290	334	203
	Variable cost	Baht/rai	696.24	1294.99	822.14	487.15	1844.20
	Fixed cost	Baht/rai	160.70	130.20	117.20	98.03	118.55
	Total cost	Baht/rai	836.91	1425.19	939.34	585.18	1962.75
	Total cost	Baht/rai	3.10	2.34	0.41	1.75	9.67

Source : Agricultural Statistics of Thailand

and maize can realize some profit by low cost of production. Production cost of cotton is very high, but it can realize some profit due to comparatively high price (Table 9).

B) The Movement of Farm Economy

Table 10. shows the movement of farm economy from 1970 to 1981. Average farm income (agricultural income + non agricultural income) became 5.8 times in the past 12 years. Increasing rate on consumer prices index is about 3 times during the same period, net farm income seems fairly increase.

Table 9. Income per rai

Unit:Baht

Year	Item	Major rice	Second rice	Cassava	Maize	Cotton
1975/76	Income	-38.1	170.5	446.1	98.5	-193.1
1977/78	Income	-152.3	400.1	134.6	-34.0	234.8
1979/80	Income	-119.8	148.2	490.3	193.3	403.4
1980/81	Income	-234.8	663.3	297.3	159.6	367.7

Farm income in Northeast was the highest increase as 7.7 times by the increase production such commercial crop as rice, maize and cassava. Increase rate of farm income in other regions are as follow; South 6.5 times, North 5.6 times and Central Plain 4.7 times. On the other hand, increase rate of expense for agricultural production are 3 to 4 times in the regions, these are smaller than the increasing rate of income. Therefore, increase rate of net farm income are exceed farm income as follows; Average Thailand is 7.0 times, Northeast is 9.6 times, South is 7.7 times, North is 6.5 times and Central Plain is 5.6 times. Consequently, net income per farm household average Thailand in 1981 became 24,684 baht. Net income per farm household by regions are as follows ; Central Plain is 33,248 baht, South is 30,469 baht, North is 23,929 baht and Northeast is 19,067 baht.

Recently farm income in Thailand is increasing rapidly as looking above, next we compare farm income with income of other sectors. Average income of non-skilled worker in 1982 is 19,704 baht per year. On the other hand, that of skilled worker in 1982 is 65,248 baht. Looking at the whole farm household, farm income is bigger than average income of non-skilled labour. But if consider the such state as a farm household have four farm labour, farm income per one farm labour become below half of income of non-skilled worker. Therefore, absolute income level of farm is low though recently it is increasing. Average of non-agriculture income per farm household in 1978/79 was 8.429 baht, it shared

Table 10. Average Cash Income from Non-Agricultural Sector per Agricultural Household by Type of Income Sources and Regions, 1978/79

Unit : Percentage

Incomes	North	North east	Central Plain	South	Average whole Kingdom
Hiring-out amimals	0.66	0.38	0.24	0.33	0.40
Hiring-out farm equipment	12.03	2.02	5.62	3.57	5.57
Hired farm works by every household members	15.39	10.53	11.29	13.18	12.36
Salaries	17.64	22.71	20.64	14.37	19.37
Hired non-farmworks by every household members	21.98	26.26	17.06	23.40	22.27
Selling of non-raised animals	2.57	5.18	1.56	0.95	2.78
Selling of off-farm plants and crops	2.45	3.90	1.84	0.60	2.37
Selling of other homemade goods	4.45	4.86	5.18	6.04	5.09
Relatives or rituals and ceremonies	2.53	9.0	3.61	1.86	4.68
Rented-out land and living guarters	2.48	1.09	1.97	0.54	1.52
Loan interest	0.25	0.12	0.67	0.24	0.32
Others	17.57	13.95	30.32	34.92	23.29
Total (baht/farm)	7239 (100)	6459 (100)	12064 (100)	11314 (100)	8429 (100)

Source : Agricultural Statistics of Thailand

Table 11. Farm Net Cash Income and Expenses Per Farm Household

Year	Items	Northeast	North	Central Plain	South	Average
1953	Farm & Nonfarm Income	1833	3317	4218	5441	3544
	rate of increase	(57.2)	(57.5)	(34.6)	(99.7)	(59.9)
	Farm Expense	206	346	1355	623	664
	rate of increase	(17.2)	(16.8)	(21.5)	(41.4)	(27.8)
	Farm Net Cash Income	1627	2971	2863	4818	2880
	rate of increase	(81.9)	(80.2)	(48.5)	(121.9)	(81.6)
1970	Farm & Nonfarm Income	3203	5768	12199	5458	5921
	rate of increase	(100)	(100)	(100)	(100)	(100)
	Farm Expense	1195	2055	6291	1504	2390
	rate of increase	(100)	(100)	(100)	(100)	(100)
	Farm Net Cash Income	1986	3703	5909	3954	3531
	rate of increase	(100)	(100)	(100)	(100)	(100)
1975	Farm & Nonform Income	8834	13940	24525	14321	14915
	rate of increase	(275.8)	(241.7)	(201.0)	(262.4)	(251.9)
	Farm Expense	2767	4646	11025	2760	5421
	rate of increase	(231.5)	(226.1)	(175.3)	(183.5)	(226.8)
	Farm Net Cash Income	6068	9295	13500	11562	9494
	rate of increase	(305.5)	(251.0)	(228.5)	(292.4)	(268.9)
1977	Farm & Nonfarm Income	9955	18549	36980	13477	17826
	rate of increase	(310.8)	(321.6)	(303.1)	(246.9)	(301.1)
	Farm Expense	2637	4718	15994	1938	5636
	rate of increase	(220.7)	(229.6)	(254.2)	(128.9)	(235.8)
	Farm Net Cash Income	7318	13831	20986	11539	17770
	rate of increase	(386.5)	(373.5)	(355.2)	(291.8)	(503.3)
1981	Farm & Nonfarm Income	24675	32285	56937	35517	34537
	rate of increase	(770.4)	(559.7)	(446.7)	(650.7)	(583.3)
	Farm Expense	5608	8356	23689	5048	9855
	rate of increase	(469.9)	(406.6)	(376.6)	(335.6)	(412.3)
	Farm Net Cash Income	19067	23929	33248	30469	24684
	rate of increase	(960.1)	(646.2)	(652.7)	(770.6)	(699.1)

Source : Agricultural Statistics of Thailand

Table 12. Average Cash Expenses for Agriculture Sector per Agricultural Households by Type of Expenses and Regions, 1978/79

Unit : percentage

Expenditures	North	Northeast	Central Plain	South	Average whole Kingdom
Rented-purchase land	10.66	2.41	7.25	4.70	6.88
Land tax	1.02	2.09	0.61	2.10	1.13
Loan interest	8.33	6.59	6.38	6.41	6.89
Other rents	1.53	1.18	1.76	0.63	1.49
Hiring services	34.51	32.58	28.27	41.05	31.78
Transportation	1.64	5.46	7.28	2.33	5.10
Fuels	12.19	4.10	5.64	8.77	7.19
Repairs	5.08	4.90	2.77	2.76	3.73
Chemical fertilizer	5.34	15.47	12.47	10.11	11.14
Animal manure	0.09	1.18	0.70	0.62	0.64
Lime	0.01	0.01	0.12	-	0.06
Insecticides	1.78	3.20	3.21	0.50	2.62
Seeds	3.50	1.93	2.99	0.28	2.66
Food in changing labour	2.60	2.67	0.34	3.15	1.83
Equipment lower 100 baht	1.03	2.92	0.80	2.58	1.44
Purchase of swine & duck	2.64	2.78	0.70	2.28	1.71
Chicken	0.16	0.50	2.47	1.74	1.47
Purchase of other poultly	0.41	0.10	0.15	0.04	0.19
Fish and aquatic animals	0.16	0.04	0.37	0.06	0.23
Animal nutrition & medecine	4.0	5.75	11.8	8.3	8.44
Others	3.42	4.14	3.4	1.6	3.38
Total (baht/farm)	6658 (100)	3550 (100)	18655 (100)	4549 (100)	7326 (100)

Source : Agricultural Statistics of Thailand

about 40% of total farm income. Looking at by regions, Central Plain and South are high, but North and Northeast are low. Looking at the items of non-agriculture income, total income of hired farm works, salaries and hired non-agriculture works shared over 50%. Hiring out farm equipment in North Thai is comparatively larger as 12%.

On the other hand, the items of cash expense for agriculture production, hiring labour shared large portion. Especially, it shared 41% for total in South Thai As far as expense except hiring labour, there are differ from regions.

Expense order in North Thai is as follws ; fuels > rented purchase land > loan interest > chemical fertilizer > loan interest > animals nutrients & medicine > transportation. Expense order in Central plain is as follows; chemical fertilizer > animals nutrients & medicine > transportation > rented-purchase land > loan interest > fuels. Expense order in South Thai is as follows; chemical fertilizer > fuels > animal's nutrients & medicine. Expense rate of insecticides for the total expense is very low in all region such as Central Plain 3.2%, North 1.78% and South 0.5%. Pesticides and herbicides are not record as expense items, its utilization at present time may be very small.

4) The Movement of Use and Price of Herbicides

Looking into amount of fertilizer use in Thailand has been increasing every year until 1979, but it was suddenly decreased in 1980, then went up in 1981 to 800 thousand ton and again declined in 1982 to 780 thousand ton. Above movement shows that fertilizer use in Thailand is not stable in recent years (Table 13).

On the other hand, insecticide and fungicide use in Thailand are also not increase after 1978. However, herbicides use are steadily increasing after 1978. It is said that herbicides price is the most cheap level in the world, because most of advanced countries are developing sales competition of new products in Thailand. Those agricultural chemical companies are paying

Table 13. Fertilizer used in Thailand and paddy

Unit : tons

Year	Total	N	P_2O_5	K_2O	% use on paddy	
					Major rice	Second rice
1969	273,686	47,339	61,294	10,950	199,505 (72.9)	13,400 (4.9)
1970	280,279	48,590	53,814	10,300	168,415 (60.0)	14,740 (5.3)
1971	261,479	47,929	40,625	9,650	164,696 (63.0)	15,500 (5.9)
1972	407,350	69,541	82,482	16,100	228,038 (55.9)	25,000 (6.1)
1973	418,396	67,472	76,603	17,500	192,940 (46.1)	39,310 (9.4)
1974	390,332	66,875	57,334	14,910	132,597 (34.0)	61,145 (15.7)
1975	506,428	83,949	76,670	17,930	172,462 (34.1)	70,310 (13.9)
1976	664,391	115,961	59,482	20,452	240,802 (36.2)	82,530 (12.4)
1977	764,113	140,726	79,972	30,517	265,662 (34.8)	104,308 (13.7)
1978	780,978	135,559	109,971	27,444	291,365 (37.3)	128,635 (16.5)
1979	792,002	124,919	121,355	44,132	300,000 (37.9)	178,500 (22.5)
1980	716,900	106,641	101,627	35,402	320,000 (44.6)	100,940 (14.1)
1981	800,000	132,830	97,402	22,185	332,116 (41.5)	154,092 (19.3)
1982	780,000	125,821	102,511	20,851	280,000 (35.9)	169,453 (21.7)

Source : Agricultural Statistics of Thailand

Table 14. Use of Farm Pesticides Classified by Type of Use

Unit : tons

Year	Insecticide	Fungicide	Herbicides
1974	5945	1400	1397
1975	7784	1600	1344
1976	8182	1700	2244
1977	9743	2000	4449
1978	13853	2900	5800
1979	13658	3000	5700
1980	13565	3000	7000
1981	13000	3000	10000
1982	14000	3000	8000

Source : Agricultural Statistics of Thailand

efforts as the explanation of chemical use and demonstration for farmers. These activity make an offer important source of technical information to farmers, because extention service does not fulfill it's function sufficiently yet. Price of many kind of herbicides is increasing after 1983. Although herbicides price in Thailand is still the most cheap level in the world, it is presumed to be increasing in the future through the survey.

3. Possibility of Chemical Weed Control Through the Actual Farming Practice of Major Crops

We examined next two subject for investigate the extension possibility of chemical weed control. The purpose of first subject is to make clear the economical effect of chemical weed control in the farm which use herbicides. The purpose of second subject is to make clear the extension possibility of chemical weed control in the farm which not use herbicides. For analysis of the first subject, we utilized the results of two pilot project (Greater Mae Klong Irrigation Project and Greater Chao Phya Basin Project) cooperated by JICA which are carrying out in Central Plain. For analysis of the second subject, we applied the survey of actual condition of farming at Petchabun in Northern Thai.

1) Paddy Rice

(A) Outline of The Project.

The project in Mae Klong and Chao Phya are started in 1977. The purposes of these pilot projects are to increase yield, to apply modanized farming and to organize the formation farmer's based on the establishment of double cropping technique in rice at irregation agea.

Mae Klong Pilot Project has two pilot areas. Pilot No. 1 (total area 403.6 ha) is carrying out intensive type land consolidation. Pilot No.2 (total area 550.5 ha) is carrying out extensive type land consolidation. Moreover, traial farms have constracted in each pilot area, those become the core of establishment of farming techniqued and its extension.

(B) The Survey to Measure the Effect of a Technology Expansion.

In the project, farming survey in area and out of area has been carried out twice to measure the effect of technology expansion. We pick up the results in connection with weed control from these survey and consider the economical effect of weed control by herbicides. The outline of survey areas showed Table 15 - Table 17

Table 15. General features of the study areas. (Mea Klong)

	Pilot No. 1	Thatakor	Nongplamor	Pilot No. 2	Doncha-em
Total area (rai)	2,522.5	15,625	18,426	3,440.6	12,642
Arable area	2,298.6(100)	10,710(100)	16,570(100)	3,273.1(100)	10,588(100)
Paddy field area	2,248.8(98)	4,908(46)	15,937(96)	2,839.4(87)	2,097(20)
Sugarcane field area	23.8(1)	4,489(42)	300(2)[a]	305.6(9)	7,964(75)[b]
Number of farm households	149[c]	479	785	313[c]	622
Land consolidation type	Intensive	Extensive	Extensive	Extensive	Extensive
Land consolidation year	1979-81	1983-84	To be 1985	1981-82	1981-82
Dry season rice	Planting	Planting	Not planting	Planting	Planting
Name of irrigation canal	1L-1R	1R-2R	7L-1R	Left Main & 3L	4L
Means of irrigation	Pump up	Gravity	Gravity	Gravity	Gravity
Number of farmers interviewed	42	21	21	42	42

Source: M. Tomitaka, Historical Change of Rice Farming in Mea Klong Area (unpublished paper)

Notes: Information on Thatakor, Nongplamor, and Doncha-em is obtained at Thamuang, Banpong, and Thamaka Agricultural Extension Office, respectively.

[a] Upland crop area (sugarcane is included).

[b] Include upland crop area.

[c] Number of households having agricultural land in the area.

Table 16. Adoption of planting methods (%). (Mea Klong)

		Wet season			Dry season		
		Transplanting	Direct sowing	Both methods	Transplanting	Direct sowing	Both methods
Pilot No. 1	1981	90.0 (38)	0.0	9.5 (4)	66.7 (12)	16.7 (3)	16.7 (3)
	1983/84	61.9 (26)	14.3 (6)	23.8 (10)	2.5 (1)	90.0 (36)	7.5 (3)
Thatakor	1981	100.0 (21)	0.0	0.0	100.0 (6)	0.0	0.0
	1983/84	95.2 (20)	0.0	4.8 (1)	36.8 (7)	15.8 (3)	47.4 (9)
Nongplamor	1981	100.0 (21)	0.0	0.0	-	-	-
	1983/84	100.0 (21)	0.0	0.0	-	-	-
Pilot No. 2	1981/82	100.0 (42)	0.0	0.0	65.5 (19)	10.3 (3)	24.1 (7)
	1983/84	78.6 (33)	4.8 (2)	16.7 (7)	45.2 (19)	28.6 (12)	26.2 (11)
Doncha-em	1981/82	78.6 (33)	16.7 (7)	4.8 (2)	84.4 (27)	9.4 (3)	6.3 (2)
	1983/84	85.7 (36)	4.8 (2)	9.5 (4)	68.3 (28)	19.5 (8)	12.2 (5)

Source: M. Tomitaka, Historical Change of Rice Farming in Mea Klong Area (unpublished paper)

Note: Figures in brankets are number of farmers reporting.

Table 17. General features of pilot areas (Chao Phya)

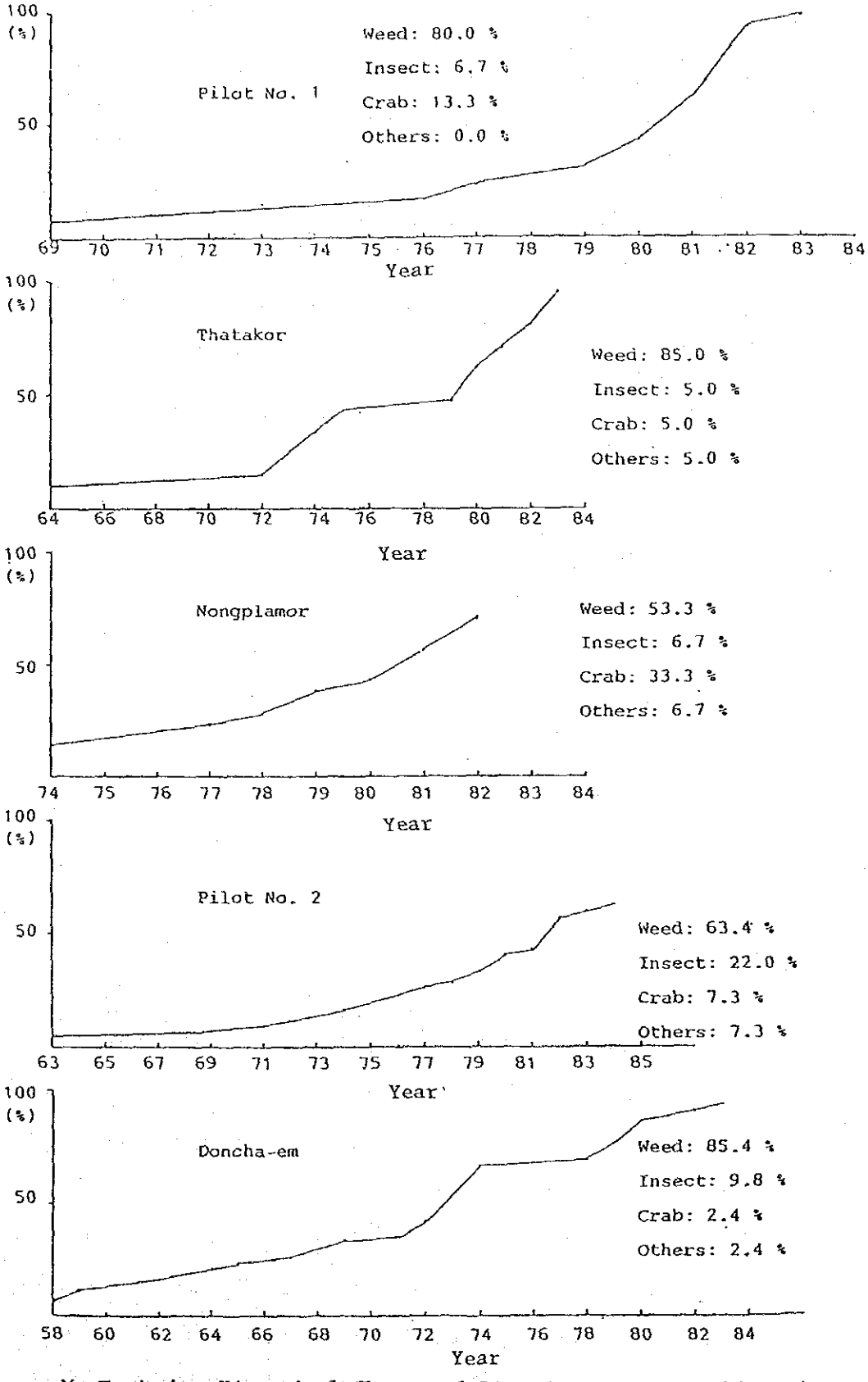
Paddy fields area	344.6 ha
Vegetable fields area	26.1 ha
Main pumping station	1
Secondary pumping station	4
Number of farm households	124
Average cultivation area	3.0 ha
Rice cultivation method (Direct sowing)	78.2%
(Transplanting)	21.8%

(C) Autual Condition and Economical Effect of Weed Control in Mae Klong Pilot Area.

Figure show the movement of farm household rate of agricultural chemicals using. It shows that a number of farm household using agricultural chemicals is steadily increasing every year. At present, its rate become almost 100% in Pilot No. 1, Tatakor and Doncha-em. Looking at the items of utilized agricultural chemicals, use rate of herbicide become over 50% in every areas. Especially, use rate of herbicide in Pilot No.1, Thakakor and Doncha-em become over 80%. Regardless of transplanting or direct-sowing, chemical weed control is broadly expanding in these areas. Apply Saturn G about 5 kg per rai after padding is practicing in these areas. In the case of direct-sowing, it was applied before sowing. When timing is appropriate, only one application is enough. Moreover, if effect of herbicide appear fully, weed control by man-power is not need. The farmers who apply herbicide over two times not exist in all pilot areas, because it needs much money. Sometimes, there are cases of weed control by man-power once, when the effect of herbicides is insufficient.

Average cost of agricultural chemical vary by areas at a range of 13-30 baht per rai. Price of Saturn G which have been used in the area is about 20 baht/kg. Therefore, it is supposed that farmer's throw into Saturn G about 1 kg/rai. This value is very low in comparison with the suggested guide of National Weed Science Research Institute as about 5 kg/rai. A share of chemical cost to total management in 1983 increased in every area from 1981. Chemical share was about 5%, it did not largely pressure upon management cost. On the other hand, hired-labour cost which occupied about 30-50% for the management cost of the major rice in 1981 decrease about 50% in 1983 except for Doncha-em. Especially, in Thatakor which remarkably increase agricultural chemical cost, it become under 25%. Similar tendency is recognized in second rice. Chemical weed control brought on the decline of the weed control cost by decreasing hired-labour which occupied a great part of total management cost,

Figure 1. First year of using chemical for farming. (Mea Klong)



Source: M. Tomitaka, Historical Change of Rice Farming in Mea Klong Area (unpublished paper)

Table 18. Change of chemical use. (Mea Klong)

		Wet season		Dry season	
		% used	Amount (B/rai)	% used	Amount (B/rai)
Pilot No. 1	1981	85.7	13.1 (36)	87.5	17.0 (14)
	1983/84	90.5	22.3 (38)	92.5	21.5 (37)
Thatakor	1981	85.7	13.4 (18)	83.3	65.5 (5)
	1983/84	52.4	29.8 (11)	73.7	56.7 (14)
Nongplamor	1981	85.7	9.0 (18)	-	-
	1983/84	61.9	12.6 (13)	-	-
Pilot No. 2	1981/82	95.2	12.4 (40)	82.8	18.5 (24)
	1983/84	64.3	20.6 (27)	71.4	21.0 (30)
Doncha-em	1981/82	76.2	20.3 (32)	65.6	23.4 (21)
	1983/84	66.7	17.1 (28)	51.2	28.6 (21)

Source: M. Tomitaka, Historical Change of Rice Farming in Mea Klong Area (unpublished paper)

Table 19. Practice of chemical use. (Mea Klong)

1983 wet season

	% of farmers used			Average cost (Baht/rai)			Purpose: Control of				
	HYV	Local	Total	HYV	Local	Total	Weed	Insect	Disease	Crab	Rat
Pilot No. 1	96.4	75.0	90.5	24.3 (27)	19.8 (21)	22.3 (38)	(30)	(9)	-	(10)	-
Thatakor	100.0	50.0	52.4	73.0 (3)	16.0 (10)	29.8 (11)	(6)	(1)	(1)	(6)	-
Nongplamor	-	61.9	61.9	-	12.6 (13)	12.6 (13)	(7)	(4)	-	(3)	-
Pilot No. 2	67.6	55.6	64.3	23.7 (23)	19.8 (15)	20.6 (27)	(14)	(10)	-	(3)	(1)
Doncha-em	62.5	66.7	66.7	12.8 (5)	18.3 (26)	17.1 (28)	(13)	(7)	-	(5)	(2)

1984 dry season (all HYVs)

Pilot No. 1	92.5			21.5 (37)			(32)	(7)	-	(2)	-
Thatakor	73.7			56.7 (14)			(12)	(3)	-	-	(1)
Nongplamor	-			-			-	-	-	-	-
Pilot No. 2	71.4			21.0 (30)			(20)	(8)	-	(2)	(1)
Doncha-em	51.2			28.6 (21)			(12)	(6)	-	(5)	(2)

Source: M. Tomitaka, Historical Change of Rice Farming in Mea Klong Area (unpublished paper)

Table 20. Average cost of wet season rice cultivation (Baht/rai)[a]. (Mea Klong)

		Hired labour	Machine rental	Fuel & lubricant	Repair & maintenance	Seed	Fertilizer	Chemical	Total
Pilot No. 1	1981	148.0(27)	187.4(44)	55.6(19)	88.0(9)	32.7(42)	87.8(32)	13.1(36)	428.5(42)
	1983	97.9(22)	172.5(42)	39.5(26)	22.4(7)	36.9(42)	77.5(38)	22.3(38)	378.8(42)
Thatakor	1981	194.2(15)	96.5(19)	61.4(18)	89.9(9)	37.6(21)	43.9(8)	13.4(18)	383.0(21)
	1983	43.6(15)	124.6(21)	44.7(13)	39.3(9)	35.1(21)	78.5(11)	29.8(11)	292.1(21)
Nongplamor	1981	204.4(17)	144.4(21)	61.6(17)	26.8(9)	20.8(21)	78.2(21)	9.0(18)	477.9(21)
	1983	107.4(16)	135.5(20)	38.7(14)	20.0(8)	22.3(21)	80.3(20)	12.6(13)	350.9(21)
Pilot No. 2	1981	180.5(32)	160.3(30)	52.5(18)	57.5(8)	32.3(42)	84.0(30)	12.4(40)	389.6(42)
	1983	94.3(27)	141.2(42)	45.6(25)	65.9(17)	38.1(42)	136.3(41)	20.6(27)	440.0(42)
Doncha-em	1981	173.4(33)	148.6(34)	61.7(24)	102.9(19)	36.2(42)	99.9(25)	20.3(32)	445.3(42)
	1983	165.8(26)	135.2(38)	57.2(27)	256.0(19)	40.3(42)	126.6(29)	17.1(28)	516.7(42)

Source: M. Tomitaka, Historical Change of Rice Farming in Mea Klong Area (unpublished paper)

Notes: [a] Exclude land rent fee and irrigation water fee.

Figures in brankets are number of farmers reporting.

Table 21. Average cost of dry season rice cultivation (Baht/rai)[a]. (Mea Klong)

		Hired labour	Machine rental	Fuel & lubricant	Report & maintenance	Seed	Fertilizer	Chemical	Total
Pilot No. 1	1981	136.2(9)	213.6(16)	50.5(6)	33.3(1)	33.5(16)	146.7(16)	17.0(14)	506.3(16)
	1984	50.6(20)	177.5(40)	37.8(22)	49.9(4)	44.7(40)	112.8(40)	21.5(37)	406.0(40)
Thatakor	1981	152.5(4)	91.2(5)	93.5(5)	0.0	55.4(6)	149.3(6)	65.5(4)	504.0(6)
	1984	64.8(7)	140.8(19)	44.8(12)	82.6(4)	40.2(19)	161.4(19)	56.7(14)	416.7(19)
Nongplamor	1981	-	-	-	-	-	-	-	-
	1984	-	-	-	-	-	-	-	-
Pilot No. 2	1982	165.2(19)	118.0(28)	55.4(18)	108.4(3)	33.7(29)	103.0(28)	18.5(24)	429.3(29)
	1984	86.4(23)	150.4(42)	42.6(25)	49.1(10)	44.0(42)	140.8(42)	21.0(30)	434.6(42)
Doncha-em	1982	163.2(22)	141.4(29)	61.1(18)	240.4(4)	36.9(32)	137.7(31)	23.4(21)	490.4(32)
	1984	145.3(22)	151.2(38)	52.3(27)	197.6(14)	42.9(41)	147.0(41)	28.6(21)	524.6(41)

Source: M. Tomitaka, Historical Change of Rice Farming in Mea Klong Area (unpublished paper)

Notes: [a] Exlude land rent fee and irrigation water fee.

Figures in brankets are number of farmers reporting.

Table 22. Average rice yields in different crop seasons (kg/ha)[a] (Mea Klong)

1. Pilot area No. 1

	Dry season			Wet season		
	Highest	Lowest	Average	Highest	Lowest	Average
1980	6,100	1,325	4,125	4,625	1,625	3,134
1981	6,250	1,750	3,862 (3,544)	4,825	2,165	3,294 (3,002)
1982	6,042	1,258	3,639	5,728	1,409	3,432
1983	7,703	3,003	5,253	5,675	2,060	3,699 (3,123)
1984	7,026	1,431	4,184 (3,601)	7,388	1,648	3,680

2. Pilot area No. 2

	Dry season			Wet season		
	Highest	Lowest	Average	Highest	Lowest	Average
1981				4,943	2,270	3,556 (3,172)
1982	5,750	2,062	3,558 (3,618)	5,550	1,289	3,738
1983	6,751	2,078	4,485	5,508	2,101	3,684 (3,571)
1984	6,099	1,894	4,551 (4,304)	6,228	2,673	4,373

Source: M. Tomitaka, Historical Change of Rice Farming in Mea Klong Area (unpublished paper)

Notes: [a] Obtained by the Agricultural Demonstration Center.

Figures in brankets are those from the farm surveys.

it contribute to decrease production cost in double cropping rice area. Total management cost in both major rice and second rice in 1983 decreased in comparison with 1981.

(d) Actual Condition and Economical Effect of Weed Control in Chao Phya Pilot Area.

Whichever major rice or second rice, direct-sowing is practicing by over 90% of farmers' in Chao Phya Pilot Area. Therefore, all the farmers practice weed control by herbicides. Different from Mae Klong area, the weed control technology by applying 5 kg/rai of Saturn G at one time is common. On direct-sowing, almost all the farmers do not performed weed control by man-power after herbicides application. Therefore, when effect of herbicide is insufficient, yield loss is large. Many barn-millet appear in this pilot area differed from Mae Klong Pilot area, its control become as important subject. In the case of serious weed problem, practicing transplanting two or three times of cropping, then direct-sowing again is obtaining good results. A share of chemical cost to total management cost is 14-15% and cost is about 150 baht/rai. This ratio is higher than Mae Klong Pilot. Furadan G, Padan Mipcin and Sumithion EC are used for the control of RRSV and rice blast disease. Therefore, agricultural chemical cost become large.

In this area, the ratio of agricultural chemicals and fertilizers for total cost is higher than Mae Klong area, but management which utilized more family Labour is performed, therefore cost for hired labour and machine rental relatively low. Total management cost of one cropping per rai is about 570 baht, it is a little larger than Mae Klong area. A income ration is about 40%.

Working time per rai in the case of direct-sowing is very little as 54.8 hour. Moreover, 43.8% for whole working time is for harvesting. Average working time of weed control is very little for application of herbicide (half hour/rai) and weeding by man-power (1.8 hour/rai). If only weed control by man-power is performed, it needs 4-5 man/rai. Wage for weed control is about 30-35 baht/day, then weed control cost per rai become very expensive as 120-

Table 23. The comparison of farming expenditure between two surveys

	Total farming expenditure per farm family in Baht.		Farming expenditure per rai in Baht		Percentage of cost	
Year	1982	1984	1982	1984	1982	1984
Fertilizers	9,241.28	9,261.59	297.53	227.56	28.49	22.03
Wage (not included family labor)	4,831.07	7,370.21	155.54	181.09	14.90	17.53
Chemicals	4,509.60	6,145.27	145.19	150.99	13.91	14.61
Machinery, Repairing and Implements	671.21	4,872.10	21.61	119.71	2.07	11.59
Irrigation	-	2,838.11	-	69.73	-	6.75
Seed	1,436.84	2,732.29	46.26	67.13	4.43	6.50
Fuel, Lubricant	3,817.58	2,420.90	122.91	59.48	11.77	5.76
Interest	5,476.19	2,298.24	176.31	56.46	16.89	5.46
Machinery rental cost	523.03	2,174.52	16.84	53.43	1.61	5.17
Tenant charge & Tax	1,924.48	1,933.57	61.96	47.51	5.93	4.60
Total	32,431.28	42,046.80	1,044.15	1,033.09	100	100

Source : N.Iguchi, The Report of Farm Survey (unpublished paper)

Note: Total cultivation area per farm family were 31.06 rai in 1982 and 40.70 rai in 1984

175 baht/rai. Considering from this calculation, weed control by herbicides is profitable to the curtailment of cost. But effect of herbicides variable and unstable depend on field conditions , time of application and the type of weeds in comparison with man-power weeding. Technology development to overcome these unstable factors may be dominate the expansion of chemical weed control in future.

Table 24. Working hours on rice cultivation

Direct sowing

Kind of works	Working hours	
- Field preparation and miscellaneous	3.1	hours
- Plowing	1.9	
- Puddling, Planking and leveling	2.0	
- Drainage	0.5	not included in transplanting
- Sowing	0.5	not included in transplanting
- Fertilizer application (3 times)	1.5	
- Chemical application	3.5	
- Weeding	1.8	
- Harvesting	24.0	
- Collecting	8.0	
- Threshing	7.2	
- Water management	0.8	
Total	54.8 = 6.9 days	

Source : N. Iguchi, The Report of Farm Survey (unpublished paper).

2) Field Crops

A) The Outline of Agriculture in Phetchabun Province.

Farm survey in field crops performed in Phetchabun Province. Phetchabun city which is the seat of the prefectural office is located about 450 km from Bangkok, it administratively belongs to Northern Thailand, id, and it belongs Zon 6 as Agro-Economic Zone which is established by Ministry of Agriculture and Co-operatives in Thailand, become major production area for maize, sorghum, tobacco, cotton, mungbean and soybean. Planted area of maize is the largest as 1,460 thousand, followed by major rice as 1,040 rai, sorghum, mungbean, cotton, groundnuts and soybean. Yield level of major rice and maize are larger than average of Thailand, but yield level of other field crops are almost same or slightly less than whole kingdom.

Agricultural area in Phetchabun Province is divided into four regions based upon the geographical conditions. The first region is a wet lowland areas, such cropping system as major rice & mungbean or tobacco are performed. The second region is a lowland areas, such cropping system as maize + mungbean

Table 25. Planted Area, Production and Average Yield 1982/83, Phetchabun

Unit: rai,ton/kg

	Planted area	Production	Average yield	
			Phetchabun	Kingdom
Major rice	1,040,883	355,219	341	263
Maize	1,460,332	450,610	309	286
Mungbean	529,780	50,839	96	93
Sorghum	145,850	21,294	146	154
Soybean	10,689	1,293	121	146
Groundnuts	12,910	2,536	196	191
Cotton	83,485	13,358	160	171

Source: Agricultural Statistics of Thailand

or sorghum or cotton alone are performed. The third region is a tableland area, such cropping system as mungbean + maize or cotton or soybean are performed. The fourth region is a mountainous areas, such cropping system as maize + perennial crops are performed.

In the production of these field crops, herbicides are hardly utilized in these region now.

B) Outline of management at surveyed farms.

We selected one farm from the first region (C farm) and two farms from the second region (A farm and B farm). A farm had immigrated from Suphan Buri in Central Plain nineteen years ago, it become at present scale of land by opening forest and purchase land year by year. B farm had also immigrated from Central Plain twenty years ago, had started management from 25 rai. After that he purchased land from the farmers around who abondoned one's land. C farm had immigrated from Northeastern of Thailand, he possessed cultivative land as 40 rai, but present cultivative land is 10 rai because he had done the conveyance of his property for his children several years ago (the eldest son 10 rai, the second son 10 rai, the eldest daughter 5 rai, the second daughter 5 rai).

A Farm

Family members of A farm are 6, owner and his wife, the eldest son and his wife, the second son, the eldest daughter and second daughter, but the eldest daughter and second daughter is still studying, a number of family labour are five persons. These five member full-time engage on farming. Land is 140 rai which is upland field only. This farm possess agricultural equipment as follows; one big tractor (77 ps) which purchased as second-hand over 10 years ago, one plow, one ridger, two power sprayer which purchased last year, five knapsack sprayer, one agricultural track and one thresher. A farm is one of the biggest farm in this village on size and equiped capital. Cropping system as maize & soybean is performed in its farm.

Table 26. Outline of Farm Management

	Farm Household Members				Agricultural Land		Agricultural Equipment		
	Relation	Age	Sex	Days engaged in own farmning	Kind of land	Area (rai)	Kind of agricultural equipment	Year of purchased	Value (baht)
Farm A	head of household	54	male	over 150	orchard				
					mango	20 trees	tractor (77ps)	Over 10	270,000
	wife of head	54	female	over 150	coconut	30 trees	plow	years ago	
	eldest son	29	male	over 150			furrow		
	wife of eldest son	30	female	over 150	upland field	140	power sprayer	1984	4,600
							power sprayer	1984	3,000
	second son	28	male	over 150			knapsack sprayer	1984	700
	eldest daughter	20	female	0 (student)			" "	-	-
	second daughter	18	female	0 (student)			" "	-	-
							" "	-	-
							" "	-	-
							agricultural track	1984	155,000
							sheller	1984	350,000
Farm B	head of household	38	male	over 150	paddy field	10	tractor (77ps)	1977	150,000
					orchard		fullow	1984	4,000
	wife of head	40	female	over 150	mango	50 trees	Knapsack sprayer	1980	?
	eldest son	18	male	1-29	coconut	100 trees	" "	1984	800
	second son	14	male	1-29	casterd apple	300 trees	" "	1984	800
	eldest daughter	12	female	1-29	Upland field	150			
Farm C	head of household	55	male	over 150	paddy field	10	tiller (8 ps)	1982	24,000
							disk	1982	2,000
	wife of head	53	female	over 150			knapsack sprayer	1984	800
	eldest daughter	16	female	1-29			water pump	1981	3,000
	second daughter	12	female	1-29					

B Farm

Family member of B farm are 5 as owner and his wife, the eldest son, the second son and the eldest daughter, but every chidlren are still in studying a number of family labour is only two persons. B farm possess 10 rai paddy fields and 150 rai upland field. This farm possess agricultural equipment as follows; one big tractor (77 ps) which purchased as second-hand 8 years ago and three knapsack sprayer. Cropping system as maize & mungbean, soybean and sorghum) is performed in this farm. B farm is one of the most biggest farm in its village like A farm.

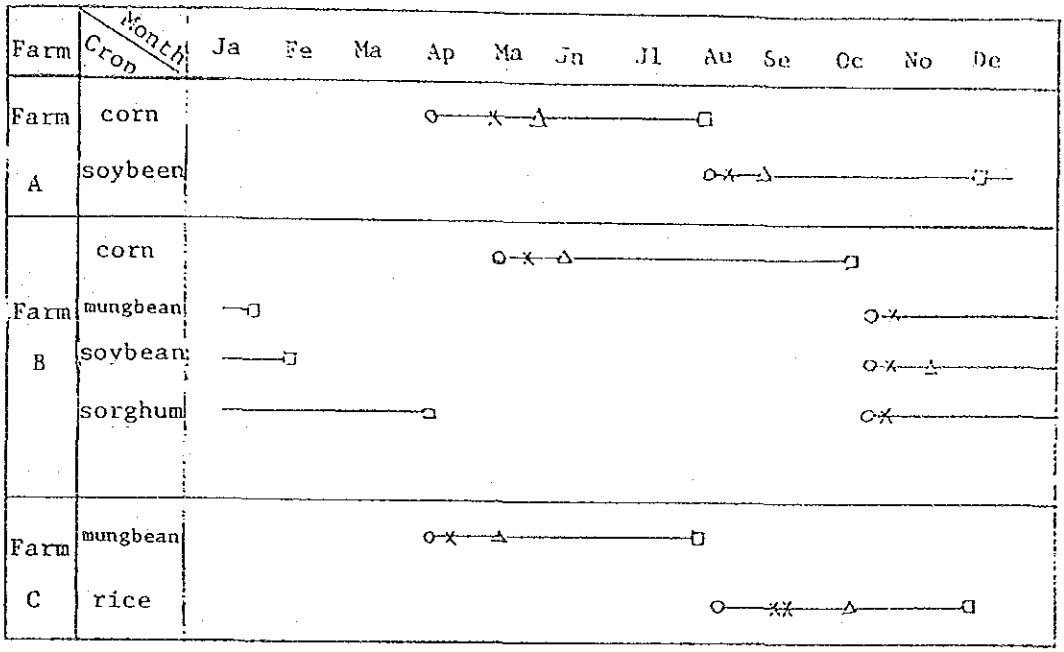
C Farm

C farm is very small scale farm different from A and B farms. Family member of this farm are 4 as owner and his wife, the eldest and second daughter, but two daughters are working apart from the home, they are come back home at busy time. Therefore, a number of family labour is only two persons. This farm possess only 10 rai paddy field. This farm possess agricultural equipment as follows ; one power tiller which purchased as new three years ago, one knapsack sprayer and one pump. Such cropping system as rice & mungbean is performed.

C) Cropping System.

In these farms, cropping system is double cropping each year (Figure). A number of plowing is two times at first crop production after dry season, and at second crop is generally performed only one time (but a farm performed two times). Plowing is done by tractor in all cases. All plowing in A farm performed by own-tractor. In case of B farm, a part of maize and all of rice are hired. C farm which do not have tractor, the first plowing of mungbean and rice are done by others. Either broad casting or drilling on planting is performed by man-power. Mechanization on planting is not recognized, and hired labour are utilized in many cases.

Figure 2. Cropping System



Note: ○ ----- plowing × ----- seeding
△ ----- weeding ×× ----- transplanting
□ -----harvesting

Chemical weed control is not practiced in all farm and any crop production. All weed control is performed by man-power, except on maize in A farm has done by hired labour. Weeding for all crops except for maize in B farm and mungbean in C farm which have done twice, is performed one time. No weed control for sorghum and rice in B farm is practiced. A ratio of weed control to total work are as follows; maize (A farm)---41.6%, soybean (A farm)---33.1%, maize (B farm)---28.5%, mungbean (B farm)---0.04%, Soybean (B farm)---45.0%, mungbean (C farm)---55.2%, rice (C farm)---31.3%. Weed control except mungbean in B farm shares 1/3 - 1/2 of total work. Chemical is used only for the noxious insects of pulse, no disease control is recognized. Except for using power sprayer in A farm, B and C farms used knapsack sprayer.

Harvesting of all crops is done by man-power. Moreover, except on rice in

Table 27. The State of Labour Input

	Corn	Soybean	Corn	Mungbean	Soybean	Sorghum	Rice	Mungbean	Rice
Farm	A	A	B	B	B	B	B	C	C
Harvested area (rai)	140	140	150	25	25	90	5	10	10
Plowing + Fullowing									
number of times	2	2	2	1	1	1	1	2	1
method	tractor	tractor	tractor	tractor	tractor	tractor	tractor	tractor tiller	tractor
family labour (hour/rai)	0.81	0.57	2.32	2.32	2.32	2.32	-	0.80	-
hired labour (hour/rai)	-	-	2.32	-	-	-	1.60	2.40	0.80
seed ing or Transplanting	seed ing	seed ing	seed ing	seed ing	seed ing	seed ing	Transplan-ting	seed ing	seed ing
number of times	1	1	1	1	1	1	1	1	1
method	human power	human power	human power	human power	human power	human power	human power	human power	human power
family labour (hour/rai)	1.03	1.31	-	0.64	0.64	0.36	-	-	8.00
hired labour (hour/rai)	3.43	3.43	8.00	-	0.64	-	32.00	16.00	-
Paddling									
number of times	-	-	-	-	-	-	1	-	-
method	-	-	-	-	-	-	tractor	-	tiller
family labour (hour/rai)	-	-	-	-	-	-	-	-	8.0
hired labour (hour/rai)	-	-	-	-	-	-	1.60	-	-
Weeding									
number of times	1	1	2	1	1	-	-	2	1
method	human power	human power	human power	human power	human power	-	-	human power	human power
family labour (hour/rai)	2.74	-	-	-	-	-	-	-	-
hired labour (hour/rai)	9.14	8.00	9.60	0.8	20.00	-	-	64.00	24.00
Control									
chemical name	-	insecti-cide	-	-	insecti-cide	-	-	insecti-cide	-
number of times	-	5	-	-	6	-	-	3	-
method	-	power sprayer	-	-	knapsack sprayer	-	-	knapsack sprayer	-
family labour (hour/rai)	-	2.86	-	-	-	-	-	-	-
hired labour (hour/rai)	-	-	-	-	4.8	-	-	0.8	-
Harvesting									
method	human power	human power	human power	human power	human power	human power	human power	human power	human power
family labour (hour/rai)	-	-	-	-	-	-	-	-	36.00
hired labour (hour/rai)	11.43	8.00	11.43	14.93	16.00	11.89	11.43	32.00	-

C farm, harvesting work is done by hired labours. Wage, except for harvesting, is paid by day, wage for harvesting is paid by piece. Work for harvesting is more or less same as weed control work.

D) Management Cost.

In every crop production, farmers utilize materials for production are seeds, insecticides and fuel. Seeds are procured by three ways as purchase, self-sufficiency and free distribution from extension office. The rate of seed cost to total management cost differ on crops. Seed cost on soybean occupys about 30-40% to total management cost, because quantity of seedling is much as 15-16 kg/rai, moreover, its price is expensive as 15 baht/kg. On the other crop cost of seed normally share about 10% of total management cost.

Cost of seed on the other crops occupy about 5-9% of total management cost, it is fairly small.

The ratio of agricultural chemical cost (insecticide) on mungbean in farm B is the most large as 25.8%, follow soybean in farm B is 11.7%, mungbean in farm C is 5.6%.

The ratio of fuels of maize in farm A is the largest as 14.2%, following sorghum in farm B is 13.7%, then maize in farm B 12.5%. The ratio of fuels on the other crops is under 10%, because plowing on these crops has hired. If they utilize a tractor only for plowing, cost of fuels may become under 15% of total management cost. Cost of hired labour is the largest except for sorghum in farm B and rice in farm C. Hired labour cost on rice in farm B occupy 76% of total management. The raio of hired labour cost on the other crops are as follows; Mungbean in farm C--63.4%, maize in farm A--61.2%, maize in farm B --53.1%, soybean in farm A --39.6%,

The ratio of hired labour cost of weeding to the total hired labour cost are very large as follows; maize in farm A --44%, soybean in farm A--37.8%, maize in farm B --30.6%, soybean in farm B --48.3%, mungbean in farm

Table 28. Management Cost

Unit:baht

	corn	soybean	corn	mungbean	soybean	sorghum	rice	mungbean	rice
	A 140	A 140	B 150	B 25	B 25	B 90	B 5	C 10	C 10
Seed									
purchased (value)	5,000	31,500	6,750	675	6,000	-	-	360	-
self-supplied (value)	-	-	7,000	-	-	900	210	-	150
total (value)	5,000	31,500	13,750	675	6,000	900	210	360	150
purchase (value/rai)	35.7	225.0	45	27	240	-	-	36	15
self-supplied (")	-	-	46.7	-	-	10	42	-	-
total (")	35.7	225.0	91.7	27	240	10	42	36	15
input (kg/rai)	3.57	15.0	10.7	3.0	16.0	2.0	14.0	3.0	3.0
Agricultural chemicals									
total (value)	-	-	-	1,990	1,750	-	-	360	-
value/rai	-	-	-	79.6	70	-	-	36	-
Oil									
total (value)	7,350	9,800	7,875	438	438	1,575	-	70	245
value/rai	52.5	70.0	52.5	18	18	18	-	7	24.5
Hired labour									
total (value)	31,800	37,000	33,470	2,700	3,430	2,600	2,050	4,050	1,000
value/rai	227.1	264.3	223.1	108	137.2	28.9	410.0	405.0	100
Agricultural equipment									
total (value)	7,750	8,790	7,900	1,560	1,560	4,500	250	1,340	1,450
value/rai	55.4	62.8	52.7	62.4	62.4	50.0	50.0	134	145
Thresh									
total (value)	-	6,300	-	350	1,715	1,950	189	210	560
value/rai	-	45	-	14.0	68.6	21.7	37.8	21.0	56.0
Total (A)									
value	51,900	93,390	62,995	7,713	14,893	11,525	2,699	6,396	3,405
value/rai	299.3	667.1	420.0	309.0	596.0	128.1	539.8	639.0	341.0
Yield per rai (kg)	357	150	333	56	196	144	540	84	525
price (baht/kg)	2	7	2	10	7	2	2.8	7.5	2.7
Revenue (B)									
total (value)	100,000	147,000	100,000	14,000	34,300	26,000	7,560	6,300	14,175
value/rai	714	1,050	667	560	1,372	289	1,512	630	1,418
Income (B-A)									
total (value)	48,100	53,610	37,005	6,287	19,407	14,475	4,861	-90	10,770
value/rai	415	383	247	251	776	161	972	- 9	1,077

C --55.6%, rice in farm C --40%,

Durable years of agricultural equipment fixed for 10 years, and depreciation cost of these distributed according as the planted area of each crops. The share of depreciation cost for total management is low as 11.4% and 15.8% in farm A and B which has large land, on the other hand, that is compatively large as 28.5% in farm C which have small land. Threshing of all crops is done by middle men. Selling is performed by three ways as follows; (1) selling to middle men after threshing (2) selling at nearest market (3) selling to extension office. Yield level on maize and sorghum in these farms are the same as average level of the province, and that of soybean and rice are higher than average level of the province. That of mungbean in farm B is lower than average level of the province, but that of C is the same.

Income rate of rice is higher as 64.3% and 76.0% than other crops. income rate of the other crops are as follows;

maize in farm A --- 58.1%, maize in farm B --- 37%, soybean in farm A --- 36.5%, soybean in farm B --- 56.6%, mungbean in farm B --- 44.8%, mungbean in farm C --- 0.

Income of farms are as follows;

farm A --- 101,710 baht, farm B --- 82,035 baht, farm C --- 10,680 baht.

The income of farm C is lower than annual income level of non-skilled worker, but the incomes of farm A and B are higher than annual income level of skilled worker.

4. Method of Economical Evaluation of Weed Control

1) Fundmental Idea and Method of Economical Evaluation.

There is three objects in chemical weed control. One is to curtail of weed control work. Second is to elevate of yield. Third is to ease its work intensity.

In advanced countries, herbicides price are relatively cheap in comparison with wage and prices of agricultural product, therefore chemical weed control have more advantage than weed control by man-power. However, in Thailand, wage level and price of agricultural products are very cheap, moreover prices of herbicides is relatively expensive. Therefore, it is not able to say that chemical weeding has always advantage than weeding by man-power.

For the above reason, economical evaluation of weed control is necessary for the diffusion of chemical weed control technology. In this chapter, I explain how to use the computer program which have been written for economical evaluation of weed control.

2) Outline of This Computer Program

This computer program calculate a necessary labour and a cost of weed control by herbicides and man-power. Necessary informations for analysis can input by conversation style, anybody will be able to utilize this.

3) Way of Practice in This Program

(1) load the program from fropy disk LOAD "EEWC" ↵

(2) start the program RUN ↵

appear the title of this program on graphic display

(3) data input according to questions

Q --- question from computer A --- user's answer

Q1 --- HIT ENTER RETURN?

A1 --- press "return" key

Q2 --- WHAT IS THE NAME OF EVALUATE CROP?

A2 --- input crop name

Q3 --- PLANTED AREA OF THIS CROP (UNIT:RAI)?

A3 --- input planted area of a crop

Question of Q4-Q8 related to the weed control by man-power.

Q4 --- HOW MANY TIMES PERFORM WEED CONTROL BY MAN-POWER?

A4 --- input the number of weed control frequency

Q5 --- HOW MANY MAN-POWER NEED PER RAI?

A5 --- input man/day of weed control labour per rai

Q6 --- WAGE LEVEL OF WEED CONTROL (BAHT/MAN/DAY)?

A6 --- input wage for weed control (baht/man/day)

Question Q4-Q6 appear same as the number of weed control frequency.

Q7 --- YIELD LOSS BY WEED UNDER THIS WEED CONTROL (KG/RAI)?

A7 --- input yield loss by weed under this weed control (kg/rai)

Q8 --- PRICE OF THIS CROP (BAHT/KG)?

A8 --- input price of the crop (baht/kg)

Question Q9-Q25 related to the chemical weed control

Q9 --- HOW MANY TIMES APPLY HERBICIDES?

A9 --- input the number of herbicides application frequency

Q10 --- WHAT IS THE NAME OF HERBICIDE?

A10 --- input name of herbicide

Q11 --- INPUTS OF THIS HERBICIDE (KG/RAI)?

A11 --- input the applied quantity of the herbicide (kg/rai)

Q12 --- PRICE OF THIS HERBICIDE (BAHT/KG)?

A12 --- input the price of this herbicide (baht/kg)

Q13 --- APPLY METHOD (POWER SPRAYER = 1, KNAPSACK SPRAYER = 2, BY HAND = 3)?

A13 --- input method of herbicide application by as follows;

when utilize power sprayer .... input 1

when utilize knapsak sprayer ... input 2

when utilize man power ..... input 3

Q14 and Q15 appear only when utilize power sprayer.

Q14 --- QUANTITIES OF OIL USE BY POWER SPRAYER (L/RAI)?

A14 --- input amount of fuel to apply herbicide by power sprayer (l/rai)

Q15 --- PRICE OF OIL (BAHT/L)?

A15 --- input fuel price (baht/l)

Q16 --- HOW MANY TIME TO APPLY HERBICIDE (HOUR/RAI)?

A16 --- input necessary time to apply herbicide (hour/rai)

Q17 --- WAGE LEVEL OF APPLY HERBICIDE (BAHT/RAI)?

A17 --- input wage to apply herbicide (baht/rai)

Q18 --- HOW MANY TIME PERFORM WEED CONTROL BY MAN-POWER AFTER APPLY HERBICIDES?

A18 --- input the number of weed control frequency by man-power after herbicides applied

Q19 --- HOW MANY MAN-POWER NEED PER RAI?

A19 --- input man/day of the necessary weed control labour (man/rai)

Q20 --- WAGE LEVEL OF THIS WEED CONTROL (BAHT/MAN/DAY)?

A20 --- input wage of weed control (baht/man/day)

Q21 --- YIELD LOSS BY WEED UNDER THIS WEED CONTROL SYSTEM (KG/RAI)?

A21 --- input the yield loss under the chemical weed control system

Q22 --- HOW MANY EQUIPMENT TO USE WEED CONTROL?

A22 --- input the number of equipment for weed control

Q23 --- PURCHASE PRICE OF THIS EQUIPMENT?

A23 --- input the purchased price of this equipment

Q24 --- HOW MANY YEARS TO USE THIS EQUIPMENT?

A24 --- input years of this equipment to be used

Q25 --- USING RATE OF THIS EQUIPMENT FOR WEED CONTROL (%)?

A25 --- input rate of the utilized for weed control to the total use of this equipment (%)

```
10 '*************************************************************************
20 '         ECONOMIC EVALUATION OF WEED CONTROL
30 '                              1985      T.MOMMA
40 '*************************************************************************
45 CLS
50 PRINT'*************************************************************************
60 PRINT:PRINT
70 PRINT'      THIS PROGRAM IS BEING EVALUATE ECONOMICALY WEED CONTROL
80 PRINT:PRINT
90 PRINT'*************************************************************************
110 PRINT:PRINT:PRINT:PRINT:PRINT
120 INPUT'HIT ENTER RETURN';RE:CLS
130 INPUT'WHAT IS THE NAME OF EVALUATE CROP';NAM$
135 PRINT:INPUT'PLANTED AREA OF THIS CROP(UNIT:RAI)';HA
140 CLS
150 PRINT:PRINT'***  INPUT OF THE INFORNATION ABOUT WEED CONTROL BY MAN-POWER'
160 PRINT:INPUT'      HOW MANY TIMES PERFORME WEED CONTROL BY MAN-POWER';WM1
170 FOR I=1 TO WM1
180 IF I=1 THEN NM$='FIRST WEED CONTROL'
190 IF I=2 THEN NM$='SECOND WEED CONTROL'
200 IF I=3 THEN NM$='THIRD WEED CONTROL'
210 IF I=4 THEN NM$='FOURTH WEED CONTROL'
220 CLS
230 PRINT:PRINT'INPUT OF THE INFORMATION ABOUT ';NM$
240 PRINT:INPUT'      HOW MANY MAN-POWER NEED PER RAI';X1(I)
250 PRINT:INPUT'      WAGE LEVEL OF WEED CONTROL(BAHT/MAN/DAY)';X2(I)
260 NEXT I:CLS
270 PRINT:INPUT'      YIELD LOSS BY WEED UNDER THIS WEED CONTROL(KG/RAI)';Y1
280 PRINT:INPUT'      PRICE OF THIS CROP(BAHT/KG)';P1
290 CLS
300 PRINT'***  INPUT OF THE INFORMATION ABOUT WEED CONTROL BY HERBICIDES'
310 PRINT:INPUT'      HOW MANY TIMES APPLY HERBICIDES';WH
320 FOR I=1 TO WH
330 IF I=1 THEN HM$='FIRST WEED CONTROL BY HERBICIDES'
340 IF I=2 THEN HM$='SECOND WEED CONTROL BY HERBICIDES'
350 IF I=3 THEN HM$='THIRD WEED CONTROL BY HERBICIDES'
360 CLS
370 PRINT'INPUT OF THE INFORMATION ABOUT ';HM$
380 PRINT:INPUT'      WHAT IS THE NAME OF HERBICIDE';NA1$
390 PRINT:INPUT'      INPUT OF THIS HERBICIDE(KG/RAI)';H1(I)
400 PRINT:INPUT'      PRICE OF THIS HERBICIDE(BAHT/KG)';H2(I)
410 PRINT:INPUT'      APPLY METHOD (POWERSPRAYER=1 , KNAPSACKSPRAYER=2 ,BY HAND=3
)';H3
420 IF H3<>1 GOTO 450
430 PRINT:INPUT'      FUEL USE BY POWERSPRAYER(L/RAI)';H4(I)
440 PRINT:INPUT'      PRICE OF FUEL(BAHT/L)';H5(I)
450 PRINT:INPUT'      HOW MANY TIMES TO APPLY HERBICIDE(HOUR/RAI)';H6(I)
460 PRINT:INPUT'      WAGE LEVEL OF APPLY HERBICIDE(BAHT/RAI)';H7(I)
470 NEXT I:CLS
480 PRINT:INPUT'      HOW MANY TIME PERFORME WEED CONTROL BY MAN-POWER AFTER APPL
Y HERBICIDES';AF
490 IF AF<1 GOTO 580
500 FOR I=1 TO AF
510 IF I=1 THEN NM$='FIRST WEED CONTROL BY HAND'
520 IF I=2 THEN NM$='SECOND WEED CONTROL BY HAND'
580 CLS
540 PRINT'INPUT OF INFORMATION ABOUT ';NM$
550 PRINT:INPUT'      HOW MANY MAN-POWER NEED PER RAI';Q1(I)
560 PRINT:INPUT'      WAGE LEVEL OF WEED CONTROL(BAHT/MAN/DAY)';Q2(I)
570 NEXT I:CLS
580 PRINT:INPUT'      YIELD LOSS BY WEED UNDER THIS WEED CONTROL SYSTEM(KG/RAI)';
Y2
590 CLS
600 PRINT'***  DEPRECIATION OF EQUIPMENT
610 PRINT:INPUT'HOW MANY EQUIPMENT TO USE WEED CONTROL';EW
620 IF EW<1 GOTO 695
630 FOR I=1 TO EW
640 PRINT'INFORMATION OF EQUIPMENT NO.';I
660 PRINT:INPUT'      PURCHASE PRICE OF THIS EQUIPMENT';PE1(I)
670 PRINT:INPUT'      HOW MANY YEARS USE THIS EQUIPMENT';PE2(I)
680 PRINT:INPUT'      USING RATE OF THIS EQUIPMENT FOR WEED CONTROL(%)';PE3(I)
```

```
690 NEXT I
695 CLS
700 '  ECONOMICAL EVALUATION START
710 PRINT'*****  RESULTS OF ECONOMICAL EVALUATION OF WEED CONTROL ABOUT '
715 PRINT'          CROP ----- ';NAM$;:PRINT'      (BAHT/RAI)' :PRINT:PRINT:PRINT
720 PRINT'WEED CONTROL BY MAN-POWER                 WEED CONTROL BY HERBICIDES'
730 PRINT:PRINT'   1) INPUT OF LABOUR(MAN/DAY)'
740 TOT1=0:FOR I=1 TO WN1:TOT1=TOT1+X1(I):NEXT I
750 TOT2=0:FOR I=1 TO WH:TOT2=TOT2+H6(I):NEXT I
760 TOT2=TOT2/8
770 TOT3=0:FOR I=1 TO AF:TOT3=TOT3+Q1(I):NEXT I
780 TOT4=TOT2+TOT3
790 PRINT'       ..                 ';:PRINT USING'###.#';TOT1;
800 PRINT'                                      ';:PRINT USING'###.#';TOT4
810 PRINT'   2) COST OF HERBICIDES(BAHT/RAI)'
820 TOT5=0:FOR I=1 TO WH:TOT5=TOT5+H1(I)*H2(I):NEXT I
830 PRINT'                                                                  ';:PRINT U
SING'###.#';TOT5
840 PRINT'   3) COST OF EQUIPMENT DEPRECIATION(BAHT/RAI)'
850 TOT6=0:FOR I=1 TO EW
860 IF PE2(I)>10 GOTO 880
870 DC=PE1(I)/10*PE3(I)/100/HA:TOT6=TOT6+DC
880 NEXT I                                                                  ';:PRINT U
890 PRINT'
SING'###.#';TOT6
900 PRINT'   4) COST OF FUEL(BAHT/RAI)'
910 TOT7=0:FOR I=1 TO WH:TOT7=TOT7+H4(I)*H5(I):NEXT I
920 PRINT'                                                                  ';:PRINT U
SING'###.#';TOT7
930 PRINT:PRINT'   5)YIELD LOSS BY WEED(BAHT/RAI)'
940 Y1=Y1*P1:Y2=Y2*P1
950 PRINT'                      ';:PRINT USING'###.#';Y1;
960 PRINT'                                      ';:PRINT USING'###.#';Y2
970 PRINT:PRINT'TOTAL COST (BAHT/RAI)'
980 TOTM=0:TOTH=0
990 FOR I=1 TO WN1:TOTM=TOTM+X1(I)*X2(I):NEXT I
1000 TOTM=TOTM+Y1
1010 FOR I=1 TO WH:TOTH=TOTH+H6(I)/8*H7(I):NEXT I
1020 FOR I=1 TO AF:TOTH=TOTH+Q1(I)*Q2(I):NEXT I
1030 TOTH=TOTH+TOT5+TOT6+TOT7+Y2
1040 PRINT'                      ';:PRINT USING'####.#';TOTM;
1050 PRINT'                                       ';:PRINT USING'####.#';TOTH
1060 LPRINT CHR$(&HC);
1070 COPY 1
1080 END
```

***** RESULTS OF ECONOMICAL EVALUATION OF WEED CONTROL ABOUT
CROP ----- RICE (BAHT/RAI)

	WEED CONTROL BY MAN-POWER	WEED CONTROL BY HERBICIDES
1) INPUT OF LABOUR(MAN/DAY)	5.0	1.5
2) COST OF HERBICIDES(BAHT/RAI)		100.0
3) COST OF EQUIPMENT DEPRECIATION(BAHT/RAI)		0.0
4) COST OF FUEL(BAHT/RAI)		0.0
5)YIELD LOSS BY WEED(BAHT/RAI)	29.0	0.0
TOTAL COST (BAHT/RAI)	204.0	152.5

5. Consideration

1) Possibility of Chemical Weed Control Examined though the Movement of Agriculture in Thailand

As the result of examined though the movement of agriculture in Thailand, we can point out the favourable and unfavourable conditions for the development of chemical weed control as follows;

< favourable conditions >

(1) increasing of owned farmers

(2) increasing of irrigation areas

(3) decreasing of landless agricultural labours

(4) increasing of wage

(5) increasing of farm income

< unfavourable conditions >

(1) decreasing of agricultural land per farm

(2) increasing of unemployment

(3) under development of mechanization except plowing

(4) prices of agricultural products are very low

(5) existence of low income elasticity of demand for agricultural products

(6) unstable international market prices for agricultural products

(7) the absolute farm income is low

(8) possibility of herbicides prices increasing

It may be clear by above mentioned points, there are not only favourable conditions for the development of chemical weed control. And it is difficult to increase irrigation area in very short-term. Farm income have been in increasing, but its absolute level is still low in comparison with the wage level of urban labours. If high level of economical growth will continue, such labour in a village as landless labours, small scale farmers and young labours will decrease.

At the result of this, wage level of agricultural labour will increase. Under these situation, such farms which hired many cheap labour will start to practice chemical weed control. On the other hand, it is not easy to solve an unfavourable condition. Especially, the cheapness of agricultural product price sustain the development of Thai economy and people's life, rapid change may bring a social disorder. Moreover, drastically increasing of production has possibility to largely decrease prices because present demand structure for major agricultural products is stable. It is need that compound and diversified of farming. For stabilize farm management, compound and diver sified of farming must be recommended.

For the future development of agriculture in Thailand, it is important that increasing productivity and saving cost by the establishment of diversified farming by introducing hopefull crops for domestic and international market. Weed control will pay important role on development on new agricultural system. For the establishment of weed control technology in Thailand, economical evaluation must always be made. Looking at economically, farmers are not able to invest much money for agricultural chemicals. Establishment of such economical integrated weed control technology as combination of herbicides, man-power and physical method (burning, mowing, mulching and cultivation) is important. Moreover, establishment of such technology considered environmental effect of chemical is important.

2) Possibility of Chemical Weed Control Examined through the Actual Farming Practice of Major Crops

Chemical weed control may become major technology in rice double-cropping area which practice direct-sowing. Diffusion of chemical weed control may contribute not only saving labour but also decreasing cost by saving hired labour. But in the direct-sowing, careful technical guidance is necessary, because hand weeding after herbicide application is impossible by mistaking time of application, kind of herbicide and quantity.

On the other hand, damage by weed in transplanting is not so problem as direct-sowing, it will be recovered by control combined herbicides and man-power. In the case of small farm who has enough own-labour, hand weeding system by utilizing own-labour is desirable.

On the other hand, how is possibility of chemical weed control for field crop farms which have not been used herbicides? In the case of small scale cropping, combination of such physical weed control as burning, slashing, mulching, cultivation and hand weeding is to be desirable. In the case of large scale cropping which utilize many hired labour, physical plus chemical weed control is desirable for saving cost. But application of large amount or many kind of herbicides is economically impossible by reason of low price of upland field crops. Establishment of weed control system base upon the economical evaluation of chemical weed control in comparison with hand weeding is required.

3) Method of Economical Evaluation of Weed Control

Computer program for which evaluate weed control economically was made by author. It will be able to make suggested guide for economical weed control by using this program. By shortage term of studying, analitical data collection is insufficient, making suggested guide had not done. And it will be important to add on program such simulation function as evaluation of the valuable price and working time etc. It needs to be continued a study by Agro-economist to make clear these subject

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