THE DEMOCRATIC REPUBLIC OF THE SUDAN
MINISTRY OF AGRICULTURE, FOOD
AND NATURAL RESOURCES

FEASIBILITY REPORT
ON
RICE DEVELOPMENT PROJECT
IN ABU GASABA BASIN

ANNEX(SUPPLEMENTARY REPORT Ⅲ)

(FINAL REPORT ON RICE EXPERIMENTS)

Main Report

OCTOBER, 1979

JAPAN INTERNATIONAL COOPERATION AGENCY

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JAPAN INTERNATIONAL COOPERATION AGENCY

FOREWARD

In response to the request of the Government of the Democratic Republic of the Sudan, the Japanese Government has decided to make a feasibility study on the Abu Gasaba Rice Development Project and entrusted the Japan International Cooperation Agency (JICA) with its study.

The Japan International Cooperation Agency, which is responsible for implementing Government's technical cooperation programmes, commissioned the study to the Nippon Koei Co., Ltd. The company dispatched to the Sudan an expert team headed by Dr. S. Matsushima from June, 1977 to October, 1979. They carried out rice experiments to obtain basic information on rice cultivation in a semi-arid area in the Sudan and prepared its final report.

The report presented by them contains new ecophysiological findings on rice plant in a hot and dry climate and may contribute to the rice cultivation in arid areas in the world as well as in the Sudan.

I sincerely hope that this report will make a contribution to the economic development of the Sudan as well as to the promotion of the friendship between our two countries.

I wish to take this opportunity to express my deep appreciation to the authorities concerned of the Democratic Republic of the Sudan for their kind cooperation and assistance extended to the experts.

January, 1980

Keisuke Arita

Keisuke ARITA
President

JAPAN INTERNATIONAL COOPERATION AGENCY

LETTER OF TRANSMITTAL

Mr. Shinsaku Hogen
President
Japan International Cooperation Agency

Dear Sir,

We have the pleasure of submitting the final report on the rice experiments which have been carried out for nearly two years since June, 1977, as a supplementary work to the feasibility study on Abu Gasaba Rice Development Project. The experiments have terminated with this fourth supplementary work.

The present report contains all the findings obtained from the commencement to termination of the experiments, especially all the results of studies on the selection of promissing varieties suitable to the Project Area, on the appropriate cropping pattern and on its appropriate cultivation methods.

It is our sincere hope that the report will be fully utilized for the Rice Development Project promoted by the Sudanese Government.

The rice experiments have fully proved the possibility of the double cropping of rice contemplated in the feasibility study and also its high productivity even under the tropical arid climate.

The training of the counterpart personnel dispatched by the Sudanese Government was also conducted on the way of carrying out of the experiments, and much technical knowledge on rice cultivation might have been transfered to the personnel, though whose number was restricted.

In submitting this report, we wish to express our sincere appreciation and gratitude to all the personnel of your Agency, Ministry of Agriculture and Fishery, Ministry of Foreign Affairs, and the Embassy of Japan in Sudan, and the officers of the Sudanese Government concerned, for the countries and cooperation extended to us during our field work and home office work.

Very truly yours,

Seizo Matsushima

A. Maeda
Akio Maeda

CONTENTS

1. INTRODUCTION

This is a report on the 4th supplemental work of the rice experiments, which have been carried out as a supplemental work to the feasibility study conducted by Japan International Cooperation Agency, on the Abu Gasaba Rice Development Project in White Nile Province, Sudan. This report consists of the main report and the annex report, in which all the rice experiments are detailed.

1.1 Historical Background of the Rice Experiments

These rice experiments have been carried out through 1st to 4th supplementary work for nearly 2 years starting with a small scale experiment at 0.3 ha field in June, 1977 as a part of the feasibility study, and then expanding to 2.0 ha field.

At the early stage of the experiments, only a variety test on about 30 varieties and a seasonal planting test were carried out in a small scale from the view point of land productivity, because of the experimental field being limited to 0.3 ha and farm inputs and equipments being insufficient. The experimental results revealed that even under the hot and dry climate, rice plants grew vigorously and produced very high yields, attaining the highest record of 9.0 ton/ha in the past in Sudan, which fully proved the possibility of rice cultivation in the Project Area. The experiments extended to 2.0 ha in December, 1977 and were kept on as the first supplementary work to the feasibility study. Major subjects of these experiments were the studies on the possibility of the rice cultivation in the off-season, and therefore the variety test, the seasonal planting test, the fertilizer element test, the nitrogen amount test, the cultivation method test and the spacing and sowing density test were carried out.

The 2nd supplementary work was conducted in the period from May to December, 1978. In this work the experiments started in the 1st supplemental work were completed and the second tests in the main-season were initiated. It had long been said that the rice cultivation in the off-season was quite impossible in Sudan. The work, however, confirmed that high yields of more than 5.0 ton/ha could easily be obtained even in the off-season, if only proper cultivation practices were applied.

The 3rd supplementary work was carried out from December 1978 to March, 1979 with a view to completing the tests in the main-season and to commencing the tests in the off-season. In this work, the new highest record of 11 ton/ha of grain was obtained, which clearly demonstrated the high profitability as well as high possibility of rice cultivation in the Project Area.

With the 4th supplementary work, which will be mentioned in the following section, the rice expeliment has been completed.

1.2 Objectives and Work Items of the 4th Supplementary Work

The objectives of the 4th supplementary work are the completion of the rice experiments and the drawing of the conclusion based upon the results obtained from the preceeding studies and the experiments. In the field work rice cultivation, the growth observation of rice plants and yield determination were carried out.

Work items in the 4th supplementary work are as follows.

(1) The completion of the experiments started in this work period, in which growth observation and yield determination are included.

(2) Technical training and guidance for counterpart personnel on the following items.

   i) Cultivation techniques and actual practises, especially ways of fertilization

   ii) Methods of plant growth observation

   iii) Methods of crop yield determination

(3) Compilation of data obtained and analyses of the results for the selection of appropriate varieties, cropping pattern, cultivation methods, etc.,

(4) Selection of the appropriate varieties, cropping pattern and cultivation methods for the formulation of the appropriate double cropping of mechanized rice cultivation.

This 4th supplemental work consists of the field work during 128 days from May 7 to September 11, 1979 and the home office work during 50 days from September 12 to October 31.

The field work is made up of the rice experiments and the training of counterpart personnel.

In the rice experiments, the management of various tests, growth observation, harvesting and yield determination were carried out. The following tests were completed in the 4th supplementary work.

. Variety test
. Cultivation method test
. Seasonal planting test
. Fertilizer element test
. Nitrogen amount and application time test
. Spacing and sowing density test
. Herbicide test

Besides the above tests, rice quality test, measurement of evapotranspiration by rice plants and observation of various climatic factors, etc., were conducted.

The training of counterpart personnel was conducted in the course of carring out various kinds of the experiments and the yield determination. In the 4th supplementary work, for further understanding of the experimental work each counterpart personnel took charge for each test or work, and on weekly meetings on Sunday, reporting of progress of his work, discussion on technical problems and arrangement of working schedule were made.

The on-the-job training of the farm labourers was also carried out on the way of growth observation, yield determination, raising of seedlings, land levelling and water management.

In the home office work, compilation of all the data obtained so far in the rice experiments and their analyses were made, and on the basis of the analyses, the varieties, cropping pattern and cultivation method suitable to the Project Area were selected, and further formulation of individual techniques for conducting on efficient double cropping of rice was made.

There was no difficulty in obtaining farm inputs such as fertilizers and agrichemicals, because the amounts of them were very small and Gezira Board, Agricultural Corporation in Duiem and Provincial Government cooperated in supplying them. Serious difficulty was raised in obtaining fuel for automobiles and pumps, but just enough amount of fuel for the execution of the experiments was supplied by the aid of the Provincial Government. The Japanese Government extended full cooperation to the rice experiments by supplying farm machinery and equipments, agrichemicals and fertilizer which were difficult to be obtained in Sudan.

The major farm machinery and equipments supplied by the Japanese Government during a period from 1st to 4th supplemental work are listed below.

Name	Type	Amount	Remark
Hand Tiller	Yanmar YC90-G, 9PS	1	
Thresher	Yanmar CN_2	1	
Rice Huller	Shinomiya MB	1	
Engines	Yanmer 40C-G	1	for rice polishing machine
"	" NSA 50C	1	for rice huller
"	" NS65C-G	1	for thresher
Rice Polishing Machine	" R2-B	1	
Irrigation Pumps	made in China	2	with engines, 4PS
Microscope	optical	1	
"	stereoscope	1	
Grain Rigidity Tester		1	
Grain Moisture Meter		1	
Grain sieve grader	hand type	1	
Bird net	2 cm x 2 cm	3 ha	

1.3 Staffs Concerned

Staffs assigned to the rice experiment are listed below.

(1) Japanese experts

Name	Assigned Period	
	Field work	Home office work
Dr. Seizo Matsushima (Nippon Koei Co., Ltd.)	August 8 to September 6, 1979	-
Mr. Akio Maeda (Nippon Koei Co., Ltd.)	May 7 to September 11, 1979	September 12 to October 31, 1979
Fumihiro Nagao (Nippon Koei Co., Ltd.)	-	September 16 to October 16, 1979

In addition to the experts assigned formally to the home office work, Dr. Seizo Matsushima and Mr. Hisashi Ikewada who have been kept in touch with the experiments from its commencement, joined in making the final report, i.e. analyses of the experimental results and preparing discussions and conclusions.

(2) Sudanese staffs

Sudanese staffs assigned by the Sudanese Government are listed below. They shared the management of the experiments with the Japanese experts and received the on-the-job training.

Mr. El Rayah Ahmed (Project Manager)
Mr. Issam Mustafa (Project Site Manager)
Mr. Ali ElAmin
Mr. Ismail Mustafa Adam (Acting Project Manager)
Mr. Badar El Deen
Mr. Ali Abdel Wahab
Mr. Ahmed El Siddig
Mr. Mohammed Fouzi
Mr. Ezz El Deen
Mr. El Amin
Mr. Fatah
Mr. Ali El Amin
Mr. Abdarabagi
Mr. Hassan Omer
Mr. Abdara

2. RICE EXPERIMENT

2.1 Variety Test

The objective of this test is to select the varieties suitable to the project area with high-yielding ability, high quality, high resistance to diseases, insect pests and lodging under the mechanized farming and irrigated conditions.

From various rice growing countries of the world, 59 varieties were collected and raised in the plots by mean of the transplanting method. Details of raising method and the results are shown in the section 5.1 in the annex report.

Physiological trouble presumably caused by hot and dry wind was observed in April or May. This caused heavy damage to the leaves and to the grains, increasing sterile grains and imperfectly ripened grains. Varietal differences in susceptibility to the hot temperature of 40 to 42.1°C at heading stage were observed and the varieties were classified according to the susceptibility.

Quality of major varieties of rice grown in the main-season*1 and in the off-season*1 was checked in the form of polished rice and the classification was made.

Judging from yielding ability, quality and susceptibility to diseases and hot temperature, following varieties may be recommended.

Main-Season: BR-4, BG-33-2, IR-36, BG-34-12, TOS-103, BG-90-2, IR-29, BG-34-6, IR-2053, IR-298-12-1-1-1

Off-Season : BG-90-2, IR-24, IR-22, IR-2053, IR-2153, IR-1561, Dawn

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Note (*1) The main-season means a growing season of the rice plant whose sowing is carried out from June to August, while the off-season means a growing period whose sowing is done in other months.

2.2 Fertilizer Element Test

The objective of this test is to clarify the effectiveness of N, P, K and S on the yield of rice. In the experiment sulphur was specially tested, because the high value of pH of soil and water of around 8.0 in the project area may be decreased by the application of sulphur.

Four tests with respective treatments were carried out obtaining the following results, according to the randomized block method with three replications.

Yield Responses to Fertilizer Elements

(Test I)

Block Number	Treatment				
	Non-N (ton/ha)	Non-P (ton/ha)	Non-K (ton/ha)	Non-N.P.K. (ton/ha)	Standard (ton/ha)
I	3.5	7.7	8.9	2.8	9.4
II	4.2	9.7	9.4	3.0	7.9
III	6.7	7.5	7.5	3.5	7.7
Mean	4.8	8.2	8.6	3 1	8.3

(Test II)

Block Number	Treatment					
	Non-N (ton/ha)	Non-P (ton/ha)	Non-K (ton/ha)	Non-S (ton/ha)	Non-N.P.K.S. (ton/ha)	Standard (ton/ha)
I	4.6	6.1	6.8	7.3	2.2	8.4
II	3.0	4.9	6.1	5.8	2.2	6.2
III	2.5	6.9	5.3	5.5	1.4	6.0
Mean	3.4	6.0	6.1	6.2	1.9	6.9

(Test III)

Block Number	Amount of Potash Applied			
	0kg K_2O/ha (ton/ha)	50kg K_2O/ha (ton/ha)	100kg K_2O/ha (ton/ha)	200kg K_2O/ha (ton/ha)
I	2.7	2.1	2.1	2.1
II	3.2	1.6	1.6	2.5
III	3.4	2.0	1.9	1.2
Mean	3.1	1.9	1.9	1.9

Note: $F = 4.74 < 4.76\ F\ (3, 6 : 0.05)$

(Test IV)

Block Number	Amount of Sulphur Applied			
	0kg S/ha (ton/ha)	50kg S/ha (ton/ha)	100kg S/ha (ton/ha)	150kg S/ha (ton/ha)
I	3.8	2.1	3.6	4.2
II	2.9	3.8	4.2	3.4
III	5.1	2.7	5.0	2.5
Mean	3.9	2.9	4.3	3.4

Note: $F = 1.14 < 4.76.F\ (3, 6 : 0.05)$

Significant differences among average yields were examined for the test I and II. The results revealed that the standard treatment showed a significant difference with 95% probability against the treatment of Non-N, Non-N.P.K or Non-N.P.K.S, while the treatment of Non-N.P.K or Non-N.P.K.S had a significant defference aggainst Non-P, Non-K or Non-S.

As the result of examining the analyses of variance on the mean yields among the treatments applied with different amounts of potash or sulphur, no difference was recognized among all treatments.

The above-mentioned results clearly proved that nitrogen is indespensable and the most efficient element for increasing the rice yield. The effects of the application of phosphatic, potash and sulphuric fertilizers could hardly be observed, so far as the present experiment was concerned.

2.3 Nitrogen Amount and Application Time Test

The objective of this test is to determine the most effective timing and the optimum quantity of nitrogen to be applied under the climatic and soil conditions in the project area. For the objective, the tests were carried out in the main season and in the off season according to the randomized block method with 3 replications.

The treatments and the results are shown in the following tables.

Responses of Yield of Rice to Nitrogen Amount and Application Time

(1) Main Season

Block Number	Treatment and Yield				
	50kg N/ha (ton/ha)	100kg N/ha (ton/ha)	150kg N/ha (ton/ha)	200kg N/ha (ton/ha)	250kg N/ha (ton/ha)
I	4.3	5.5	7.4	6.3	7.9
II	4.2	5.4	7.1	8.4	10.0
III	4.1	5.7	6.8	7.6	7.0
Mean	4.2	5.5	7.1	7.4	8.3

(2) Off-season

	Treatment and Yield				Average yield (ton/ha)
0kg N/ha	(0-0-0)				3.0
I	3.7				
II	3.0				
III	2.3				
Mean	3.0				
50kg N/ha	(50-0-0-0)*	(20-10-10-10)	(30-0-20-0)	(20-0-20-10)	4.2
I	4.3	4.3	4.8	5.2	
II	5.9	3.6	3.8	3.6	
III	3.6	3.7	3.7	4.0	
Mean	4.6	3.9	4.0	4.3	

Note(*): Numerals in parenthesis express the amount of nitrogen applied per hectare at the transplanting, at 20th day after transplanting, at the spikelet differentiation stage and the full heading stage in the order from left to right.

Treatment and Yield					Average yield (ton/ha)
100kg N/ha	(100-0-0-0)	(30-30-20-20)	(60-0-40-0)	(40-0-40-20)	4.5
I	4.1	5.7	4.6	4.9	
II	3.9	3.2	4.6	4.2	
III	4.2	4.8	4.4	4.7	
Mean	4.1	4.6	4.5	4.6	
150kg N/ha	(150-0-0-0)	(50-30-40-30)	(80-0-70-0)	(70-0-60-20)	5.3
I	5.7	5.9	6.8	5.9	
II	3.3	5.1	6.9	5.3	
III	3.5	-	4.9	4.3	
Mean	4.2	5.5	6.2	5.2	
200kg N/ha	(200-0-0-0)	(120-0-80-0)			5.6
I	6.7	6.2			
II	4.2	5.9			
III	4.7	5.5			
Mean	5.2	5.9			
250kg N/ha	(80-60-60-50)				6.1
I	6.2				
II	5.4				
III	6.8				
Mean	6.1				

From the point of the average yield, it can be said that the more in dosage of nitrogen applied, the more in yield within a range from 0 to 250 kg N/ha.

According to the significant difference test on the average yield in each treatment, however, significant differences were observed between treatments of 50 kg N/ha and 100 kg, 100 kg N/ha and 150 kg N/ha in the test in the main-season, and 0kg N/ha and 50 kg N/ha, 100 kg N/ha and 150 kg N/ha in the test in the off-season, and no significant difference was observed among treatments more than 150 kg N/ha, both in the main-season and the off-season.

From the fact it can likely be taken that the optimum amount of nitrogen to be applied seems to be 150 kg/ha, so far as the present experiment is concerned.

As to the effects of the time of application on yields, judging from the results of the significant difference test no significant difference is found within the treatments applied with an identical amount of nitrogen, i.e. 50 kg/ha, 100 kg/ha, 150 kg/ha and 200 kg/ha. However, only little or no difference is found among treatments applied with an identical amount of nitrogen in case of relatively small amount of nitrogen being applied, i.e. 50 kg and 100 kg/ha, while some differences can be recognized among treatments with an identical amount of nitrogen in case of relatively large amount of nitrogen being applied, i.e. 150 kg and 200 kg/ha, showing that split application is better than one time application.

2.4 Spacing and Sowing Density Test

Method

The objective of this test is to find the most suitable spacing for transplanted or directly sown rice plants and sowing density for directly sown rice plants. The test was carried out four times under the randomized block method with three replications. Treatments and the results in each test are summarized in the following tables.

Yields of spacing and sowing density test

(Test I) (Main-season)

	Treatment				
Block Number	30 x 30 cm (11.1hills/ m2)	30 x 20 cm (16.7hills/ m2)	30 x 15 cm (22.2hills/ m2)	25 x 15 cm (26.7hills/ m2)	30 x 10 cm (33.3hills/ m2)
I	7.3 ton/ha	7.4	7.6	10.4	8.8
II	5.7	6.5	7.6	9.7	8.7
III	6.1	7.1	7.3	6.3	7.8
Mean	6.4	7.0	7.5	8.8	8.4

(Test II) (Main-season)

Block Number	50kg Seed/ha		80kg Seed/ha					100kg Seed/ha
	30cm	Broadcast	15cm	20cm	30cm	40cm	Broadcast	30cm
I	6.7(ton/	9.4	9.6	8.5	6.7	8.1	9.4	10.5
II	8.2 ha	8.0	10.6	-	-	-	-	9.5
III	-	-	-	-	-	-	7.1	-
Mean	7.5	8.7	10.1	8.5	6.7	8.1	8.3	10.0
	8.1				8.6			10.0

(Test III) (Main-season)

Block Number	Cultivation Method and Yield				
	Ordinary Transplanting		Broadcast Transplanting		Transplanting with Broadcastable Seedlings
	30 x 30 cm (11.1hills/m2)	30 x 20 cm (16.7hills/m2)	17 hills/m2	22hills/m2	30 x 15 cm (22.2hills/m2)
I	3.8 ton/ha	4.0	4.3	5.8	3.7
II	3.6	4.7	3.9	4.1	-
III	3.3	4.4	-	5.1	4.9
Mean	3.6	4.4	4.1	5.0	4.3

(Test IV) (Off-season)

Cultivation Method	Spacing or Sowing Density	I (ton/ha)	II (ton/ha)	III (ton/ha)	Mean (ton/ha)
1. Ordinary transplanting	15 x 15 cm 44 hills/m2	10.4	8.5	8.3	9.1
	25 x 10 40	8.1	8.5	8.0	8.2
	30 x 10 33	9.4	9.5	8.2	9.0
	25 x 15 27	5.9	6.1	8.4	6.8
	30 x 15 22	4.5	7.0	6.5	6.0
	30 x 20 17	4.4	5.8	6.0	5.4
	25 x 25 16	6.5	6.1	7.0	6.5
	30 x 30 11	4.0	4.2	3.8	4.0
2. Broadcast transplanting	17 hills/m2	3.8	5.9	5.2	5.0
	22	6.6	5.3	5.5	5.8
	40	8.4	11.4	7.1	9.0
3. Ordinary transplanting with broadcastable seedling	30 x 15 cm, 22 hills/m2	7.3	5.7	7.1	6.7
4. Direct sowing:	without puddling 50kg Seed/ha	6.3			
	(upland) 75	6.2			
	100	6.4			
	with puddling 50	5.8			
	(submerged) 75	9.9			
	100	7.1			

The results obtained from Test I and IV show a curvilinear increase in yield against the planting density. But the significant difference test on average yields shows that the highest density treatments, i.e. 33.3 hills/m2 for the test I and 44 hills/m2 for the test IV, have no significant difference against treatments denser than 22.2 hills/m^2 in the test I and 26.7 hills/m2 in the test IV.

Taking the results of Test I and V and the idea of labour saving into account, 22.2 hills or 26.7 hills per m2 can be taken as an optimum planting density for the transplanting method to the project area.

As to the direct sowing, i.e the test II, so many missing plots occurred that the analysis of variance among treatments with 3 blocks was impossible. Then, making the treatments with an identical seeding amount as a group, only a comparison by "t" test on the average yield was made.

According to the analysis, no significant difference is found among sowing densities.

Secondaly, examining the yields in the direct sowing in Test IV, no consistent relation is observed. In case of "without puddling", no difference is found in yield among treatments of 50 kg, 75 kg and 100 kg/ha, while in case of "with pudlling" the treatment of 75 kg/ha is highest in yield.

Bringing together the results of Test II and Test IV, it may be deduced that any amount of seed per ha within a range from 50 kg to 100 kg/ha can be taken as an optimum sowing density.

2.5 Cultivation Method Test

The objective of this test is to find out the most adequate cultivation method among three different methods, i.e. the ordinary transplanting method, the direct sowing method and the broadcast transplanting method.

The test was carried out as a part of the variety test in the main-season in 1977 and as a part of the spacing and sowing density test in the main-season in 1978 and off-season in 1978/1979.

The yields of the test in 1977 are shown below.

Cultivation method	Yield (ton/ha)
Direct sowing (Drilling)	7.0
Direct sowing (Broadcasting)	5.8
Transplanting (Ordinary)	7.5
Transplanting (Broadcast)	7.9

From these results it can be recognized that the broadcast transplanting method is highest in yield, followed by the ordinary transplanting method and the broadcast direct sowing method is lowest.

Significance tests among treatments of same spacing in 1978 were carried out to compare the ordinary transplanting with the broadcast transplanting and with ordinary transplanting using broadcastable seedlings.

The results show that the broadcast transplanting method or the ordinary transplanting method using broadcastable seedlings has no significant difference against the ordinary transplanting. The fact proves statistically that the broadcast transplanting method is by no means inferior in yield to the labour intensive ordinary transplanting method.

Comparison among the treatments of ordinary transplanting, broadcast transplanting and ordinary transplanting with broadcastable seedlings was made using the results of test in 1978/79. Analysis of variance shows that no significant difference in the average yields among 3 methods exists.

Second, comparisons between the direct sowing method and the ordinary transplanting method were tentatively made using the results of the test IV in the spacing and sowing density test for the direct sowing method and those of the nitrogen amount test in the main-season, which were conducted by transplanting. As seen in the following table, significant differences of 3 treatments of the direct sowing method were tested against 8 treatments of the transplanting method, showing "t" value for each comparison.

Comparisons on Yields between Direct Sowing Method and Transplanting Method by "Student" Method

Cultivation Method			Transplanting Method							
Planting or Sowing Rate			27 hills/m2	27	27	11	17	22	27	33
Nitrogen Applied			150kg N/ha	200	250	150	150	150	150	150
Average Yield			7.1 ton/ha	7.4	8.3	6.4	7.0	7.5	8.8	8.4
Direct Sowing	50kg Seed /ha	180kg N/ha	8.1 ton/ha	1.49	0.84	0.20	2.21	1.59	0.91	0.56	0.42
	80kg Seed /ha	180kg N/ha	8.6 ton/ha	1.78	1.31	0.30	2.49	1.88	1.31	0.18	0.23
	100kg Seed /ha	180kg N/ha	10.0 ton/ha	6.68**	2.98	1.41	4.97**	5.97**	6.34**	0.72	2.88

Remark: The numeral in each cell expresses Student's "t" value which shows the difference between the yield of transplanting method and that of direct sowing method.

Out of 24 comparisons only 4 comparisons showed significant differences between the transplanting method and the direct sowing method. Roughly speaking, a significant difference could hardly be recognized between two methods. However, following points may be noted (1) the direct sowing method applying a high rate of seed (100 kg Seed/ha) and a high rate of nitrogen (180 kg N/ha) is superior to any transplanting methods from a view point of an average yield and is also superior, taking variance of yields into consideration, to the transplanting methods applying a lower rate of transplanting density than 27 hills/m^2 and ordinary application of nitrogen (150 kg N/ha), (2) the maximum yield, 10.6 ton/ha, obtained by the direct sowing method exceeds the maximum yield, 10.0 ton/ha, by the transplanting method.

From these facts, it may be said that the direct sowing method with applications of a high rate of nitrogen and seed is superior to the transplanting method applying an ordinary rate of nitrogen and transplanting density, although this comparison is not so scientific because the two methods are different in sowing dates, i.e. about half month apart each other, fertilization and experimental fields.

It must be borne in mind, however, that the direct sowing in this test was conducted on a nicely levelled field with nice drainage facilities. If the direct sowing were carried out on a badly levelled and ill-drained field, the yields of direct sowing would be much less than those of the transplanting method.

2.6 Herbicide Test

The objective of this test is to select the appropriate herbicides not only for the transplanting rice cultivation but also for the direct-sown rice cultivation in due consideration of the effectiveness for weeding and of the phytotoxicity. In case of the direct sowing method four herbicides for soil treatment and 3 herbicides for soil and foliage treatment were tested. In case of the transplanting method six kinds of herbicides were tested.

The results of the test of the herbicides for the soil treatment are shown in the following table.

Effect of Herbicide for Soil Treatment

Herbicide	Survived Weeds	
	Cyperaceae	Echinochloa crus-galli
	(hills/m^2)	(hills/m^2)
Control (no application)	69	10
MO	4	2
Saturn	0	0
X-52	1	1
Ronstar*	0	0

Remark: Severe phototoxicity was observed on the rice plants applied with Ronstar.

Survived weeds were investigated on the 20th day after the treatments.

The effects of herbicides for soil treatment were very remarkable compared with the results of the no-application plots. The most effective and safety herbicide was Saturn followed by X-52 and MO. Ronstar brought about severe phytotoxicity on the rice plants, giving rise to a low percentages of established seedlings and many stunted plants.

Effects of the herbicides for the soil and foliage treatment could not be identified, because the effect of Saturn applied for the soil treatment was so strong that no weed was left for the test of herbicides for the soil and foliage treatment.

As for the transplanted rice, effects of the herbicides were judged by eye estimation. According to the judgement, Suturn, MO, X-52, SWEP (M) and NIP had powerfull effects for weeding. Ronstar brought about severe phytotoxicity on transplanted rice plants.

2.7 Seasonal Planting Test

The objective of this test is to determine the optimum sowing for the main-season cropping and the off-season cropping for establishing the most suitable pattern of two croppings a year for the project area.

In this test the following 4 varieties were sown every month on the year round in general; Chen-Chu-Ai (C-11) (Short-term variety), IR-20 (medium-term variety), IR-8 (long-term variety) and C-6 (long-term variety).

The results show that the rice plants sown during the period from early October to late January produce relatively low yields, while those sown in the period from early February to late August produce relatively high yields. The reason why the plants sown from early October to late January produce poor yields can surely be ascribed to the fact that the plants sown in the said period are seriously damaged by low temperatures during December and January in which the monthly minimum temperatures are 17.7 and 15.8^{o}C, respectively.

There are two minima in the yield indexes during the suitable sowing period, i.e. in the middle February and the early or middle July, though the two minima are not ascertained whether they are significant or not. The two minima may be ascribed to the high temperatures at the heading stage or at the active ripening stage because when the rice plants are sown in the Middle February and early or middle July. These heading dates occur in May and in October in most cases and the average air temperature during 20 days after heading is highest in May and second-highest in October. Then, the suitable sowing time may be taken as the period from late February to late August excluding early and middle July so far as this experiment is concerned.

To make the relation between the sowing date and the yield clearer, the relationships between the growth of rice plants and the natural environment were investigated.

Among the climatic factors, the most important factors to the rice yield are found to be the average air temperatures during the ripening stage and the water temperature during a period from the spikelet differentiation stage to the most active meiosis of pollen mother cells. High temperature during the ripening stage and the cool water temperature from the spikelet differentiation stage to the most active meiosis of pollen mother cells reduced the yield substantially. If two croppings of rice a year are contemplated, two optimum heading seasons can likely be pointed out from the investigation as those from late June to middle July and from late October to middle November.

In order to get the most suitable cropping pattern for the double cropping in the project area, combining the varieties with different growth durations for the first cropping with those for the second cropping, many attempts were made. From the attempts it has made clear that only a combination of the long-term or the middle-term varieties sown from late February to early April with the short-term varieties sown from middle August to middle September is suitable.

2.8 Sowing Method Test

Large scale rice cultivation will have to be carried out through the direct sowing method, because the number of available labourers for the transplanting will be limitted in the project area. Establishment of seedlings and weed control are the key to the success in the rice cultivation through direct sowing method. The objective of this experiment is to find the most suitable sowing method for the direct sowing method. Effects of the depth of covering soil, an oxygen supplying chemical, i.e., calcium peroxide, forced germination, duration of time from puddling to sowing and duration of submergence of seeds after sowing, on the rate of emergence of seedlings were studied.

Results of the test on the effect of depth of covering soil, calcium peroxide and the moisture condition of the soil on the emergence of seedlings are given in the following table.

Effects of Depth of Covering Soil, Calcium Peroxide and Soil Misture Conditions of the Soil on the Emergence of Seedling

Variety	Sowing depth	Non-flooded condition		Flooded condition	
		Percentage of germinated seeds	Average number of days required for germination	Percentage of germinated seeds	Average number of days required for germination
Non-treated					
IR-8	Surface	74	7.5	78	7.8
	2 cm	93	7.8	56	8.1
	5 cm	77	11.0	no test	no test
TOS-103	Surface	49	8.1	53	10.6
	2 cm	72	8.0	39	9.0
	5 cm	62	8.8	no test	no test
Treated with Calper					
IR-8	Surface	87	7.4	92	5.3
	2 cm	86	7.4	83	6.8
	5 cm	48	8.3	no test	no test
TOS-103	Surface	14	10.0	53	9.0
	2 cm	46	8.8	59	8.8
	5 cm	32	9.5	no test	no test

As seen in the table, in case of the dry field condition, the most appropriate depth of soil cover is 2 cm, while in case of the flooded field condition, that is 0 cm (Surface). Effects of the calcium peroxide on the emergence of seedlings were not observed in case of the dry field condition, but in case of the flooded field condition, some effects were observed.

Results of the tests on the effects of the hastening germination, of duration of time from puddling to sowing and of duration of submergence of seed after sowing on the establishment of seedlings are shown in the next table.

Variety	Treatment	Degrees of Emergence of Seedlings/2 Block Number 1	2	3	4	Average
IR-8	A1B1C1/1	0	0	0	0	0.00
	" C2	1	1	1	0	0.75
	" C3	1	0	0	0	0.25
	A1B2C1	1	1	1	0	0.75
	" C2	0	0	1	2	0.75
	" C3	2	2	2	1	1.75
	A2B1C1	2	1	2	2	1.75
	" C2	2	2	2	2	2.00
	" C3	2	2	2	2	2.00
	A2B2C1	2	3	3	2	2.50
	" C2	2	3	3	3	2.75
	" C3	2	2	3	1	2.00
IR-20	A1B1C1	0	0	0	0	0.00
	" C2	0	0	0	0	0.00
	" C3	0	0	0	1	0.25
	A1B2C1	0	0	0	1	0.25
	" C2	0	1	0	0	0.25
	" C3	0	0	1	2	0.75
	A2B1C1	1	1	1	2	1.25
	" C2	1	2	2	2	1.75
	" C3	1	1	1	2	1.25
	A2B2C1	2	2	2	2	2.00
	" C2	2	3	0	2	1.75
	" C3	0	0	1	1	0.50
C-6	A1B1C1	1	0	0	0	0.25
	" C2	0	0	0	0	0.00
	" C3	1	1	0	0	0.50
	A1B2C1	0	1	1	1	0.75
	" C2	0	1	1	1	0.75
	" C3	2	1	2	1	1.50
	A2B1C1	1	0	1	1	0.75
	" C2	1	2	1	2	1.50
	" C3	1	2	2	2	1.75
	A2B2C1	2	1	2	2	1.75
	" C2	2	2	2	2	2.00
	" C3	2	2	2	2	2.00
C-11	A1B1C1	0	0	0	0	0.00
	" C2	0	1	0	0	0.25
	" C3	0	0	1	0	0.25
	A1B2C1	1	0	0	0	0.25
	" C2	0	0	1	1	0.50
	" C3	1	2	1	2	1.50
	A2B1C1	2	2	1	2	1.75
	" C2	3	2	2	3	2.50
	" C3	3	3	2	3	2.75
	A2B2C1	1	2	1	2	1.50
	" C2	2	2	2	2	2.00
	" C3	2	2	2	2	2.00
TOS-103	A1B1C1	0	0	0	0	0.00
	" C2	1	0	0	0	0.25
	" C3	0	1	0	1	0.50
	A1B2C1	1	1	0	1	0.75
	" C2	1	1	0	1	0.75
	" C3	1	1	2	1	1.25
	A2B1C1	2	2	2	1	1.75
	" C2	2	2	2	1	1.75
	" C3	2	1	2	2	1.75
	A2B2C1	1	2	2	2	1.75
	" C2	2	2	2	2	2.00
	" C3	2	2	2	1	1.75

Remarks /1: A1, 3 days soaking
A2, 3 days soaking and 2 days forced germination
B1, Sown just after puddling
B2, Sown 1 day after puddling
C1, 1 day submergence of seed after sowing
C2, 3 days submergence of seed after sowing
C3, 7 days submergence of seed after sowing

/2: Degrees of emergence were judged by eye estimation with 0 to 5 value, of which 5 is highest emergence.

2.9 Measurement of Evapotranspiration by Rice Plants

Evapotranspiration by rice plants is a very important factor in the design of the irrigation facilities, in the water management and in water balance study. The measurement of evapotranspiration was carried out using a tank filled with water.

The tank was 1 m cube (1x1x1m) with the bottom. The measurement was carried out using a hook gage. The varieties used for the experiment were Reimei sown on January 16, 1978 for the 1st test and IR-20 sown on December 1, 1978 for the 2nd test.

Besides the measurement of evapotranspiration by rice plants, the measurement of evaporation was carried out concurrently.

Peak evapotranspiration by a variety of Reimei was found at 20 mm/day, while it was 22 mm/day by IR-20.

The relation between Piche evaporation and pan evaporation was investigated using mean values in a 5-day period obtained during the period from January, 1978 to May, 1979, because daily Piche evaporation has been recorded for many years, and if a definite relation can be obtained between them, the values of pan evaporation for many years will be estimated.

A regression line calculated by the least square method is

$$Y = 1.56 + 0.576\ X$$

when Y stands for the class-A pan evaporation and X for Piche evaporation. Judging from the results of a variance test, the regression line is highly adaptable with more than 99% probability of confidence.

The hastening germination has a significiant effect on the degrees of emergence of seedlings on each variety. Average degrees of emergence of seedlings treated with the hastening germination are significantly higher than these without hastening germination with 99 % probability, while the effect of 1 day duration from puddling time to sowing time, in the case of seeds treated with hastening germination, is significantly clear for varieties, IR-8, C-6 and C-11 with more than 95 % probability. Duration of submergence after sowing seems to have no effect on the degrees of emergence of seedlings, because an analysis of variance showed no difference in the average degrees of emergence of seedlings among the treatments when seeds being treated with hastening germination. It can be said, from these results, that seeds should be subjected to the hastening germination treatment and be sown one day later than puddling.

3. Formulation of Most Suitable Double Cropping of Rice to Project Area Based on Results Obtained in Experiments

By for the biggest objective in the present rice culture experiment through two years is to examine the possibility of the double cropping of rice a year and to know the attainable yields, and further, if possible, to establish a recommendable cropping system at the first stage.

As clearly demonstrated in the foregoing sections, the two croppings of rice a year are easily, safely and effectively can be carried out without fail in the project area. Moreover, much higher yields have actually been obtained in the two seasons than the target yields which have been envisaged in the feasibility study. Referring to the highest yields in the two seasons, i.e. 10.5 ton/ha in the main-season and 11.4 ton/ha in the off-season, each yield is more than two times as large as the target yield, respectively, i.e. 6 ton/ha in the main season and 4 ton/ha in the off season. Thus, the biggest objective in the experiment has fully been achieved. In the following the main actual practises of the double cropping will be mentioned.

Sowing time

An appropriate sowing time appears to be from the late February to early April with long- or middle-term varieties in the first cropping season (off-season) and from the middle August to the middle September with short-term varieties in the second season (main-season), as discussed in the section 5.7 in the ANNEX REPORT.

Varieties

Among the varieties recommended from the results of variety tests, in view of actual practices of the double cropping of rice mentioned above, only the following varieties will be effectively used.

For the first cropping (off-season, February to August)

BG-33-2, BG-34-12, BG-34-6

For the second cropping (main-season, August to December)

BG-90-2, IR-24, IR-22, IR-2053, IR-2153, IR-1561, Dawn

Sowing method

As can be seen in the sowing method test, sowing can successfully be practiced on the dry field conditions, seeds should be covered with the soil of 2-cm depth, while seeds should not be covered with soil at all under the flooded conditions. Further, before sowing seeds must be subjected to the hastening germination treatment and must be sown one day later than puddling.

The rate of sowing is 50 kg to 100 kg per ha for the direct sowing method, 60 g to 70 g per m^2 for the ordinary transplanting method, and 60 g to 80 g per box for the broadcast transplanting method.

Fertilization

When fertilizing on the main field, 150 kg of nitrogen and 75 kg to 50 kg of phosphate should be applied, not applying any amount of potassium at all, as discussed in the sections of both the fertilizer element test and the nitrogen amount and the application time test. The total amount of potassium should be applied as basal dressing, but nitrogenous fertilizer must be split-applied four times, i.e. (1) basal dressing, (2) 15th day after transplanting for transplanted plants and at the 5th leaf-stage for directly sown plants, (3) at the late spikelet differentiation stage and (4) at the full heading stage.

Spacing and sowing density

As mentioned in the section of the spacing and sowing density test, in the case of transplanting plants should be transplanted at the spacing of 22 hills to 27 hills per m^2 with 2 or 3 seedlings per hill, and in the case of direct sowing seeds should be sown at the density of 50 kg to 100 kg per ha.

Weeding

For weeding for transplanted fields the herbicides such as Saturn (6 ℓ/ha), X-52 (30 kg/ha) and MO (30 kg/ha) can safely and effectively

be used, as can be seen in the herbicide test. For directly sown fields, firstly, the soil treatment herbicides such as MO (30 kg/ha, granule) and Saturn (30 kg per ha) must be applied just after sowing or just before emergence of seedlings. Secondly, just after flooding Saturn, X-52 or MO must be applied again at the 3 to 5 leaf-age of rice plants with the dosages mentioned above.

4. RECOMMENDATION

Particular stress should be laid on the further rice growing experiments in Gassaba Rice Pilot Farm for the successful development of rice cultivation in the Abu-Gassaba Rice Development Project. Though the outline of rice cultivation techniques, which can be applied to the project area at the first developmental stage, could tentatively be revealed through the experiments mentioned above, further detailed experiments should strongly be intensified along the following line.

As for the operation of the pilot farm, basic experiments as well as practical operation techniques should intensively be studied taking the recommendations itemized below into consideration.

1) Experiments on mechanized cultivation,
2) Experiments on farm management,
3) Experiments on yield maximizing,
4) Generalization of the results of yield-maximizing experiments,
5) Establishment of the most appropriate double cropping system,
6) Selection of the superior varieties through the screening of varieties collected from all over the world,
7) Experiments on the direct sowing method and the broadcastable transplanting method,
8) Water management, especialy for the economical water use,
9) Physiological and ecological experiments on the rice plant under the hot and dry climate conditions, especially varietal difference under the conditions,
10) Preparation of facilities in the experimental farm (especially, building of iron net house, concrete boundaries etc.),
11) Improvement of experimental equipment (i.e. meteorological observation facilities, laboratory equipments, etc.),
12) Increase of the officers and training of the officials and farmers.