THE DEMOCRATIC REPUBLIC OF THE SUDAN

MINISTRY OF AGRICULTURE, FOOD

AND NATURAL RESOURCES

PRELIMINARY EXPERIMENTS ON RICE CULTIVATION UNDER THE HOT AND DRY CLIMATE IN SUDAN

– ANNEX TO SUPPLEMENTARY REPORT III –

October, 1979

JAPAN INTERNATIONAL COOPERATION AGENCY

REPORT

to the

GOVERNMENT OF THE DEMOCRATIC REPUBLIC OF SUDAN

on

PRELIMINARY EXPERIMENTS ON RICE CULTIVATION UNDER THE HOT AND DRY CLIMATE IN SUDAN

October, 1979

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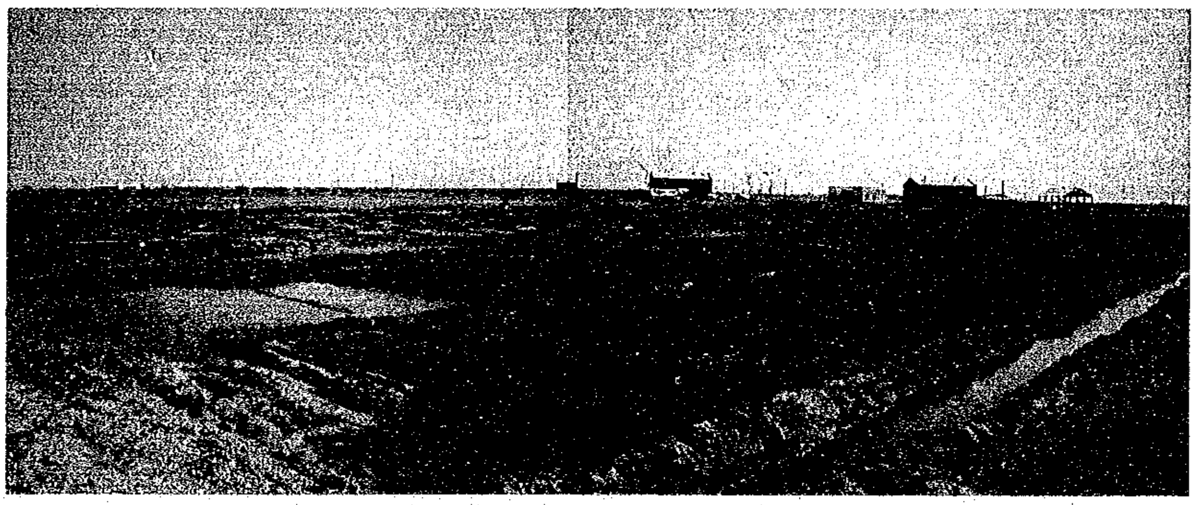
(Rice Trial Team Dispatched by JICA)

JAPAN INTERNATIONAL COOPERATION AGENCY, TOKYO

Ripening Stage of Rice Plants
(IR-8, Sown on Feb. 15, yielded 8.2 ton/ha)

General View of the Experimental Field (2 ha)



Nursery Bed in the Pilot Farm (50 ha)

PRELIMINARY EXPERIMENTS ON RICE CULTIVATION

UNDER THE HOT AND DRY CLIMATE IN SUDAN

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8. ANNEX

1. INTRODUCTION

This is the final report on the rice experiments which have been implemented in Dueim, White Nile Province, in the Democratic Republic of the Sudan. These experiments were conducted for two and a half years from June 1977, to October 1979 as one part of the Abu-Gasaba Rice Development Project feasibility study. The experiments were undertaken by Nippon Koei rice experts dispatched by the Japan International Co-operation Agency. And, an experimental field was prepared at a small field of 0.3 ha in June, 1977. This was expanded to 2.0 ha in March, 1978.

Objectives

The objectives of the experiments were to clarify the possibility of rice cropping twice a year under the extremely hot and dry climate of Sudan, and to formulate the most appropriate rice cultivation system applicable in the Abu-Gasaba area. The essential scope of the experiments are summarized as follows.

- Estimation of yield potential of the land for rice cultivation in the off-season (from November to April) as well as in the main-season (from May to October).

- Selection of the most suitable improved varieties and cultivation methods for the project.

- Determination of the most appropriate cropping pattern for the double cropping of rice.

- Estimation of the optimum kinds and amounts of farm inputs such as fertilizers, insecticides, fungicides and herbicides.

- Selection of appropriate farm machinery for the project.

Major Work

To achieve these objectives the following major experiments were carried out.

A. Variety tests

To select for the project area, the most suitable varieties with high-yield ability, high quality, high resistance to diseases and insect pests, and lodging under mechanized farming and the irrigation conditions. Fifty nine varieties were tested.

B. Seasonal planting tests

To select the optimum sowing date for the off-season crop as well as for the main-season crop to establish the most suitable double cropping system for the project area.

C. Fertilizer element tests

To clarify the effectiveness of nitrogen, phosphorus, potassium and sulphur on rice yields.

D. Nitrogen tests

To clarify the effect on rice cultivation of nitrogen dosage, and to determine the optimum amount of nitrogen to be applied.

E. Cultivation methods tests

To compare various cultivation methods (regular transplanting, broadcast transplanting, and direct sowing, and to select the most appropriate cultivation method.

F. Spacing tests

To select the most suitable spacing for the transplanted plants and the optimum seeding rate for the direct sowing method.

G. Herbicide tests

To select the optimum type and dosage of herbicides for weeds in the project area.

H. Sowing technique tests

To determine the most suitable sowing technique for the direct sowing method. The studies investigated the effects on the emergence of seedlings of: the depth of covering soil, an oxygen supplying chemical (calcium peroxide), forced germination, time lapse from puddling to sowing, and duration of submergence of seeds after sowing.

In the crop experiments, the growth process of rice plants, climatic conditions and evapotranspiration of water by rice plants were also investigated. In addition, seed multiplication of promising varieties was carried out for a operation of 50 ha pilot farm, and sufficient seed was obtained.

These rice experiments were carried out as the following five studies in the periods indicated.

Feasibility Study	:	May to December, 1977
1st Supplementary Study	:	December, 1977 to March, 1978
2nd Supplementary Study	:	May to December, 1978
3rd Supplementary Study	:	December, 1978 to March, 1979
4th Supplementary Study	:	May to October, 1979

The results of the tests performed in the feasibility study and the 1st, 2nd and 3rd Supplementary Studies have been reported in Supplementary Reports I and II. This report is a compilation of the experimental results from all the previous experiments (from June, 1977 to March, 1979) as well as those from the 4th Supplementary Study (from May 7 to October 31, 1979)

Personnel

Personnel assigned to the cultivation trials are listed below.

	Japanese Experts: Field Work	Japanese Experts: Home Office Work	Counterpart Personnel
(1)	Feasibility Study (May to Dec. 1977)		
	Dr. Seizo Matsushima	Dr. Seizo Matsushima	Mr. Ahmed Khalid Shouk
	Mr. Susumu Honma		Mr. Hassan Omer
	Mr. Hisashi Ikewada		Mr. Abdul Moniem
			Mr. Ali El Amin
(2)	1st Supplementary Study (Dec. 1977 to March 1978)		
	Mr. Hisashi Ikewada	Mr. Susumu Honma	Mr. Ali El Amin
		Mr. Tadaharu Murono	Mr. Hassan Omer
(3)	2nd Supplementary Study (May to Nov. 1978)		
	Dr. Seizo Matsushima	Dr. Seizo Matsushima	Mr. Ali El Amin
	Mr. Hisashi Ikewada	Mr. Hisashi Ikewada	Mr. Hassan Omer
	Mr. Hikaru Niki		Mr. Ali Abdel Wahab
			Mr. Ahmed El Sideg
(4)	3rd Supplementary Study (Dec. 1978 to March 1979)		
	Mr. Akio Maeda	Dr. Seizo Matsushima	Mr. El Rayah Ahmed
	Mr. Hikaru Niki	Mr. Hisashi Ikewada	Mr. Issam Musttafa
		Mr. Akio Maeda	Mr. Ali El Amin
		Mr. Susumu Honma	Mr. Ali Abdel Wahab
			Mr. Ahmed El Sideg
			Mr. Mohamed Fouzi
(5)	4th Supplementary Study (May to October, 1977)		
	Mr. Akio Maeda	Dr. Seizo Matsushima	Mr. El Rayah Amhed
	Dr. Seizo Matsushima	Mr. Hisashi Ikewada	Mr. Issam Mustaffa
	Mr. Hikaru Niki	Mr. Akio Maeda	Mr. Ali El Amin
		Mr. Susumu Honma	Mr. Hassan Omer
		Mr. Fumihiro Nagao	Mr. Ali Abdel Wahab
			Mr. Ahmed El Sideg
			Mr. Mohamed Fouzi

In addition to the personnel listed above several staff members of the Agricultural office in Dueim were temporarily assigned during periods when regular counterpart personnel took their annual leave.

2. GENERAL BACKGROUND OF THE RICE PROJECT

The Democratic Republic of Sudan is the largest country in Africa with a total area of approximately 2.5 million square kilometres. The population is about 16.5 million, giving a density of 6.6 persons per square kilometre as of 1977.

Sudan has a continental tropical arid climate with two distinct seasons, wet and dry, except for a narrow strip along the coast of the Red Sea where winter rainfall predominates.

The Nile and its tributaries are indispensable to the development of the national economy, providing irrigation and municipal water. Water resources allocated to Sudan from the Nile total 18.5 billion cubic metres.

Sudan is blessed with a vast fertile land area for agricultural development. In a study carried out by the FAO in 1970, it was estimated that about 30% of the total area of Sudan was suitable for agricultural use. However, only 13% of the total area has been so used, that is, 4% for crops and 9% for pasture.

Agriculture is predominant in the national economy. About 40% of the GNP is produced in this sector, and about 70% of the population is engaged in this sector. Around 95% of the total export value is derived from this sector.

Major agricultural commodities for export are cotton, groundnuts, sesame, gum Arabic and meat, of which cotton accounts for about half of the total export amount. The national economy depends on a single crop (cotton) which is highly susceptible to adverse weather conditions and price fluctuations in the international market. In this context, the Sudanese Government has been encouraging the diversification of export crops from cotton to sugar, wheat, rice, and so forth, under a six year Development Plan (1977/78 - 82/83).

The average annual production and the average annual area under rice cultivation in the Sudan in the past six years are estimated at about 12,000 tons and about 10,000 ha. The major production areas for rice are Gezira, Bahr El Ghazal and Equatoria. The average yield of rice in 1975/76 in these area was 1.19, 0.32, and 0.57 ton/ha, respectively.

The domestic demand for rice has been exceeding the domestic production. And, the rice requirements have been met with rice imported. The amounts of rice imported in 1971/72, 1972/73 and 1973/74 were about 9,000, 9,000 and 13,000 tons, respectively, and this will increase rapidly following the increases in per capita consumption.

The target production of rice for 1982/83 under the six year Development Plan is 57,000 tons, which is 4.75 times that for 1976/77.

The Sudanese Government plans to increase rice production primarily to attain self-sufficiency and secondarily to export the surplus to neighbouring countries. The plan firstly calls for the promotion of the rice production in the vast swampy areas adjoining the banks of the White Nile, which have been subjected to seasonal inundation and have been abandoned since the completion of the Jubel Aulia Dam.

The Sudanese Government carried out a preliminary survey on seven abandoned areas, and as a result, three areas, includes the Abu Gasaba Basin, were selected as first priority.

In July, 1975, the Sudanese Government invited Nippon Koei Co., Ltd. to perform a reconnaissance survey of these three areas, in response to a technical proposal prepared by this consulting firm.

Nippon Koei submitted its reconnaissance report to the Sudanese Government in January, 1976. The report concluded that the areas were suitable for rice cultivation project both technically and economically.

At the beginning of November, 1976, the Japanese Government dispatched a contact mission in response to the request from the Sudanese Government for promotion of the project. The mission specified the Abu Gasaba Basin out of three schemes for a feasibility study to be undertaken as the next stage, in due consideration of the overall soundness of the project, the availability of topographic maps and the easiness of access.

In early 1977, the Sudanese Government requested technical assistance for the feasibility study on the Abu Gasaba Rice Development Project from the Japanese Government. And, in March 1977, the Japanese Government decided to undertake the survey, and entrusted it to the Japan International Cooperation Agency (JICA). The Agency dispatched a survey team to Sudan during May to August. The objectives of the survey were to formulate an appropriate rice development project for the Abu Gasaba Basin, and to evaluate the feasibility of the project. Along with a feasibility study, rice experiments were commenced in June 1977, to obtain basic data on rice cultivation in the project area, as mentioned in preceeding section. Their feasibility report was submitted to the Sudanese Government in June, 1978. The feasibility report concluded that a rice project of 15,600 ha in the Abu Gasaba area would be feasible both technically and economically with an internal rate of return of 17.6%. The report also concluded that, the project could produce an annual yield of 100,000 tons or more of milled rice at the stage of full development.

3. EXPERIMENTAL FIELDS - NATURAL CONDITIONS

Location

The experimental site is on the left bank of White Nile in Dueim, the provincial capital of White Nile Province, which is about 200 km south of Khartoum, the capital of Sudan. Dueim is 13,59' north in latitude, 32,20' east in longitude, and 380 m above sea level.

Topography and Geology

The topography is mostly flat. The geological formation of the experimental fields primarily consists of fluvial deposits of Quarternary origin. The geological profile may be broadly classified as an alluvial clay layer forming the surface and subsurface, and a sand layer underlying the clay layer.

Soils and Water Quality

Predominant soils in the experimental fields are Vertisols. They are very fine in texture, moderately alkaline (ranging between 8.0 and 8.5 in pH), relatively poor in organic carbon (around 3% in the surface soils and less than 0.5% in sub-soils), rich in mineral elements (0 to 0.8% in total N, 2 to 60mg/100g of available P_2O_5, 0.5 to 4.0mg/100g of exchangeable K), free from the problems caused by salinity and chemical toxicity, high in cation exchange capacity, (40 to 50 moleculor equivalent), high in water holding capacity, and very low in permeability.

The water quality of the White Nile at Dueim is excellent for irrigation purposes, as summarized in Table 3-1.

Table 3-1 Water Quality of the White Nile

1. pH : 8.0
2. EC : 220 m mho/cm/25°C

3. Soluble salts

Na^{+}	: 0.97 m.e/l	CL^{-1}	: 0.63 m.e/l
K^{+}	: 0.12 "	SO_4^{2-}	: 0.28 "
Ca^{2+}	: 0.52 "	CO_3^{2-}	: 1.70 "
Mg^{2+}	: 0.62 "		

4. Soluble Mn : 0.03 ppm
5. Soluble SiO : 25.31 ppm
6. Soluble PO^{3-} : 0.02 ppm
7, Soluble NO_3^- : 0.49 ppm

Climate

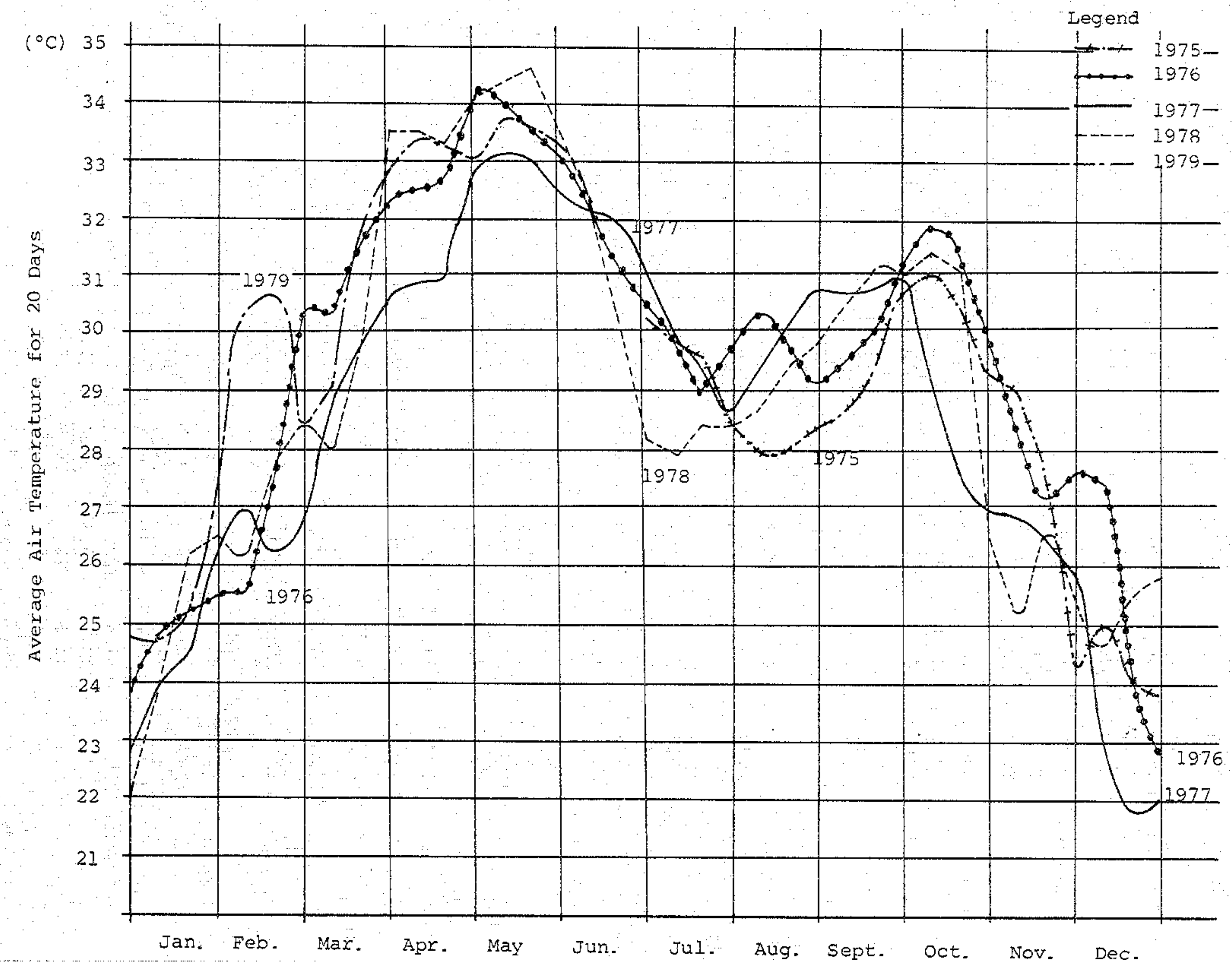
Dueim lies within the tropical hot arid zone of Central Sudan. The climate of Dueim is characterized by 2 distinct seasons, dry and wet. The average annual rainfall at Dueim from 1941 to 1970 is 280 mm, of which about 90% is concentrated in the rainy season from May to August. The air temperature varies greatly 60th annually and daily. The average monthly minimum air temperature in the coldest month, January, is 16.4°C. The average monthly maximum air temperature in the hottest month, May, is 41.1°C. Evaporation (Piche) is quite high, and ranges from 19.4 mm per day in April to 7.7 mm per day in August. The relative humidity is low especially in March and April.

Meteorological conditions during the test periods were investigated for analysis of the experimental results. Climatic data such as daily maximum air temperature, minimum air temperature, relative humidity at 8:00 a.m., and rainfall during the period from June 1977 to June 1979, were obtained from the meteorological station in Dueim.
Daily maximum and minimum water temperatures were measured at a point about 2 cm below the water surface in the rice field. These data are presented in ANNEX 1. The monthly mean meteorological values recorded during the test period are listed in Table 3-2.

Table 3-2 Meteorological Conditions during the Test Period

Month	Year	Air Temperature Max. (°C)	Air Temperature Min. (°C)	Water Temperature Max. (°C)	Water Temperature Min. (°C)	Relative Humidity at 8:00 a.m. (%)	Rainfall (mm/month)
January	1978	30.6	15.8	27.0	11.7	37	0
	1979	30.8	17.7	27.8	13.0	40	0
	Mean	30.7	16.8	27.4	12.4	39	0
February	1978	34.1	18.1	31.1	14.2	35	0
	1979	36.4	21.0	35.7	15.0	36	0
	Mean	35.2	19.6	33.4	14.6	36	0
March	1978	36.5	20.6	31.7	15.3	26	2.6
	1979	36.8	22.0	-	-	29	0
	Mean	36.7	21.3	31.7	15.3	28	1.3
April	1978	41.1	26.4	37.6	19.3	26	1.1
	1979	40.5	25.6	32.2	19.3	31	0
	Mean	40.8	26.0	34.9	19.3	29	0.6
May	1978	41.5	26.8	39.6	22.9	39	0.6
	1979	-	-	-	-	-	0
	Mean						0.3
June	1977	39.5	25.9	-	-	63	10.8
	1978	37.8	26.2	34.0	21.0	43	104.7
	1979	38.6	25.5	34.6	22.8	58	13.3
	Mean	38.6	25.9	34.3	21.9	55	42.9
July	1977	36.0	24.7	-	-	67	47.2
	1978	33.0	23.2	33.0	23.0	77	237.0
	1979	36.7	25.4	32.8	23.5	64	37.0
	Mean	36.2	24.4	33.4	23.3	69	107.1
August	1977	33.9	24.1	-	-	74	28.9
	1978	33.7	23.7	36.8	24.5	76	156.8
	1979						
	Mean						
September	1977	37.2	24.5	-	-	62	18.8
	1978	36.2	24.5	34.8	23.8	65	13.9
	Mean	36.7	24.5	34.8	23.8	64	16.4
October	1977	35.7	23.2	-	-	47	5.1
	1978	38.1	24.5	34.7	22.5	54	17.7
	Mean	36.9	23.9	34.7	22.5	51	11.4
November	1977	34.4	20.3	30.1	13.4	36	0
	1978	33.2	19.8	28.4	17.6	37	0
	Mean	33.8	20.1	29.3	15.5	37	0
December	1977	30.7	17.7	26.2	12.7	37	0
	1978	32.4	18.6	25.7	14.3	42	0
	Mean	31.6	18.2	26.0	13.5	40	0

Fig. 3-1 <u>Seasonal and Yearly Variance of Air Temperature</u>



To schematically show the seasonal and yearly variance of air temperature, the average air temperature for each 20 days from July 1975 to May 1979 are shown in Fig. 3-1. A nearly identical trend in seasonal change of air temperature can be seen in each year. Two peaks of high air temperature are visible, one in May and one in October. The minimum air temperatures occurred in December or January. The air temperatures in the winter of 1977, i.e., December, and in January of 1978 were cooler than the average year, while 1978 was warmer than the average year.

Rainfall in 1978 was abnormally heavy with a total rainfall of 534.5 mm.

4. PESTS AND DISEASES OBSERVED DURING THE EXPERIMENTAL PERIOD

Major insect pests and diseases observed during the test period are listed below in the order of their occurrence.

PESTS AND DISEASES OBSERVED

Name	Season Observed	Damaged Variety	Degree of Damage
*Army worms	August	IR-8, IR-20	great
*Ants	October	all varieties	great
*Disease resembling orange leaf disease	November	BG-90-2	moderate
*Rats	harvesting season	lodged varieties	slight
*Sparrows	harvesting season, sowing period	all varieties	great
*Damping-off	December, January	IR-28, IR-29, IR-5 IR-24, C-15, IR-38 C-11, IR-40, Toitsu, IR-36, IR-30	moderate

Name	Season Observed	Damaged Variety	Degree of Damage
*Bacterial leaf streak disease	June, July	C-15, IR-20	slight
*Disease resembling bacterial leaf blight	August, September	IR-298, C-15	slight
*Leaf miner fly	August in late August	tranplanted varieties	slight
*Rice stem borer	August, September	IR-298, C-15, BG-90-2	slight
*Southern green stink bug	June	all varieties	slight
*Green rice leaf hopper	June	all varieties	slight
*Grass hopper	June	all varieties	slight
*Locust	June	all varieties	slight
*Disease resembling sheath blight	June	all varieties	moderate

Army worms caused much damage to rice plants. They invaded the rice field from surrounding fields where their food and the grass, had been destroyed by plowing.

Ants caused much damage to rice plants by carrying ripened grains to their nests.

A disease something like orange leaf disease was observed on TOS-103 at its ripening stage. The following symptoms were observed.

1) Orange discoloration of the leaves beginning with the lower leaves and starting from the leaf tip.

2) Longitudinal rolling of affected leaves.

3) Rapid death of plant affected and white head. No leaf hopper was observed. Orange coloured insects like melon fly stuck to the bases of infected rice plants.

Sparrows damaged the rice plants ripening. Without necessary preventive means such as nets or guards, much damage would have occurred.

Damping-off was observed on rice seedlings sown in December or January. This was caused by the low air- and water-temperatures. The monthly minimum water temperatures were 12.7°C and 11.7°C in December and January, respectively. Damping-off was well prevented by applying the fungicide Hymexazol to the nursery beds.

Bacterial leaf streak disease appeared to be one of the most common rice diseases in Sudan. Damage by this disease diminished around the maximum tiller number stage.

White heads caused by rice stem borers were observed in the later stage of rice growth.

A disease like sheath blight caused serious damage to rice plants but was not fatal. Differences in susceptibility to the disease of different varieties were observed. The following grouping could be made.

Susceptible	:	IR-5, IR-28, IR-30, IR-36, IR-127, TOS-103, C-11, BG-34-8, Taichung-Ikukyu, Toitsu, Ishin,
Moderately susceptible	:	UR-20, IR-22, IR-24, IR-29, IR-40, IR-1514, IR-1561, HINO, Asominori, Reimei, Toyonishiki, Dawn, C-15
Moderately resistant	:	IR-38, IR-298-12-1-1, IR-2053, IR-2153, C-15, BG-90-2, Taichung 65, Takao-21, Hesinchu 56, Koganenishiki, Norin 17, Blue Bonnet, SML-18,
Resistant	:	IR-8, BG-11-11,

5. RICE EXPERIMENTS

5.1 Varieties Tests

Purpose

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

Method

From various rice growing countries of the world, 59 varieties were collected. These were raised in plots by the transplantion method. The name of each variety and the country in which it was bred are listed in Table 5.1-1.

Table 5.1-1 Varieties Tested in Varieties Test

	Variety	Country Bred		Variety	Country Bred
1.	Kuang Chu 15 (C-15)	China	31.	IR-2153	The Philippines
2.	C-6	"	32.	Ishin	Korea
3.	Chen Chu Ai 11 (C-11)	"	33.	Toitsu	"
4.	HINO	"	34.	Mitsuyo	"
5.	Waikyakunantoku	"	35.	Taichung Ikukyu	Taiwan
6.	BG-90-2	Sri Lanka	36.	Takao-21	"
7.	BG-34-8	"	37.	Hesinchu 56	"
8.	BG-11-11	"	38.	Taichung 65	"
9.	BG-34-11	"	39.	Taichung Native 1	"
10.	BG-33-2	"	40.	Dawn	U.S.A.
11.	BG-34-12	"	41.	Blue Bonnet	"
12.	BG-34-6	"	42.	Cawad Mali	"
13.	IR-2053	The Philippines	43.	Basmati 370	"
14.	TOS-103	"	44.	BR-4	Bangladesh
15.	BG-90-2	"	45.	BR-5	"
16.	IR-24	"	46.	SML-18	Surinam
17.	IR-5	"	47.	Asominori	Japan
18.	IR-298-12-1-1-1	"	48.	Koganenishiki	"
19.	IR-8	"	49.	Reimei	"
20.	IR-28	"	50.	Toyonishiki	"
21.	IR-30	"	51.	Norin-17	"
22.	IR-20	"	52.	Fujiminori	"
23.	IR-22	"	53.	Dewachikara	"
24.	IR-29	"	54.	Mutsunishiki	"
25.	IR-36	"	55.	Sasanishiki	"
26.	IR-38	"	56.	Matsumai	"
27.	IR-40	"	57.	Chuemon	"
28.	IR-1514	"	58.	Kiyonishiki	"
29.	IR-1561	"	59.	Oryza glaberrima S.	Nigeria
30.	IR-127	"			

Variety tests were carried out three times in the off-season*1 (dry season) and twice in the main-season*2 (wet season).

Standard methods applied to each test are listed in Table 5.1-2, below.

Table 5.1-2 Standard Methods Applied in Variety Testing

	Test Number				
	1	2	3	4	5
1. Number of Varieties Tested	26	31	20	15	40
2. Sowing Time	June, July, 1977	Nov. 3 to 6, 1977	Feb. 13 to 15, 1978	Jul. 18 to 30, 1978	Feb. 1, 1979
3. Transplant-ing Time	June to August	Nov. 29 to Dec. 8	Mar. 16 to 18	Aug. 7 to 22	Mar. 12
4. Planting Density	22.2 hills/m^2	26.7	do	do	do
5. Nitrogen Applied (Basal)	23 kg N/ha	do	do	80	do
6. Phosphate Applied	40 kg P_2O_5/ha	do	80	75	100
7. 1st Top-dressing					
Time	14th day after trans-planting	do	do	-	14th day after trans-planting
Amount	23 kg N/ha	do	do	-	45
8. 2nd Top-dressing					
Time	Just before reduction division stage	do	do	do	do
Amount	23 kgN/ha	30	do	40	45
9. 3rd Top-dressing					
Time	Full heading stage	do	do	do	do
Amount	23 kg N/ha	30	40	30	45

Note: *1 The off-season is defined as the cropping season whose sowing is carried out from Jan. to May and from Sep. to Dec.

*2 The main-season is defined as the cropping season whose sowing is carried out from June to August.

Investigation items for each variety were Sowing date, Heading date (5%, 50%, and 95%), Maturity date, Culm length, Panicle length, No. of panicles per hill, No. of panicles per m^2, No. of grains per panicle, No. of grains per m^2, Percentage of ripened grains, Percentage of non-fertilized grains, Weight of 1,000 grains, and Grain yield.

Among the items mentioned above, (1) the percentage of ripened grains and (2) the percentage of non-fertilized grains are difficult to measure. The methods for measuring them are given below.
For further information, refer to Matsushima (1966, 1980).

(1) Grains with a specific gravity greater than 1.06 are taken as ripened, and the number of ripened grains thus obtained is divided by the total number of grains. This value, as a percentage, is taken as the percentage of ripened grains (Matsushima 1966).*

(2) Non-fertilized grains can clearly be identified by iodine reaction (Matsushima and Tanaka 1960, Matsushima 1966). In the experiment, however, to save time and labor, empty grains were identified with the finger tips, and these were taken as non-fertilized grains, the percentage of which was taken as the percentage of non-fertilized grains. A comparison of the two methods shows that the iodine reaction method gives a percentage of non-fertilized grains higher by 4 - 12% than the finger tip method in most cases.

References are listed in section 7.

Results

Overall results of variety testing are given in ANNEX 2.

The results of variety testing during the rainy season of 1978 are summarized in Table 5.1-3, below:

Table 5.1-3 Summary of Results of Variety Testing in the Main-season in 1978

	Yield (Unhulled rice : ton/ha)			
	Block I	Block II	Block III	Average
C-15	8.9	10.1	9.6	9.5
C-6	8.5	10.2	-	9.3
BG-90-2	9.7	9.1	7.4	8.7
IR-2053	7.5	7.9	8.7	8.0
TOS-103	6.9	8.4	7.6	7.6
BG-34-8	7.6	8.3	6.6	7.5
IR-24	7.5	8.0	6.6	7.4
IR-5	7.2	6.9	7.7	7.3
IR-298-12-1-1-1	5.7	8.1	7.0	6.9
Ishin	6.9	7.2	6.2	6.8
Taichung 65	7.5	6.1	-	6.8
IR-8	5.9	7.1	6.9	6.6
Taichung Native 1	5.5	7.0	6.5	6.3
C-11	6.1	7.2	5.2	6.2
IR-28	5.6	6.7	5.6	6.0
IR-30	5.9	6.3	5.9	6.0
IR-20	3.7	5.5	6.7	5.3

The table below gives the result of variance analysis of the yield.

Source of variance	Degrees of freedom	Sums of squares	Mean of squares	F
Total	48	90.09	-	-
Variety	16	66.19	4.14	6.9^{**}
Block	2	5.95	2.98	-
Error	30	17.95	0.60	-

As shown by the above table, there is a significant difference in average yield with 99% probability. This difference was analyzed by Tukey's (1949) method, and the following groups were obtained.

i) C-15, C-6, BG-90-2

ii) IR-2053, TOS-103, GB-34-8, IR-24, IR-5, IR-298-12-1-1-1, Ishin, Taichung 65, IR-8, Taichung Native 1, C-11, IR-28, IR-30

iii) IR-20

Considering the results of variety testing from a statistical viewpoint, it can be said that the yield of variety IR-20 is significantly low in comparison with other varieties, while the yields of C-15, C-6 and BG-90-2 varieties are significantly high.
There is no significant difference between the varieties in each group.

A summary of the results of variety testing in the off-season of 1978/79 is given in Table 5.1-4.

Table 5.1-4 Summary of Results of Variety Testing in the 1978/79 Off-season

Variety	Block I	Block II	Block III	Average
IR-22	5.7	9.5	9.7	8.3
C-6	5.9	6.4	8.0	6.8
IR-1561	6.1	7.9	6.0	6.7
C-15	7.0	5.2	7.7	6.6
C-11	5.8	5.6	7.3	6.6
BG-90-2	5.9	7.7	5.6	6.4
Dawn	7.0	7.6	4.2	6.3
TR-24	4.6	8.2	5.8	6.2
IR-2153	5.7	6.7	6.0	6.1
Ishin	4.8	7.9	5.6	6.1
IR-2053	5.1	6.2	6.8	6.0
BG-34-8	5.7	6.0	5.9	5.9
IR-298-12-1-1-1	5.8	5.8	-	5.8
IR-1514	4.5	6.3	6.4	5.7
IR-29	4.9	7.1	5.1	5.7
Takao-21	5.1	6.4	5.3	5.6
Taichung-Ikukyu	4.7	5.9	5.9	5.5
TOS-103	4.8	5.8	5.8	5.5
IR-38	4.4	6.2	5.5	5.4
IR-40	4.5	4.9	6.6	5.3
IR-8	5.3	6.9	3.4	5.2
IR-30	3.7	6.2	5.6	5.2
Toitsu	3.9	6.1	5.4	5.1
IR-28	3.9	5.9	5.4	5.1
IR-5	4.3	4.5	5.7	4.8

Physiological trouble, presumably caused by hot dry wind, was observed in April or May. This caused heavy damage to leaves and to grains, increasing the percentage of sterile grains and imperfectly ripened grains. Varietal differences in susceptibility to the hot dry wind were observed. Table 5.15 lists varietal differences in the percentage of ripened grains and in the percentage of non-fertilized grains, when varieties headed at high air-temperatures of 40.0 to 42.1°C. According to the table, there are big differences between varieties in the degree of ripening, but these differences may be due to not only high temperature but also dry wind. The table indicates that IR-298, IR-1561 and IR-28 seem to be resistant to high temperature, while HINO, SML-18, IR-127 and IR-5 seem to be susceptible. The varietal differences given in the table, however, must be confirmed by further studies.

Osada el al. (1972) observed high percentages of empty (sterile) grains in the dry season in Thailand, and found conspicuous varietal difference in the occurrence of empty grains, attributing the occurrence to high temperature. Satake and Yoshida (1978) also recognized varietal difference in ripening under high temperatures, pointing out more than 20% of sterile grains occurring at 36.5°C at flowering time for a resistant variety and at 32°C for a susceptible variety. Enomoto et al. (1956) reported that the critical high temperature for pollen germination ranges from 41 to 45°C, and varies with varieties. Chao (1959) and Ito (1963) also recognized that the sterility percentage is markedly increased, greatly varies with varieties under the extremely dry and hot conditions in Iraq.

Thus, the importance of studies on variatal differences in tolerance to high temperature cannot be over-emphasized. (See also 5.7, Seasonal Planting Tests, in this chapter.)

Calculating the mean values of yields for three off-seasons and two main-seasons for each variety, and choosing the maximum values of them; varieties were classified by mean yields and maximum yields, as shown in Tables 5.1-6, 7, 8 and 9. With reference to these tables, the following points can be noted.

Varieties those attained more than 8.0 ton/ha mean yield in the main season were:

BR-4, C-15, C-6, BG-33-2, BG-90-2, IR-36, BG-34-12, TOS-103, IR-29, BG-34-6

The maximum yield in the main-season test was 10.2 ton/ha. This was attained by C-6 (cf. the maximum yield among plots was 11.4 ton/ha which was obtained by TOS-103 in the cultivation method test). Varieties these attained more than 9.0 ton/ha as the maximum yield in the main-season were:

C-15, C-6, BG-90-2, TOS-103, BR-5, BG-33-2

While, those that attained more than 6.0 ton/ha in the off-season were:

BG-90-2, IR-8, Taichung Native 1, IR-1561, Heshinchu-65, C-15, IR-2053, IR-24, IR-22, IR-2153, Dawn

The maximum yield in the off-season was 9.7 ton/ha. This was attained by IR-22. Varieties those attained more than 8.0 ton/ha as the maximum yield in the off-season were.

IR-22, BG-90-2, IR-8, C-6, IR-24

Variety	Block I	Block II	Block III	Average
IR-20	3.7	5.2	5.6	4.8
IR-36	3.2	5.4	3.7	4.1
BG-11-11	2.9	3.5	5.6	4.0
Heshichu	2.8	5.3	3.8	4.0
Taichung 65	2.5	3.2	5.3	3.7
IR-127	3.0	3.3	4.6	3.6
Toyonishiki	1.6	4.7	3.1	3.1
Asominori	2.7	3.6	2.7	3.0
Reimei	1.9	3.3	2.0	2.4
SML-18	3.4	2.7	0.9	2.3
Koganenishiki	1.8	2.3	1.6	1.9
Blue Bonnet	1.5	1.3	1.3	1.4
Norin-17	1.0	1.1	0.6	0.9
HINO	0.3	0.3	0.3	0.3

Based on analysis by Tukey's method, the varieties were grouped as follows:

i) IR-22

ii) C-6, IR-1561, C-15, C-11, GB-90-2, Dawn, IR-24, IR-2153, Ishin, IR-2053, BG-34-8, IR-298-12-1-1-1, IR-1514, IR-29, Takao-21, Taichung-ikukyu, TOS-103, IR-38, IR-40, IR-8, IR-30, Toitsu, IR-28, IR-5, IR-20, IR-36, BG-11-11, Heshinchu, Taichung 65, IR-127

iii) Toyonishiki, Asominori, Reimei, SML-18, Koganenishiki, Blue Bonnet, Norin-17, HINO

It can be said that the yields of IR-22 were significantly higher than those of other varieties.

Table 5.1-5 Varietal Differences in Susceptibility to High Temperature[1] (40.0 - 42.1°C) at the Heading Stage

Variety	Percentage of Ripened Grains						Average
IR-298	87.9						87.9 (76)
IR-1561	84.0	89.5	79.5				84.3 (11.8)
IR-28	76.3	83.6	86.0				81.8 (18.1)
IR-22	78.8	80.5	74.7	67.8			75.5 (19.7)
Dawn	60.9	78.3	86.2				75.1 (16.3)
BG-90-2	78.2	76.8	67.9				74.3 (20.7)
Takao	66.8	75.4	80.3				74.2 (11.0)
TOS-103	83.2	67.1	69.1	71.7			72.8 (21.1)
IR-20	72.4	76.6	74.9	51.4	68.5		70.7 (11.9)
C-11	42.2	89.3	74.6	76.8			70.7 (20.5)
IR-24	70.0						70.0 (23.7)
IR-38	69.9						69.9 (17.1)
IR-30	69.6	77.9	71.7	63.9			69.6 (25.1)
IR-36	81.1	65.2	59.9	54.1			65.1 (25.9)
Ishin	61.1	59.0	68.4	61.0			62.4 (27.5)
IR-8	62.1	51.8	41.0	65.7	68.2	88.7	62.1 (18.0)
Taichung-Ikukyu	59.5	62.5	63.9				62.0 (22.0)
IR-40	66.7	57.0					61.9 (25.4)
BG-34-8	61.4						61.4 (28.8)
Toitsu	59.5	60.8	58.2	55.7			58.6 (27.4)
C-6	65.3	58.5	47.3	49.3	61.0	66.4	58.0 (18.2)
Reimei	65.5	51.5	55.0	55.8			57.7 (34.7)
IR-29	13.9	69.9	76.8	68.3			57.2 (34.0)
Taichung 65	26.0	71.0	65.2	61.0			55.8 (27.4)
Blue Bonnet	50.6	60.1	56.4				55.7 (36.1)
Heshinshu	55.0	55.1	53.8				54.6 (22.5)
Toyonishiki	56.5	59.1	33.1				49.6 (42.1)
IR-5	50.0	38.9	57.7				48.9 (42.7)
IR-127	52.4	45.2	42.1				46.6 (43.4)
SML-18	15.9	65.3	54.3	21.8			39.3 (46.5)
HINO	65.1	12.7	25.4	16.3			29.9 (65.7)

Note 1: Average daily maximum air temperature for 10 days centered on the heading date.

Note 2: Figures in parentheses give the percentages of non-fertilized (empty) grains (identified by using the fingers).

The quality of the major varieties of rice grown in the main and off-seasons was checked in the form of polished rice, and a classification was made which is given in Table 5.1-7.

Based on the yield ability, quality and disease resistance, the following varieties may be recommended.

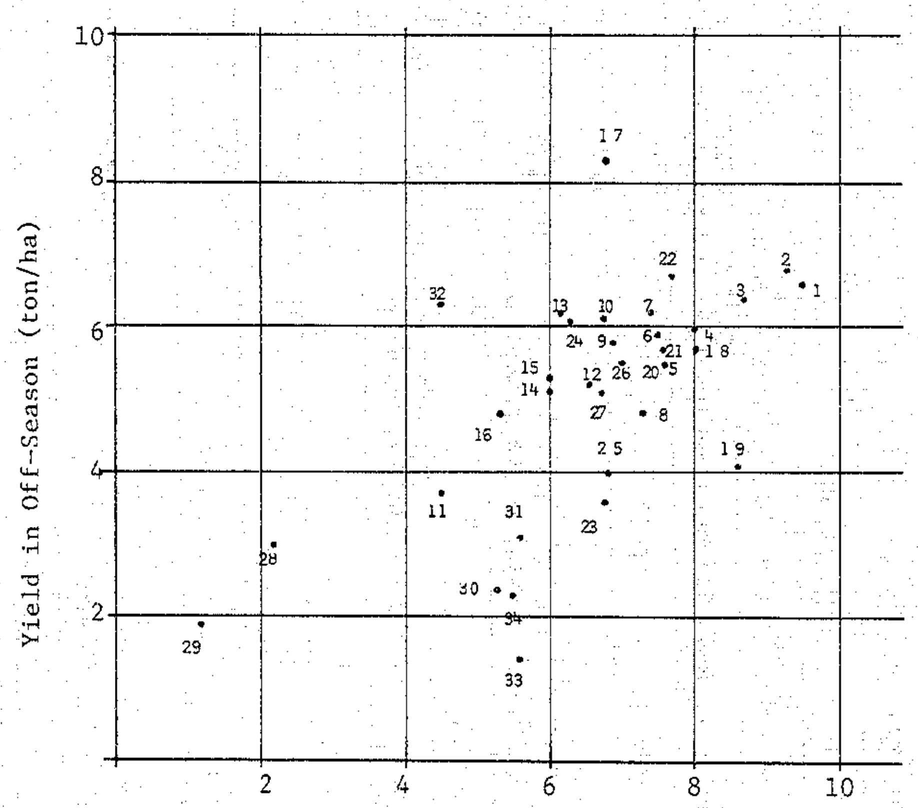
Main-season: BR-4, BG-33-2, IR-36, BG-34-12, TOS-103, BG-90-2, IR-29, BG-34-6, IR-2053, IR-298-12-1-1-1

Off-season : BG-90-2, IR-24, IR-22, IR-2052, IR-2153, IR-1561, Dawn

Besides the selection of recommendable varieties, the relation between yields in the main-season and those in the off-season was studied. The results are shown in Fig. 5.1-1.

Roughly speaking, the figure shows a clear positive correlation between the yields in the two seasons, and no variety was found to be especially well adapted to the main-season or the off-season, though some varieties appear to show slightly better adaptability to one or the other.

Fig. 5.1-1 Relation between Yields in Main-Season and Off-Season



Note: The numbers in the figure indicate the following varieties. The two lines in the figure indicate the target yields in the main-season and the off-season.

1.	C-15	8.	IR-5	15.	IR-30	22.	IR-1561	28.	Asominori
2.	C-6	9.	IR-298	16.	IR-20	23.	IR-127	29.	Koganenishiki
3.	BG-90-2	10.	Ishin	17.	IR-22	24.	IR-2153	30.	Reimei
4.	IR-2053	11.	Taichung 65	18.	IR-29	25.	BG-11-11	31.	Toyonishiki
5.	TOS-103	12.	IR-8	19.	IT-36	26.	Taichung Ikukyu	32.	Dawn
6.	BG-34-8	13.	C-11	20.	IT-38			33.	Blue Bonnet
7.	IR-24	14.	IR-28	21.	IR-1514	27.	Toitsu	34.	SML-18

Table 5.1-6 Mean Yields of Rice Varieties in Main-seasons

Yield (ton/ha)	Variety
10.0	
	BR-4,
9.5	
	C-15, C-6, BG-33-2,
9.0	
	BG-90-2, IR-36, BG-34-12,
8.5	
	TOS-103, IR-29, BG-34-6,
8.0	
	IR-2053, IR-1514, IR-1561, BG-34-11,
7.5	
	BG-34-8, IR-24, IR-5, IR-38, Taichung Ikukyu, Toitsu,
7.0	
	IR-298-12-1-1-1, Ishin, IR-22, IR-127, BG-11-11, BR-5,
6.5	
	Taichung 65, IR-8, Taichung Native 1, C-11, IR-28, IR-30, IR-2153
6.0	
	IR-20, Toyonishiki, SML-18
5.5	
	Reimei,
5.0	
	Dawn, Fujiminori, Native Oryza glaberrima
4.5	
	Basmati-370,
4.0	
	Blue Bonnet, Cawad Mali, Waikyakunantoku,
3.5	
3.0	
2.5	
	Asominori,
2.0	
1.5	
	Koganenishiki, Matsumai,
1.0	
0.5	
	Norin-17, Dewachikara, Mutsunishiki, Sasanishiki, Chuemon, Kiyonishiki,
0	

Table 5.1-7 Maximum Yields of Rice Varieties in Main-seasons

Yield (ton/ha)	Variety
10.0	C-15, C-6,
9.5	BG-90-2, TOS-103, BR-5,
9.0	BG-33-2,
8.5	IR-2053, IR-36, BG-34-12,
8.0	BG-34-8, IR-24, IR-298-12-1-1-1, IR-20, IR-29, BG-34-6,
7.5	IR-5, Taichung 65, IR-1514, IR-1561, Toitsu, BG-34-11,
7.0	Ishin, IR-8, Taichung Native 1, C-11, IR-28, Taichung Ikukyu,
6.5	IR-28, IR-22, IR-127, BG-11-11, BR-4,
6.0	IR-30, IR-2153,
5.5	Toyonishiki, SML-18
5.0	Reimei,
4.5	Dawn, Cawad Mali, Fujiminori, Native Oryza glaberrima
4.0	Basmati-370,
3.5	Blue Bonnet,
3.0	
2.5	
2.0	Asominori,
1.5	
1.0	Koganenishiki,
0.5	
0	Norin-17,

Table 5.1-8 Mean Yields of Rice Varieties in Off-season

Yield (ton/ha)	Variety
7.0	BG-90-2,
6.5	IR-8, Taichung Native 1, IR-1561, Heshinchu-56,
6.0	C-15, IR-2053, IR-24, IR-22, IR-2153, Dawn,
5.5	C-6, TOS-103, Ishin, IR-30, IR-1514, Takao-21,
5.0	BG-34-8, IR-5, IR-298-12-1-1-1, C-11, IR-20,
4.5	IR-29, IR-38, IR-40, Toitsu,
4.0	IR-36, BG-11-11, Taichung Ikukyu,
3.5	IR-28, IR-127, Waikyakunantoku,
3.0	Asominori,
2.5	Taichung 65, Toyonishiki,
2.0	Reimei,
1.5	HINO, Koganenishiki, SML-18,
1.0	Blue Bonnet, Matsumai,
0.5	Norin-17,
0	Fujiminori, Dewachikara, Mutsunishiki, Sasanishiki, Chuemon, Kiyonishiki,

Table 5.1-9 Maximum Yields of Rice Varieties in Off-season

Yield (ton/ha)	Variety
10.0	
	IR-22,
9.5	
	BG-90-2,
9.0	
	IR-8,
8.5	
	C-6, IR-24,
8.0	
	C-15, Ishin, IR-1561, Heshinchu-56, Dawn,
7.5	
	C-11, IR-29, IR-36,
7.0	
	IR-2053, TOS-103, Taichung Native 1, IR-40, IR-2153,
6.5	
	BG-34-8, IR-30, IR-38, IR-1514, Takao-21, Toitsu,
6.0	
	IR-5, IR-298-12-1-1-1, IR-28, IR-20, BG-11-11, Taichung Ikukyu,
5.5	
	Taichung 65,
5.0	
	IR-127, HINO, Toyonishiki,
4.5	
4.0	
	Asominori, Waikyakunantoku,
3.5	
	Reimei, SML-18,
3.0	
2.5	
	Koganenishiki,
2.0	
	Blue Bonnet,
1.5	
	Norin-17, Matsumai,
1.0	
0.5	
	Fujiminori, Dewachikara, Mutsunishiki, Sasanishiki, Chuemon, Kiyonishiki,
0	

Table 5.1-10 Results of Quality Tests on Rice Kernels

Grade		Main-season	Off-season
High	I	IR-36, IR-24	IR-24, IR-298-12-1-1-1,
	II	IR-298-12-1-1-1, BR-5	IR-22, IR-28, IR-29, IR-36, IR-40, IR-1514, IR-1561, IR-127, IR-2153, Asominori, Dawn, SML-18,
	III	BR-4, IR-29, TOS-103,	TOS-103, BG-90-2, Taichung Ikukyu, Takao-21, Heshichu-56, Toyonishiki, Blue Bonnet,
Medium	I	Ishin, IR-38, IR-20, IR-2053, BG-90-2	IR-8, IR-30, BG-11-11, Ishin, Koganenishiki, Norin-17,
	II	BG-34-8, C-11, C-6,	IR-5, IR-20, IR-38, HINO, Reimei,
	III	IR-8,	Taichung 65, Toitsu,
Low	I	C-15,	C-6, BG-34-8,
	II		C-11, C-15,
	III		

5.2 Fertilizer Element Tests

Purpose

This test was performed to clarify the effect of N, P, K and S on the yield of rice. In the experiment, sulphur in particular was tested, because the high value of pH (8.0) of the soil and water in the project area may be decreased by the application of sulphur.

Method

The following 4 tests with different treatments were carried out according to the randomized block method with three replications.

Table 5.2-1 Fertilizer Element Test Treatments

Test I	Test II	Test III	Test IV
Non-N	Non-N	0kg K_2O/ha	0kg S/ha
Non-P	Non-P	50kg K_2O/ha	50kg S/ha
Non-K	Non-K	100kg K_2O/ha	100kg S/ha
Non-N.P.K	Non-S	200kg K_2O/ha	150kg S/ha
Standard	Non-N.P.K.S		
	Standard		

The main points of each test are listed in Table 5.2-2, below:

Table 5.2-2 Main Points of Fertilizer Element Test

	Test I	Test II	Test III	Test IV
Variety	C-15	TOS-103	BG-34-8	IR-8
Sowing date	June 8, 1978	Feb. 1, 1979	Oct. 21, 1978	Oct. 21, 1978
Transplanting date	June 25	Mar. 8	Dec. 5	Dec. 4
Planting density	15 x 25 cm (26.7hills/m^2)	15 x 25 cm	30 x 15 cm (22.2hills/m^2)	30 x 15 cm
Standard fertilization				
N	150 kg/ha	180 kg/ha	170 kg/ha	170 kg/ha
P_2O_5	100 kg/ha	200 kg/ha	-	-
K_2O	100 kg/ha	150 kg/ha		-
S	-	200 kg/ha	-	

Results

Overall results of the tests are presented in ANNEX 3. The Table 5.2-3, below, shows the yield responses of rice plants to each treatment.

Table 5.2-3 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)	Standa (ton/h
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)	Standa (ton/h
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	50kg K_2O/ha	100kg K_2O/ha	200kg K_2O/ha
I	2.7 ton/ha	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	50kg S/ha	100kg S/ha	150kg S/ha
I	3.8 ton/ha	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 investigated for Tests I and II. The results revealed that the standard treatment showed a significant difference with 95% probability from the treatment with Non-N, Non-N.P.K or Non-N.P.K.S, while the treatment with non-N.P.K or Non-N.P.K.S had a significant difference from Non-P, Non-K or Non-S.

The results of variance analysis of the mean yields showed no difference between the treatments in which different amounts of potash or sulphur were applied.

The above-mentioned results clearly prove that nitrogen is indispensable and the most efficient element for increasing the rice yield. The effects of the application of phosphate, potash and sulphur fertilizers were hardly observable in the present experiment. These results indicate, therefore, that rice cultivation in the project area could be conducted using only nitrogen fertilizers. In actual practice, however, the application of phosphate with a half amount of nitrogen would be advantageous, because Non-P treatment gave lower yield than the standard treatment, and the content of phosphate in the soil would decrease year by year if only a nitrogen fertilizer were applied.

5.3 Nitrogen Amount and Application Time Tests

Purpose and Method

The objective of this test is to determine the most effective timing and the optimum quantity of nitrogen to be applied, under the climate and soil conditions of the project area. For this, tests were carried out in the main-season and the off-season by the randomized block method with 3 replications.
Application times were chosen with referrence to Matsushima's results (1964, 1966, 1976).

The treatments set up for this test are shown in Table 5.3-1. In the main-season, the application levels of nitrogen were mainly investigated; while in the off-season, the levels of nitrogen as well as application times were investigated, as shown in Table 5.3-1.

Table 5.3-1 Treatments for Nitrogen Amount and Application Time Test

(A) Main-season Test (1978)

Treatment	Total amount of nitrogen (kg N/ha)	Application time and amount		
		Basal dressing (kg N/ha)	Spikelet differentiation (kg N/ha)	Full heading (kg N/ha)
I	50	30	10	10
II	100	60	20	20
III	150	80	40	30
IV	200	110	50	40
V	250	140	60	50

(B) Off-season Test (1979)

Treatment	Total amount of nitrogen (kg N/ha)	Application time and amount: Basal dressing (kg N/ha)	20th day after trans-planting (kg N/ha)	Spikelet differentia-tion stage (kg N/ha)	Full heading stage (kg N/ha)
I	0	0	0	0	0
II	50	50	0	0	0
III	"	20	10	10	10
IV	"	30	0	20	0
V	"	20	0	20	10
VI	100	100	0	0	0
VII	"	30	30	20	20
VIII	"	60	0	40	0
IX	"	40	0	40	20
X	150	150	0	0	0
XI	"	50	30	40	30
XII	"	80	0	70	0
XIII	"	70	0	60	20
XIV	200	200	0	0	0
XV	"	120	0	80	0
XVI	250	80	60	60	50

The main points in each test are shown in Table 5.3-2.

Table 5.3-2 Main Points in Nitrogen Amount and Application Time Test

	Main-season test	Off-season Test
Variety	C-15 (Kuang Chu-15)	TOS-103
Sowing date	June 17, 1978	Feb. 2, 1979
Transplanting date	July 5	Mar. 12
Planting density	25 x 15 cm (26.7 hills/m^2)	25 x 15 cm
Fertilization		
P_2O_5	Half of the total amount of nitrogen was applied in each treatment	100 kg P_2O_5/ha

Results

The overall results of the tests are presented in ANNEX 4.

The test yields are summarized in Table 5.3-3.

Table 5.3-3 Response of Rice Yield 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)	200 kg 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

Block Number	Treatment and yield					Average yield
	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	
	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	

Block Number		Treatment and yield				Average yield
	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				

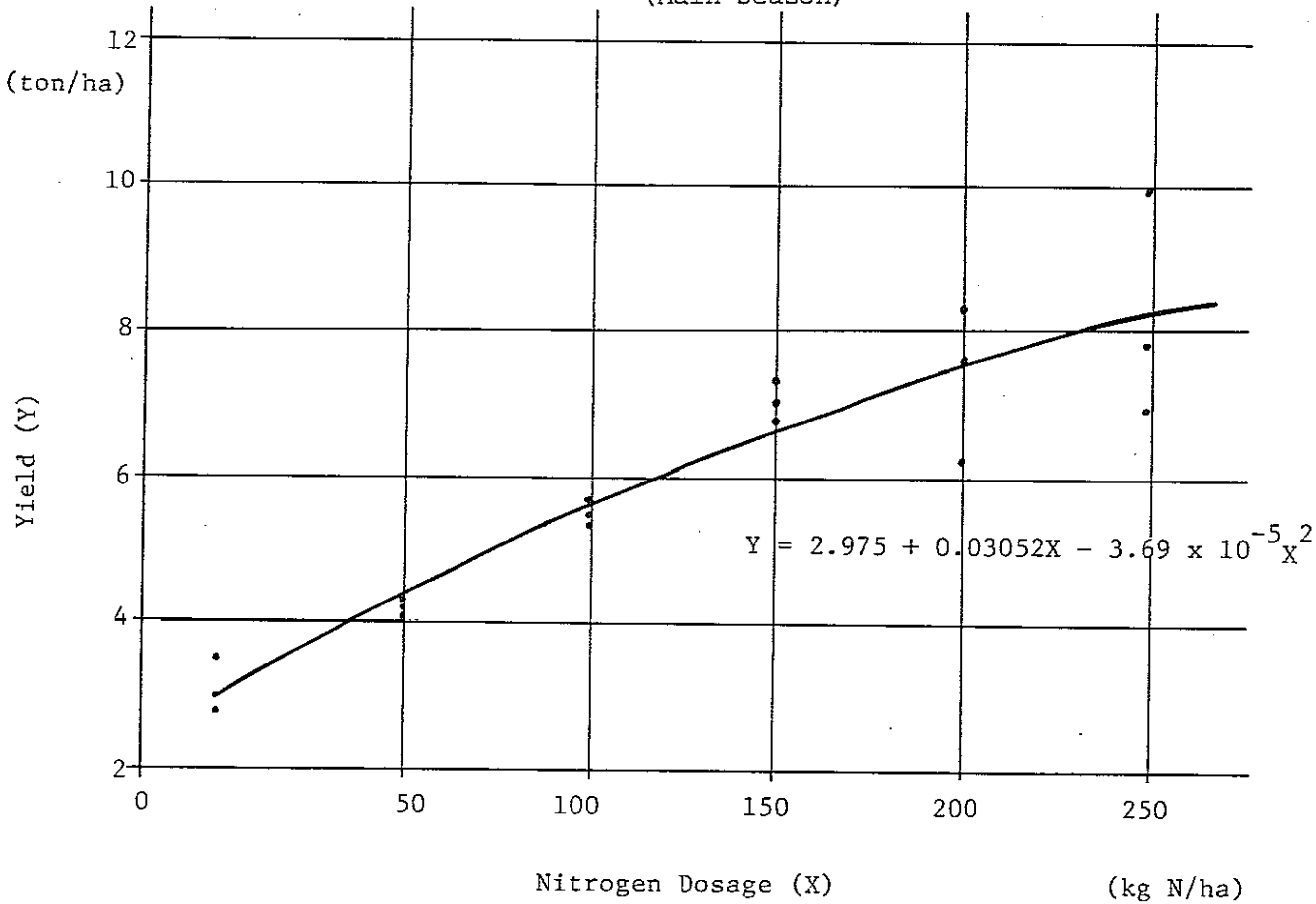
Note: Treatment (30-30-2020) means that the total amount of nitrogen was split-applied as follows; 30 kg at basal dressing, 30 kg on 20th day after transplanting, 20 kg at the spikelet differentiation stage, and 20 kg at the full heading stage.
The average yield in the right-hand column above shows the average of yields of all plots in each test.

(1) Main-season test

The yields in the main-season test are given in Fig. 5.3-1. As shown in the Figure, the yield increased in proportion to the amount of nitrogen applied within the range of nitrogen application between 50 kg N/ha and 150 kg N/ha. The yield increase, however, tailed off for treatments of 150 kg, 200 kg and 250 kg N/ha. According to the results of significant difference analysis, which are given in Table 5.3-4, the treatments of 50 kg and 100 kg/ha showed significant differences from other treatments, while no significant difference was observed between treatments of 150 kg, 200 kg and 250 kg N/ha.

Fig. 5.3-1 Relation between Nitrogen Dosage and Yield

(Main-Season)



° Yields for Non-application of nitrogen are obtained from the fertilizer element test performed in the 1978 main-season.

Table 5.3-4 Significant Difference Analysis of Nitrogen Amount Test Results (Main-season)

Comparison		"t" value*[+]	Degrees of Freedom
50 kg N/ha	vs. 100 kg N/ha	12.3**	4
50	vs. 150	15.9**	4
50	vs. 200	5.2**	4
50	vs. 250	4.6**	4
100	vs. 150	8.2**	4
100	vs. 200	3.1*	4
100	vs. 250	3.1*	4
150	vs. 200	0.47	4
150	vs. 250	1.33	4
200	vs. 250	0.83	4

Note: ** Significant with 99% probability
* Significant with 95% probability

The above results demonstrate that the optimum amount of nitrogen to be applied is likely to be 150 kg N/ha as far as the results of this test indicate.

The yield-response curve of Fig. 5.3-1 can be expressed as follows:

$$Y = 2.975 + 0.03052X - 3.69 \times 10^{-5}X^2$$

Where, Y is the yields and X is the amount of nitrogen applied. According to this expression, the rate of increase of yield per unit amount of nitrogen decreases markedly with the increase of the amount of nitrogen to be applied. For reference, therefore, considering only the prices of paddy rice and nitrogen (excluding all other factors) and taking the current market price of the area as Sudanese £8 per 50 kilogram and the paddy rice price as Sudanese £0.45 per kilogram, the following Table 5.3-5 can be produced.

+ Student's "t" value

Table 5.3-5 Economical Analysis of Nitrogen Application in Main-season

Treatment	Yield	Incremental value	Incremental cost	Value-cost ratio
0 kg N/ha	3.0 ton/ha			
50	4.3	Ŧs 586/ha	Ŧs 17/ha	34.4
100	5.6	586	17	34.4
150	6.7	495	17	29.1
200	7.6	405	17	23.8
250	8.3	315	17	18.5

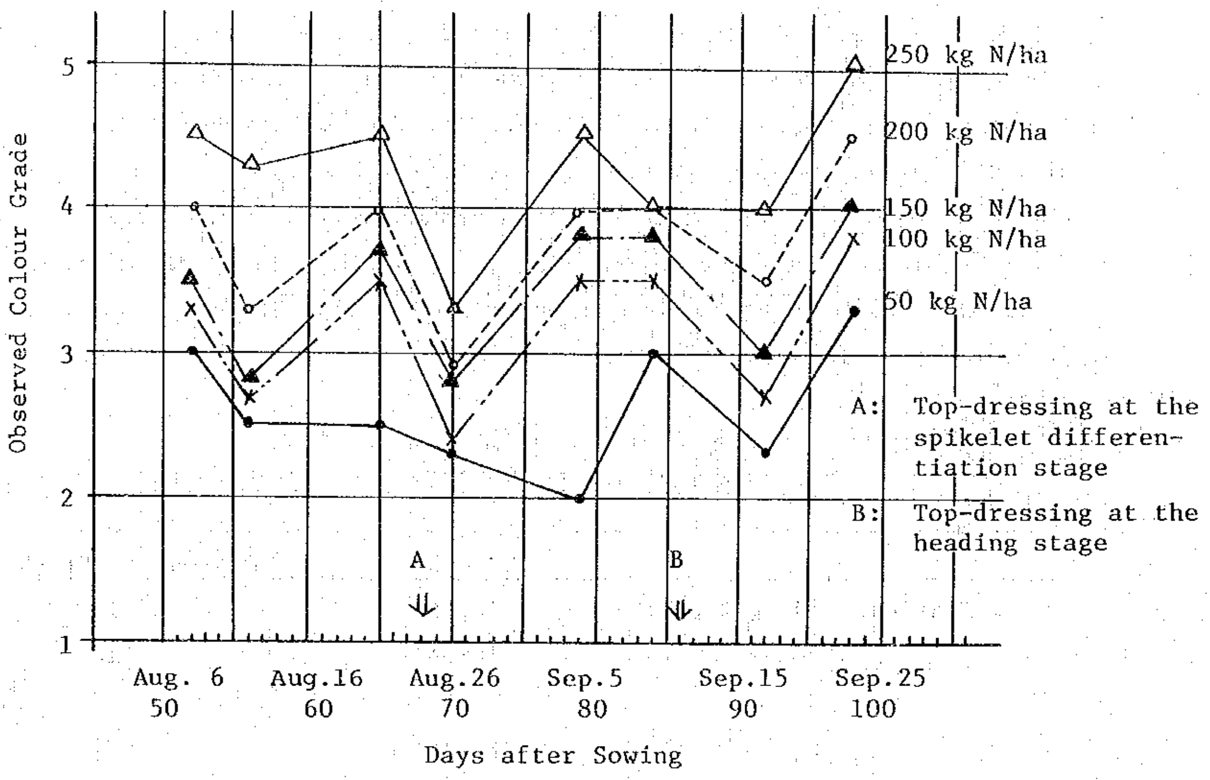
The "value-cost ratio" in the last column in the table expresses the economic efficienty per unit amount of nitrogen. The efficiency decreases with an increase of applied nitrogen, but it is still large enough at 150 kg/ha, showing a near maximum value. Economically the application of nitrogen at 150 kg/ha appears not to be unreasonable.

Further, seasonal changes in leaf-colour with differently fertilized treatments was traced in the 1978 main-season by using a standard colour plate, the value of which closely correlates with nitrogen content in leaves (Matsushima 1976). The results were shown in Fig. 5.3-2. The following points can be noted from the figure.

1) Discolouration of leaves was observed at the spikelet differentiation stage in all the treatments. The leaf colour faded even with a treatment of 250 kg N/ha at the spikelet differentiation stage with as much as 140 kg n/ha applied as a basal dressing.

2) The leaf colour faded at the heading stage in all treatments except for 250 kg N/ha. It started to deepen on the 7th day after application of nitrogen.

Fig. 5.3-2 Changes in Leaf-colour in Different Fertilization Treatments



Note 1: Variety: C-15, sown on June 17, transplanted on July 5 and harvested on October 15

Note 2: Fertilization:

	Date	Total Amount 50kgN/ha,	100	150	200	250
Basal Application	July 8	30kgN/ha	60	80	110	140
1st top-dressing	Aug.24	10	20	40	50	60
2nd top-dressing	Sep.11	10	20	30	40	50

(2) Off-season test

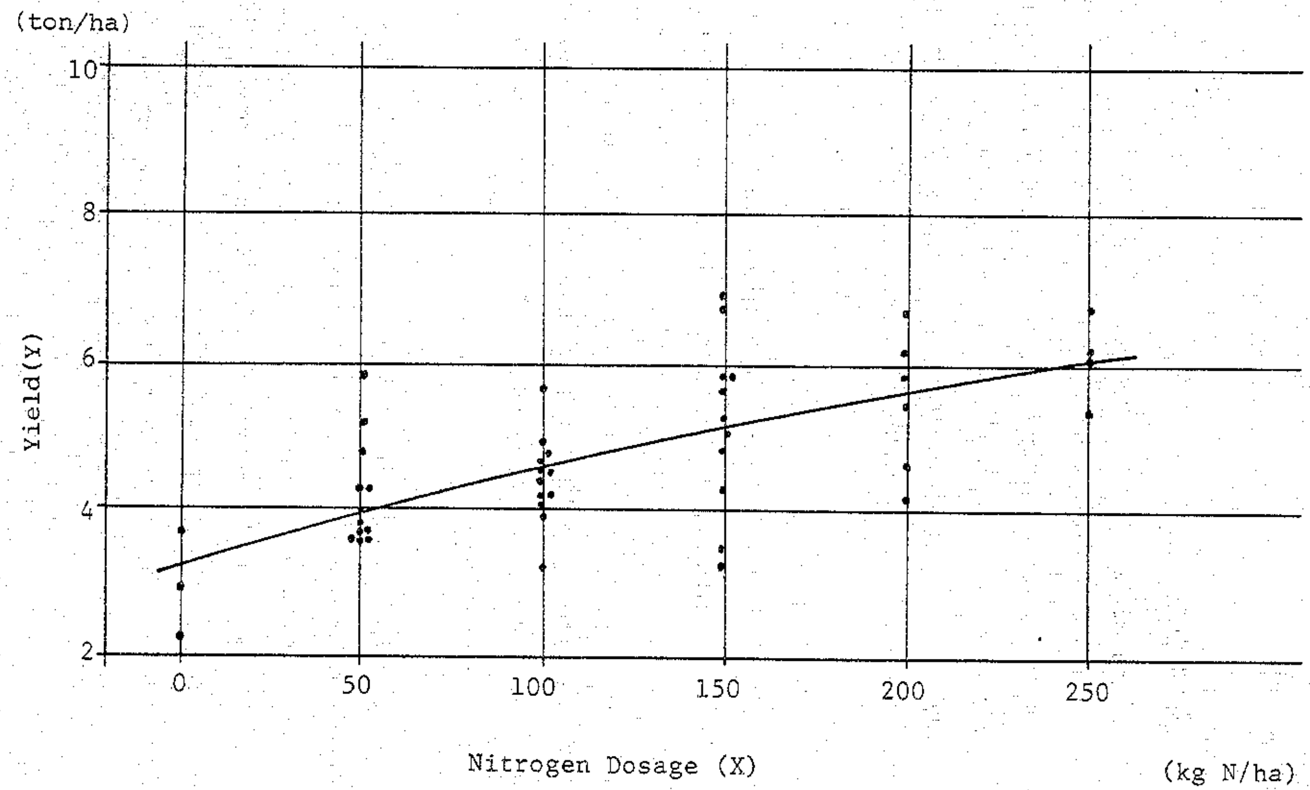
The yields of the tests in the off-season are shown in Fig. 5.3-3. All plots are included irrespective of the application time. The figure indicates that the yield increases with an increase of the amount of nitrogen applied. However, according to the results of significant difference analysis of the yields, given in Table 5.3-6, the treatment of 0 kg, 50 kg and 100 kg/ha show significant differences against all other treatments, except for 50 kg against 100 kg/ha, while the treatment of 150 kg indicates no significant difference against the treatments of 200 kg and 250 kg/ha, and further the treatment of 200 kg shows no difference against 250 kg/ha. This suggests that nitrogen application of more than 150 kg/ha does not increase yield. Thus, it can reasonably be considered that the optimum amount of nitrogen to be applied is 150 kg/ha, as far as indicated by this experiment.

Table 5.3-6 Significant Difference Analysis of Nitrogen Amount Test Results (Off-season)

			"t" value	Degrees of Freedom
0 kg N/ha	vs.	50 kg N/ha	2.53*	13
0	vs.	100	3.47**	13
0	vs.	150	3.15**	12
0	vs.	200	4.19**	7
0	vs.	250	5.41**	4
50	vs.	100	0.72	22
50	vs.	150	2.69*	21
50	vs.	200	3.46**	16
50	vs.	250	4.00**	13
100	vs.	150	2.32*	21
100	vs.	200	3.29**	16
100	vs.	250	4.20**	13
150	vs.	200	0.53	15
150	vs.	250	1.10	12
200	vs.	250	0.81	7

Remark: ** Significant with 99% probability
* Significant with 95% probability
Data of 0 kg N/ha are obtained from the results of the fertilizer element test in the off-season, 1978.

Fig. 5.3-3 Relation between Nitrogen Dosage and Yield
(Off-season)



The yield-response curve in Fig. 5.3-3 can be expressed as follows:

$$Y = 3.314 + 0.01447X - 1.44 \times 10^{-5} X2$$

Where, Y is the yield, and X is the nitrogen dosage. By the same procedure as for the main-season results, the following table can be produced.

Treatment	Yield	Incremental value	Incremental cost	Value-cost ratio
0 kg N/ha	3.3 ton/ha			
50	4.0	Rs 315/ha	Rs 17/ha	18.5
100	4.6	270	17	15.9
150	5.2	270	17	15.9
200	5.6	180	17	10.6
250	6.0	180	17	10.6

The expression shows the same trend as that for the main-season. Using the formula, yields were calculated theoretically, then the incremental value, incremental cost and the value-cost ratio were worked out, as given in the table. The value-cost ratio indicates that judging from the efficienty for the unit amount of nitrogen applied, application of nitrogen at 150 kg/ha would not be unreasonable, as in the main-season.

It is worth noticing that 150 kg of nitrogen per ha can be tentatively considered to be the optimum from the results of experiments in both the main-season and in the off-season, though further studies must be conducted to confirm this conclusion. Given that the amount of nitrogen to obtain 100 kg of brown rice is 2.0 - 2.5 kg in Japan (Matsushima 1966, 1976), a nitrogen level of 150 kg/ha appears to be reasonable to produce the yields of 8 to 7 tons per ha.

In an IRRI nitrogen response experiment (Villega. Feuer 1970), IR-8 showed a maximum yield (9.5 ton/ha) at 120 kg/ha in the dry season, for treatments of 20, 40, 60, 180, 100 and 120 kg/ha. This also indicates that the results obtained in the present experiments are not unreasonable.

As to the effects of the time of application on yields, from the results of the significant difference analysis, no significant difference was found between the treatments in which identical amounts of nitrogen were applied, i.e. 50 kg/ha, 100 kg/ha, 150 kg/ha and 200 kg/ha. Only little or no difference was found between treatments in which relatively small identical amounts of nitrogen were applied i.e. 50 kg and 100 kg/ha. While some differences could be observed between treatments in which relatively large identical amounts of nitrogen were applied, i.e. 150 kg and 200 kg/ha, showing that split application is better than single application.

5.4 Spacing and Seeding Density Test

Purpose

The objective of this test was to find the most suitable spacing for transplanted or directly sown rice plants, and the seeding density for directly sown rice plants. In this test, three different methods, i.e. the ordinary transplantation method, the direct sowing method and the transplantation method using broadcastable seedlings were also compared to select the cultivation method suitable for the climatic and soil conditions of the project area.

Method

Testing was carried out four times under the randomized block method with three replications. Treatments for each test are listed in Table 5.4-1.

Table 5.4-1 Spacing and Seeding Density Test Treatments

(Test I)

Method	No.	Spacing
Transplantation	1	25 x 15 cm (26.7 hills/m^2)
	2	30 x 30 cm (11.1 hills/m^2)
	3	30 x 20 cm (16.7 hills/m^2)
	4	30 x 15 cm (22.2 hills/m^2)
	5	30 x 10 cm (33.3 hills/m^2)

(Test II)

Method	No.	Row spacing and Seeding Density
Direct Sowing with Puddling	1	20 cm, 80 kg seed/ha
	2	30 cm, 80 kg seed/ha
	3	40 cm, 80 kg seed/ha
	4	30 cm, 50 kg seed/ha
	5	30 cm, 100 kg seed/ha
	6	15 cm, 80 kg seed/ha
	7	Broadcast 80 kg seed/ha
	8	Broadcast 50 kg seed/ha

(Test III)

Method	No.	Spacing or Seeding Density
Transplantation	1	30 x 20 cm (16.7 hills/m^2)
	2	30 x 15 (22.2 hills/m^2)
Broadcast-transplantation	3	16.7 hills/m^2
	4	22.2 hills/m^2
Hand transplantation with broadcastable seedlings	5	22.2 hills/m^2
Direct sowing in strips	6	30 cm, 80 kg seed/ha
Direct sowing (Drilling)	7	12 cm, 80 kg seed/ha
Direct sowing (Broadcast)	8	80 kg seed/ha

(Test IV)

Method	No.	Spacing or Seeding Density	
Transplantation	1	15 cm x 15 cm	44 hills/m^2
	2	25 cm x 10 cm	40 hills/m^2
	3	25 cm x 15 cm	27 hills/m^2
	4	25 cm x 25 cm	16 hills/m^2
	5	30 cm x 10 cm	33 hills/m^2
	6	30 cm x 15 cm	22 hills/m^2
	7	30 cm x 20 cm	17 hills/m^2
	8	30 cm x 30 cm	11 hills/m^2
Broadcasting transplantation	9	Broadcast	17 hills/m^2
	10	do	22 hills/m^2
	11	do	40 hills/m^2
Transplantation with broadcastable seedlings	12	30 cm x 15 cm	22 hills/m^2
Direct sowing	13	Upland (without puddling)	50 kg/ha
	14	do	75 kg/ha
	15	do	100 kg/ha
	16	Submerged (after puddling)	50 kg/ha
	17	do	75 kg/ha
	18	do	100 kg/ha

The main points of the methods used for each test are given in Table 5.4-2.

Table 5.4-2 Main Points of Method for Spacing and Seeding Density Tests

	Test I	Test II	Test III	Test IV
Variety	C-15	C-15	C-11	TOS-103
Sowing date	Jun. 17, 1978	Jun. 28, 1978	Aug. 15 and 21, 1978	Feb. 1, 197
Transplantation date	Jul. 6	-	Sep. 9 and 21	Mar. 10
Standard fertilization				
N	150	180	150	180
P_2O_5	75	75	-	100
K_2O	-	-	-	

Results

The overall results of these tests are given in ANNEX 5. The yield results of each test are summarized in Table 5.4-3, below.

Table 5.4-3 Yields of Spacing and Seeding Density Tests

(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	Seeding Density, Row Width and Yield							
	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 Transplantation		Broadcast Transplantation		Transplantation with Broadcast-able Seedlings
	30 x 30 cm (11.1hills/m2)	30 x 20 cm (16.7hills/m2)	17 hills/m2	22 hills/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 Seeding Density		Block Number I (ton/ha)	II	III	Mean
1. Transplantation	15 x 15 cm	44 hills/m^2	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

Cultivation Method	Spacing or Seeding Density	Block Number I (ton/ha)	II	III	Mean
2. Broadcast transplantation	17 hills/m^2	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 transplantation with broadcastable seedlings	30 x 15 cm, 22 hills/m^2	7.3	5.7	7.1	6.7
4. Direct sowing	without puddling (upland) 50kg Seed/ha	6.3			
	75	6.2			
	100	6.4			
	with pudding (submerged) 50	5.8			
	75	9.9			
	100	7.1			

(1) Transplantation

The relationship between planting density and yield is shown in Figs. 5.4-1 and 5.4-2, using the results obtained from Tests I and IV. As the plots in the figures show a curvilinear increase in yield with planting density, an empirical curve was worked out by the least squares method, obtaining for Test I:

$$Y = 3.8 + 2.56X - 3.37 \times 10^{-1} X^2$$

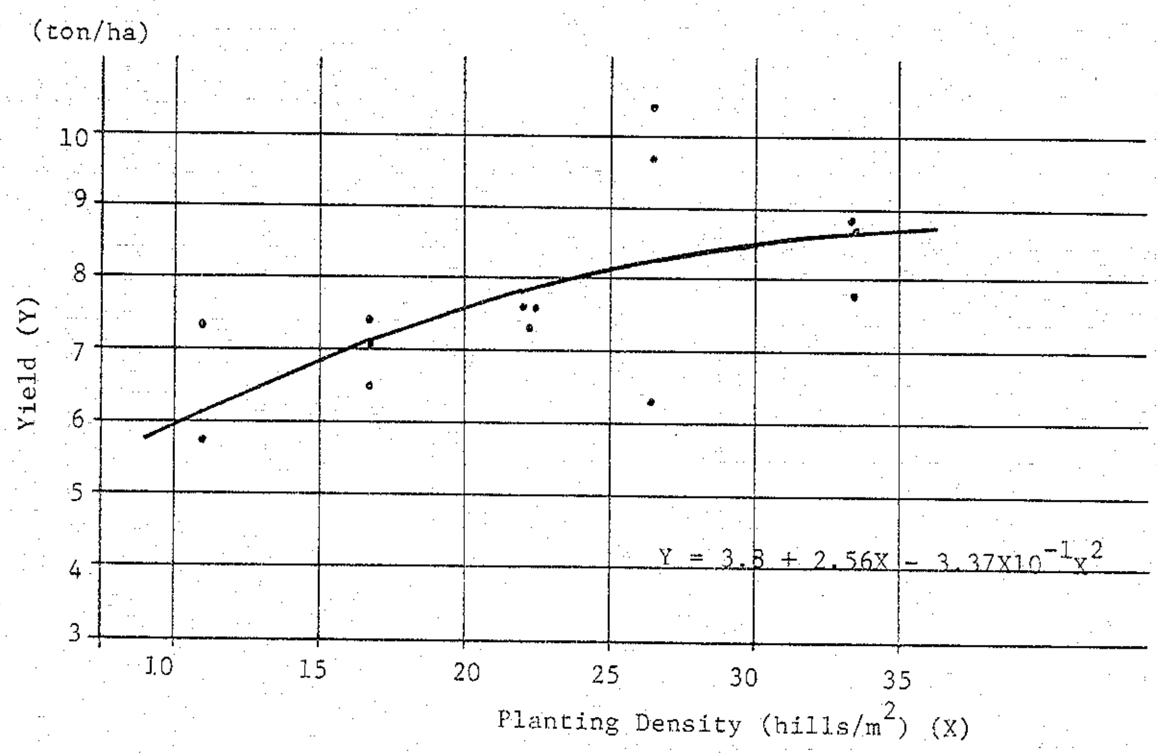
And, for Test IV:

$$Y = 1.42 + 0.3X - 2.40 \times 10^{-1} X^2$$

Where, Y is yield, and X is the planting density. According to the results of variance analysis, both equations are significant with 95% probability of confidence. The optimum planting densities derived from each equation are 38 hills/m^2 for Test I and 62 hills/m^2 for Test IV. These optimum planting densities are derived only from the above-mentioned equations. Therefore, scrutinizing the data obtained in Test I again, and making a significant test on the yields, the following conclusion was reached.

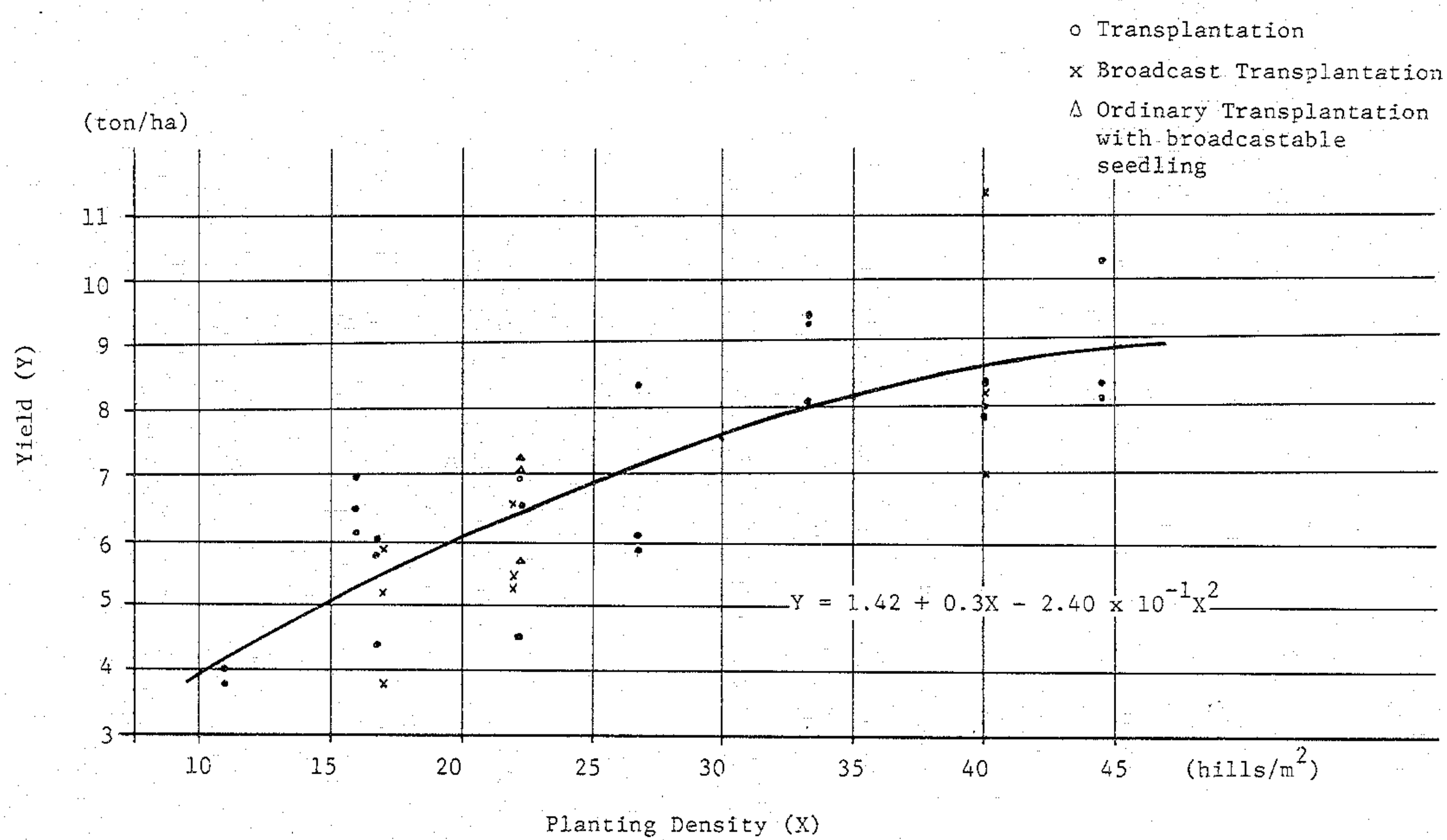
Fig. 5.4-1 Relation between Planting Density and Yield

(Main Season)



Note: C-15, Sown June 17, 1978, 150 kg N/ha, 75kg P_2O_5/ha.

Fig. 5.4-2 Relation between Yield and Planting Density



Note: TOS - 103, 180kg N/ha, 100kg P_2O_5/ha.

Judging from Fig. 5.4-1, it can be said in general that the greater the planting density, the higher the yield is. A noticeable point, however, is that no significant difference is found between treatments with planting denser than 22.2 hills per m^2, (30x15 cm), while sometimes significant differences are found between treatments with smaller planting densities than 22.2 hills/m^2, as shown by following table.

Results of Significance Analysis for the Spacing Test

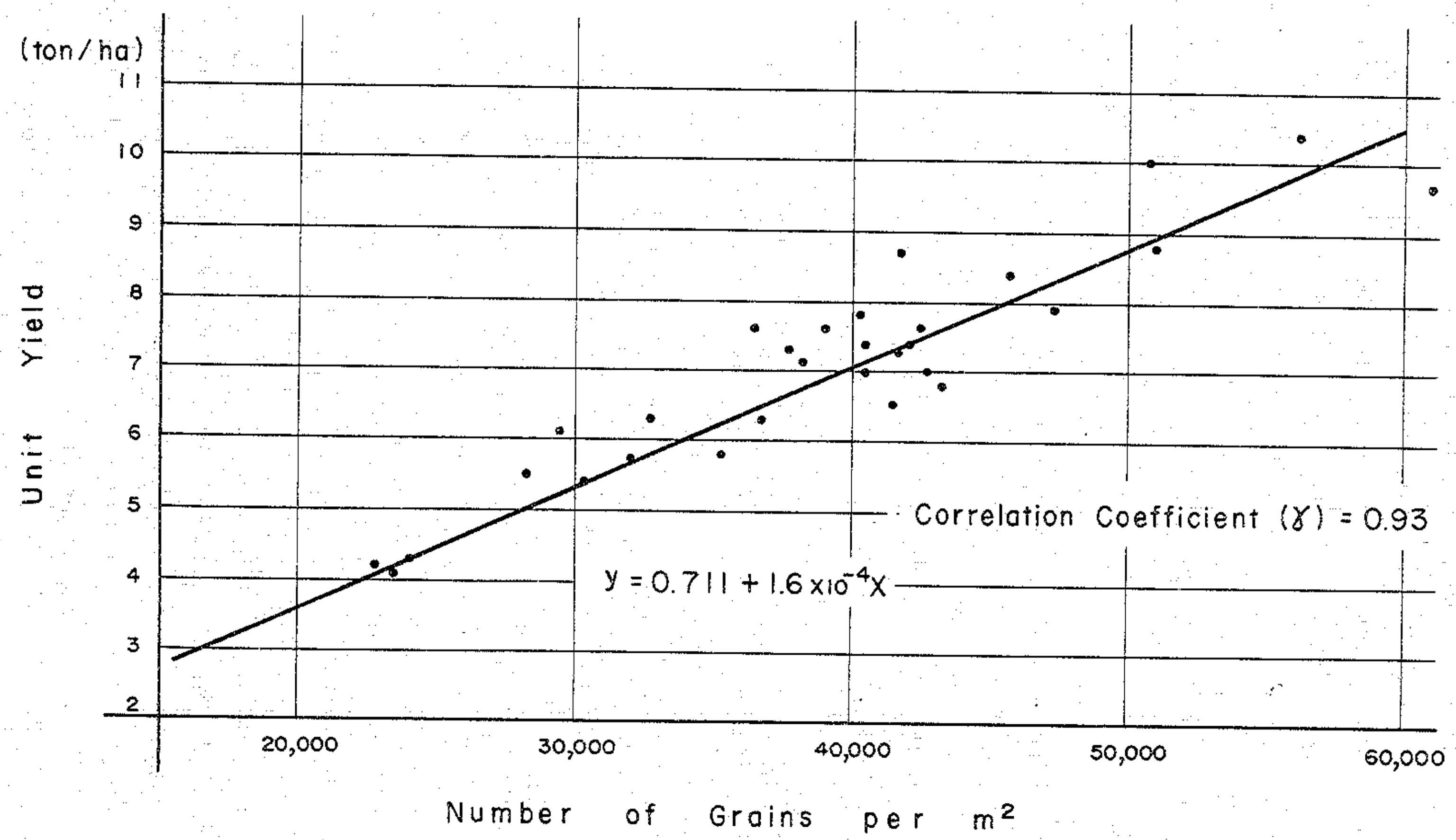
			"t" value	Degrees of Freedom
11.1 hills/m^2	vs.	16.7 hills/m^2	1.10	4
11.1 hills/m^2	vs.	22.2 hills/m^2	2.24	4
11.1 hills/m^2	vs.	26.7 hills/m^2	1.77	4
11.1 hills/m^2	vs.	33.3 hills/m^2	3.46*	4
16.7 hills/m^2	vs.	22.2 hills/m^2	1.79	4
16.7 hills/m^2	vs.	26.7 hills/m^2	1.41	4
16.7 hills/m^2	vs.	33.3 hills/m^2	3.40*	4
26.7 hills/m^2	vs.	26.7 hills/m^2	1.02	4
22.2 hills/m^2	vs.	33.3 hills/m^2	2.69	4
22.2 hills/m^2	vs.	33.3 hills/m^2	0.31	4

* Significant with 95% probability

This means that the planting density of 22.2 hills per m^2 (30x15 cm) may be taken as an optimum density for labour saving.

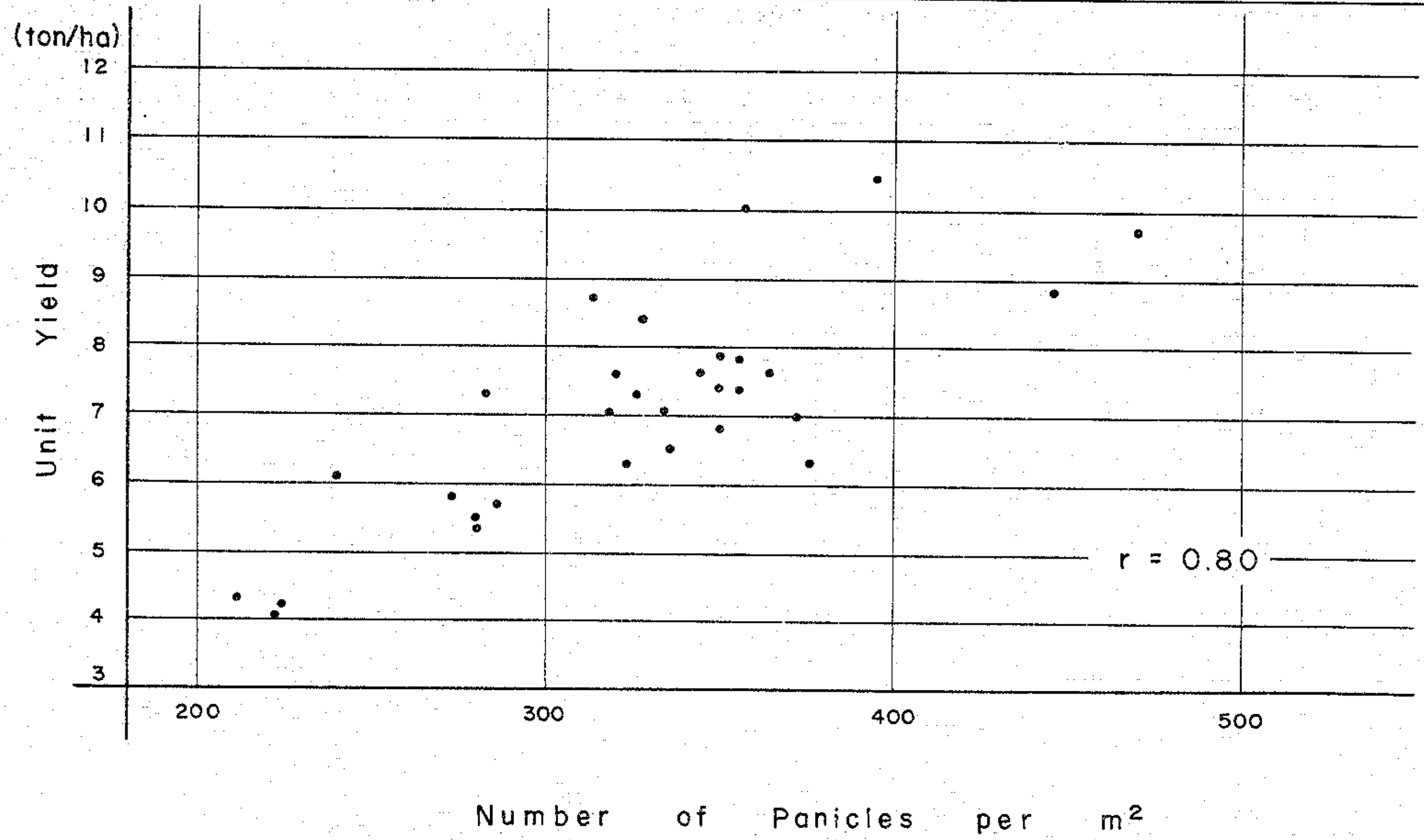
To make clear the relationship between planting density and yield. the correlations between yield and number of grains produced per m^2, between yield and number of panicles, and between yield and percentage of ripened grains are shown in Figs. 5.4-3, 4, 5 and 6 using data obtained from the nitrogen amount test and the spacing test. The correlation between yield and number of grains per m^2 was highest, showing a correlation coefficient of 0.93. This figure revealed also that a higher yield might be obtained by increasing the number of grains per m^2. The correlation between the yield and the number of panicles per m^2 was also strong, showing a correlation coefficient of 0.80.

Fig. 5.4-3 Correlation of Yield and Number of Grains Produced per m^2



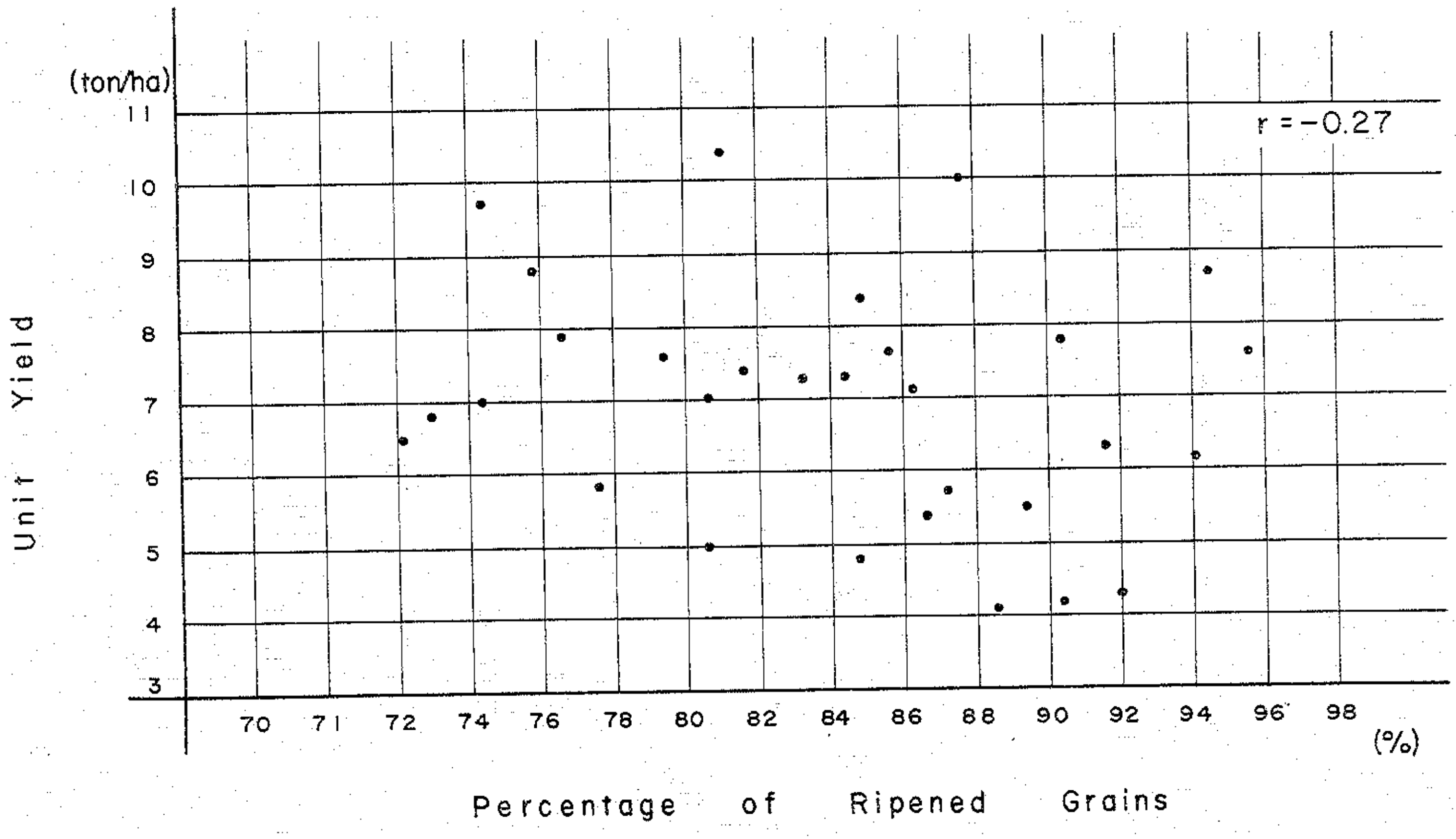
Note : Variety, C-15 ; Sowing date, June 17.

Fig. 5.4-4 Correlation of Unit Yield and Number of Panicles per m^2



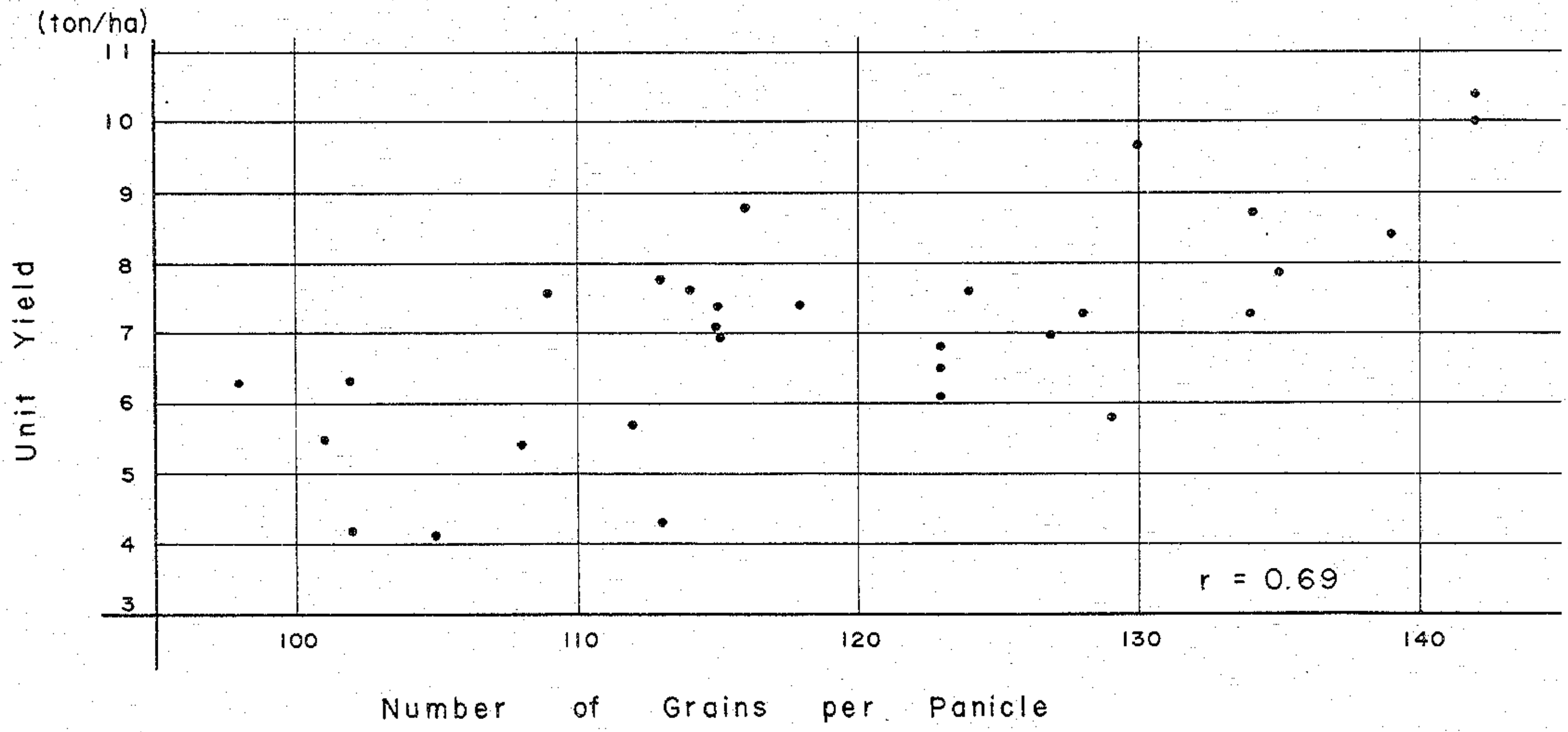
Note : Variety, C-15 ; Sowing date, June 17

Fig. 5.4-5 Correlation of Yield and Percentnage of Ripened Grains



Note : Variety, C-15 ; Sowing date, June 17.

Fig. 5.4-6 Correlation of Yield and Number of Grains per Panicle



Note : Variety, C-15 ; Sowing date, June 17.

Thus, higher yields might also be obtained by increasing the number of panicles per m^2. The correlation coefficient between yield and the percentage of ripened grains was as low as -0.27. This low coefficient explains why the higher yields are brought about with a large number of grains per m^2, even when a large number of grains is obtained. In view of this, it is quite important to increase the number of grains or panicles per square meter to obtain higher yields than those attained so far. The same fact as above was also observed in a pilot farm in Nigeria, which was operated by the Nippon Koei team. Furthermore, scrutinizing the contribution of each yield component to grain yield, Yoshida and Parao (1976) in IRRI emphasized the importance of an increase of spikelet number per square meter to increase rice yield.

Examining the data for the transplantation method in Test IV, and making a significance test of the yields, the following points were noted. According to Fig. 5.4-2, it may also be recognized that a greater planting density gives a higher yield. However, from the results of a significance test on yields shown in the following Table 5.4-5, it is recognized that denser planting treatments for densities greater than 27 hills/m^2 (i.e. 44, 40 and 33 hills/m^2) show no significant difference from treatment at 27 hills/m^2, while they show clear significant differences from thinner density treatments than 27 hills/m^2 (i.e. 22, 17, 16 and 11 hills/m^2), and furthermore the treatment of 27 hills/m^2 has a significant difference from 11 hills/m^2. In this case, if the treatment of 27 hills/m^2 had shown significant differences from 22, 17, and 16 hills/m^2, 27 hills/m^2 could clearly have been taken as the optimum planting density. The treatment of 27 hills/m^2, however, showed no significant difference from treatments of 22, 17 and 16 hills/m^2, but denser treatments than 27 hills/m^2 show significant differences against 22, 17, 16 and 11 hills/m^2. Thus, the treatment of 27 hills/m^2 may be taken as the optimum planting density.

Table 5.4-5 Significant Difference Analysis of Test IV Results

Comparison				"t" va	Degrees of Freedom
(1) Transplantation					
15x15cm (44hills/m2)	vs	25x10cm (40hills/m2)		1.31	4
"	vs	30x10	33	0.13	"
"	vs	25x15	27	2.20	"
"	vs	30x15	22	3.05*	"
"	vs	30x20	17	4.42*	"
"	vs	25x25	16	3.62*	"
"	vs	30x30	11	7.51**	"
25x10cm (40hills/m2)	vs	30x10	33	1.80	"
"	vs	25x15	27	1.71	"
"	vs	30x15	22	2.82*	"
"	vs	30x20	17	5.32**	"
"	vs	25x25	16	5.61**	"
"	vs	30x10	11	21.93**	"
30x10cm (33hills/m2)	vs	25x15	27	2.43	"
"	vs	30x15	22	3.45*	"
"	vs	30x20	17	5.50**	"
"	vs	25x25	16	5.07**	"
"	vs	30x30	11	11.52**	"
25x15cm (27hills/m2)	vs	30x15	22	0.72	"
"	vs	30x20	17	1.48	"
"	vs	25x25	16	0.36	"
"	vs	30x30	11	3.42*	"
30x15cm (22hills/m2)	vs	30x20	17	0.66	"
"	vs	25x25	16	0.62	"
"	vs	30x30	11	2.59	"
30x20cm (17hills/m2)	vs	25x25	16	1.94	"
"	vs	30x30	11	2.71	"
25x25cm (16hills/m2)	vs	30x30	11	8.75**	"

Note: ** Significant with 99% probability
* Significant with 95% probability

Taking the results of Test I and labour-saving into account, 22.2 hills or 26.7 hills per m^2 can be taken as the optimum planting density for the transplantation method in the project area. This optimum planting density is almost equal to that generally practiced in Japan.

(2) Direct sowing

For direct sowing, the grain yields of Tests II and Test IV are shown in Table 5.4-3.

Firstly, in Test II so many plots were missing that the analysis of variance of treatments with 3 blocks was impossible.
Then, for the treatments with an identical seeding amount as a group, as shown in Table 5.4-6 below, only a comparison by the "t" test of the average yield was made, giving the following results for the significant difference test.

Table 5.4-6 Comparison of Effect of Seeding Density on Yield

	50 kg/ha	80 kg/ha	100 kg/ha
	6.7 (ton/ha)	8.5 (ton/ha)	10.5 (ton/ha)
	8.2	6.7	9.5
	9.4	8.1	
	8.0	9.4	
		7.1	
		9.6	
		10.6	
Mean	8.1	8.6	10.0

Comparison	"t" Value	Degrees of freedom	Significance of difference
50 kg/ha vs. 80 kg/ha	0.61	9	nil
80 kg/ha vs. 100 kg/ha	1.32	7	nil
50 kg/ha vs. 100 kg/ha	2.15	4	nil

According to the above table, there was no significant difference in yield for different seeding densities.

Secondly, examining the yields shown in Table 5.4-3 for the direct sowing in Test IV, no consistent relation is observed. For the "without puddling", no difference was found in yield for treatments with 50 kg, 75 kg and 100 kg/ha, while for "with puddling" the treatment with 75 kg/ha gave the highest 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 the optimum seeding density. This optimum density is slightly larger than that generally used in Japan.

5.5 Cultivation Method Tests

Purpose

The objective of this test is to determine the most suitable cultivation method of three different methods, i.e. the ordinary transplantation method, the direct sowing method and the broadcast transplantation method. The broadcast transplantation method is detailed in Annex 6 and in the work of Alluri, K. (1978).

Method

The test was carried out as part of the variety test in the 1977 main-season and as part of the spacing and sowing density test in the 1978 main-season and 1978/1979 off-season. The main points of the methods used in each season are given in Table 5.5-1.

Table 5.5-1 Main Points of Methods in Cultivation Method Test

	Main-Season in 1977	Main-Season in 1978	Off-Season in 1978/79
Variety	IR-298-12-1-1-1	C-11	TOS-103
Sowing date:			
Regular transplantation	June 15, 1977	August 15, 1978	February 1, 1979
Broadcast transplantation	June 15, 1977	August 21, 1978	do
Direct sowing	June 23, 1977	-	do
Sowing density (direct sowing)	60 kg Seed/ha	-	50, 75, 100 kg Seed/ha
Transplantation density	22.2 hills/m^2 (15 x 30 cm)	16.7 hills/m^2 22.2 hills/m^2	17, 22, 40 hills/ha
Fertilization			
N	92 kg/ha	150 kg/ha	180 kg/ha
P_2O_5	40 kg/ha	75 kg/ha	100 kg/ha
Replication	1	3	1 (direct sowing) 3 (other methods)

Results

(a) 1977 Test

The overall results are given in ANNEX 2.

The yields abstracted from the tables are given below.

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

From these results it can be seen that the broadcast transplantation method gave highest yield, followed by the ordinary transplantation method. The broadcast direct sowing method gave the lowest yield.

(b) 1978 Test

The yields of the test carried out in the 1978 main-season are given for Test III in Table 5.4-3 for the spacing and seeding density test.

The results of the significance tests between treatments are shown in the following Table 5.5-2, in which ordinary transplantation is compared with broadcast transplantation at identical spacing.

Table 5.5-2 Results of Significant Difference Test for Cultivation Method Test (Main-Season in 1978)

	Seedling Broadcasting		Ordinary transplantation using broadcastable seedlings
Ordinary Transplantation	17 hills/m2	22 hills/m2	30cmx15cm (22 hills/m2)
30 x 20 cm (17 hills/m2)	t = 2.07	/	/
30 x 15 cm (22 hills/m2)	/	t = 1.12	t = 1.19

Note: t is student's "t"

From the table, it can be seen that the broadcast transplantation method showed no significant difference from ordinary transplantation. This fact proves statistically that the broadcast transplantation method is by no means inferior in yield to the labour intensive ordinary transplantation method. Furthermore, broadcast transplantation in which seedlings are randomly broadcast is also not inferior to the ordinary transplantation method using broadcastable seedlings in which broadcastable seedlings are transplanted evenly.

It is worthy of note that, the broadcast transplanting method, which can reduce transplantation labour to 1/10 - 1/15 compared with ordinary transplantation by hand, is by no means inferior to the ordinary transplantation method in which each seedling is transplanted one by one by hand at a regular spacing.

(c) 1979 Test

The overall experimental results are given ANNEX 5.
First, using the yield data given in Test IV (Table 5.4-3) an analysis of variance for the treatments of ordinary transplantation, broadcast transplantation and ordinary transplantation with broadcastable seedlings was made to give Table 5.5-3.

Table 5.5-3 Comparison of Yields for Three Different Transplantation Methods

	Ordinary Transplantation	Broadcast Transplantation	Ordinary Transplantation with Broadcastable Seedlings
	4.5 ton/ha	6.6	7.4
	7.0	5.3	5.7
	6.5	5.5	7.1
Mean	6.0	5.8	6.7

(Note: Planting density was 22 hills/m2)

Analysis of Variance

Source of Variance	Degrees of Freedom	Sums of Squares	Mean Squares	F
Total	8	734		
Treatment	2	134	67	0.67
Error	6	600	100	

As shown in the table, no significant difference is found for the three different transplantation methods, which confirms the conclusion stated in (b) 1978 Test. So far as these two experiments (Tests in 1978 and 1979) are concerned, no difference was statistically observed in yields between the ordinary transplantation method, the transplantation method using broadcastable seedlings and the broadcast transplantation method.

Secondly, using the results of the direct sowing method in Test IV and those of the nitrogen level test and Test II in Table 5.4-3, which were conducted by transplantation, comparisons between the direct sowing method and the ordinary transplanation method were tentatively made. As shown in the following table, significant differences for the three treatments of the direct sowing method were tested against eight treatments of the transplantation method, showing the "t" value for each comparison.

Comparison of yields for Direct Sowing Method and Transplantation Method with "Student's" t

Cultivation Method				Transplantation 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	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
Sowing	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
Method	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

Note: The numeral in each cell expresses Student's "t" which indicates the difference between the yield for the transplantation method and that for the direct sowing method.

Out of 24 comparisons only 4 comparisons showed significant differences between the transplantation method and the direct sowing method. Generally speaking, a significant difference could hardly be observed between the two methods. However, the followings points may be noted: (1) The direct sowing method applying a high rate of speed (100 kg Seed/ha) and a high rate of nitrogen (180 kg N/ha) is superior to any transplantation method from the view point of average yield. It is also superior, taking variance of yields into consideration, to the transplantation method with a lower transplantation density than 27 hills/m2 and an ordinary application level 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 obtained by the transplantation method.

From these facts, it may be said that the direct sowing method with applications of a high rate of nitrogen and seeding is superior to the transplantation method using an ordinary rate of nitrogen and transplantation density, although this comparison is not so rigorous because the two methods were performed with different sowing dates, i.e. about half a month apart, different fertilization and different experimental fields.

It must be borne in mind, however, that the direct sowing in this test was conducted on a well levelled field with good drainage facilities. If direct sowing were carried out on a badly levelled and ill-drained field, the yield would be much less than that for the transplantation method.

5.6 Herbicide Tests

Purpose

The objective of this test is to select appropriate herbicides not only for transplanted rice but also for direct-sown rice in due consideration of their effect on weeding and on phytotoxicity.

Method

(1) Direct Sowing

Tests of 7 herbicides, listed in Tables 5.6-1 below, 4 for soil treatment and 3 for soil and foliage treatment, were started by sowing variety, IR-20 on Oct. 8, 1978, with three replications. Control plots were set for each block. The area of a plot was 21.6 square meters. The seeding density was 80 kg of seeds per hectare. Nitrogen was applied at a rate of total 150 kg per hectare. This was split-applied as follows: 80 kg just before sowing, 40 kg at the spikelet differentiation stage, and 30 kg at the full heading stage. Total phosphate was applied at a rate of 75 kg per hectare just before sowing. Herbicides were applied just after sowing for the test on herbicides for soil treatment and after emergence of seedlings for the test on herbicides for soil and foliage treatment. For the test on herbicides for soil and foliage treatment, "Saturn" was sprayed at the time of sowing as a soil treatment, and then herbicides for the soil and foliage treatment were applied.

The number of weeds on the 20th day after treatment and the degree of phytotoxicity were investigated.

Table 5.6-1 Herbicides Tested for Direct-Sown Rice

Name	Percentage of Active Ingredient		Formulation	Application Time	Application Amount
(a) Soil treatment					
MO	CNP	7%	granule	5th day after sowing	30 kg/ha
Saturn	Benthiocarb	50%	emulsion	do	6 ℓ/ha
X-52	Chlomethoxynil	7%	granule	do	30 kg/ha
Ronstar	Oxadiazon	12%	emulsion	do	4 ℓ/ha
(b) Soil and Foliage treatment					
Molinate	Molinate	8%	granule	at full emergence of seedlings	30 kg/ha
Stam	Propanil	35%	emulsion	15th day after sowing	10 ℓ/ha
Swep (M)	Swep	20%	granule	25th day after sowing	30 kg/ha
	MCPA	0.7%			

(2) Transplantation

The six herbicides listed below were tested for the rice transplanted in 1978 with 3 replications. Control plots were set for each block. The area of a plot was 21.6 square meters. The spacing between rows was 25 cm. The distance between hills was 15 cm. Nitrogen was applied at a rate of 150 kg per hectare in total. This was split-applied as follows: 80 kg just before transplanting, 40 kg at the spikelet differentiation stage, and 30 kg at the full heading stage. Phosphate was applied at a rate of 75 kg per hectare just before transplantation.

Table 5.6-2 Herbicides Tested for Transplanted Rice

Name	Percentage of Active Ingredient		Formulation	Application Time	Application Amount
Ronstar	Oxadiazon	12%	emulsion	just after puddling	5 ℓ/ha
Saturn	Benthiocarb	50%	emulsion	Just after puddling	8 ℓ/ha
MO	CNP	7%	granule	5th day after transplanting	30 kg/ha
X-52	Chlomethoxynil	7%	granule	5th day after transplanting	30 kg/ha
SWEP (M)	MCC	20%	granule	20th day after transplanting	30 kg/ha
	MCPA	0.7%			
NIP	Nitrofen	7%	granule	5th day after transplanting	30 kg/ha

Results

(1) Direct Sowing

The results of the test an herbicides for soil treatment are given in Table 5.6-2.

Table 5.6.2 Effect of Herbicides for Soil Treatment

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

Note: Severe phototoxicity was observed on rice plants to which Ronstar was applied.

Surviving weeds were determined on the 20th day after treatment.

The effects of herbicides for soil treatment were remarkable compared with the control plots. The most effective and safe herbicide was Saturn, followed by X-52 and MO.
Ronstar caused severe phytotoxicity to rice plants, giving rise to a low percentages of established seedlings and many stunted plants.

The effects of the herbicides on the soil and foliage treatment could not be determined, because the effect of Saturn applied in the soil treatment was so strong that no weed was left for the test of herbicides for soil and foliage treatment.

(2) Transplantation

The effects of the herbicides were evaluated visually.
Every herbicide except Ronstar had a powerful effect on weeding.
Ronstar caused severe phytotoxicity to transplanted rice plants.