4. Productivity and Water Efficiency of Triple Cropping of Rice (1977—1978)

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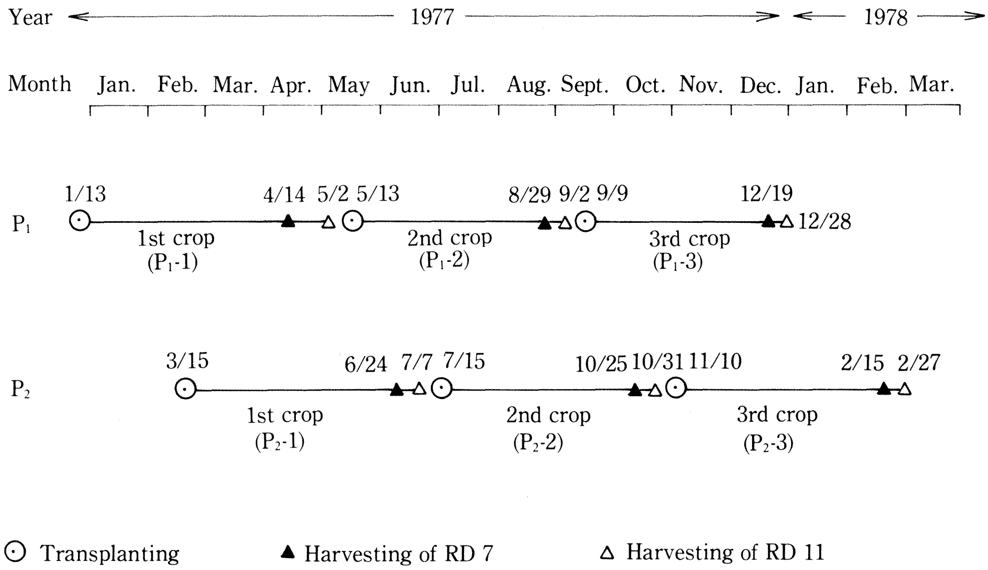
To compare the efficiency of multiple cropping systems in paddy field consisting of rice and upland crops with that of continuous rice cropping, a trial of triple cropping of rice was made in 1977—1978. The experiment was carried out to evaluate the productivity and water efficiency of triple cropping of rice with reference to rice varieties and some cultural practices such as planting cycle, water management, fertilizer application and planting density.

Material and methods

1. Planting cycle (P_1 and P_2)



2. Water management (W_1 and W_2)
   W_1: Continuously flooeded
   W_2: Non-flooded for 6 to 10 days starting from 30 days after transplanting.
3. Rate of fertilizer application in kg/ha (F_1 and F_2)

F_1: Standard	Basal dressing	N-20, P_2O_5-25
	Top dressing	N-20
F_2: High level	Basal dressing	N-30, P_2O_5-37.5
	Top dressing	N-30

   As for fertilizers, ammophos was used for basal dressing, and ammonium sulphate was applied for top dressing at 40 to 42 days after transplanting.
4. Variety (V_1 and V_2)
   V_1: RD 7

V_2: RD 11 (WP153)
Both the varieties are non-photosensitive.

5\. Planting density (D_1 and D_2)
D_1: Standard, 25 cm × 25 cm, 16 hills/m^2, 3 seedlings/hill
D_2: Desnse, 25 cm × 25 cm × 20 cm, 20 hills/m^2, 3 seedlings/hill.

6\. Design and plot size
Split plot design with one replication was applied. The orthogonal table was employed for statistical analysis of the data. The size of each plot was 69.6 m^2 (8.7 m × 8.0 m) and the number of plots was 96 (planting cycle 2 × transplanting time 3 × water management 2 × rate of fertilizer application 2 × variety 2 × planting density 2).

Results

1. Comparison between planting cycle P_1 and P_2
   1) Grain yield
      Total grain yield of three crops as an average of 16 treatments (W·2 × F·2 × V·2 × D·2) in P_1 and P_2 planting cycle was 13.69 and 12.12 ton per hectare. It means that P_1 yielded by 12.9% more than P_2 (Table 4-1). Such a clear difference of yields between P_1 and P_2 was also observed in both the varieties, RD 7 and RD 11. The highest yield among all, 15.87 ton per hectare, was obtained in the plot of P_1-W_1-F_2-V_2-D_2. Among P_2 plots, the highest yield was 13.17 ton/ha in the similar treatment, P_2-W_1-F_2-V_2-D_2 (Table 4-2).
   2) Yield components
      The number of spikelets per m^2 of P_1 was more than that of P_2, but the degree of ripening (grain yield per 1000 spikelets) of P_1 was the same or slightly less than that of P_2. Therefore, it can be assumed that the higher yield of P_1 was not due to the increase of degree of ripening but due to the increase of number of spikelets per unit area.
   3) Nitrogen absorption
      The amount of nitrogen absorption in P_1 at heading time was more than in P_2. The similar trend was observed in both the varieties, RD 7 and RD 11 (Table 4-1).
2. Comparison among transplanting times
   1) Grain yield
      The highest grain yield was obtained in P_2-1, the first crop of planting cycle P_2, which was transplanted on March 15 (Table 4-2).
      The grain yield of both the plots P_1-3 (transplanted on September 9) and P_1-1 (Transplanted on January 13) were also considerably high, but P_2-2 (transplanted on July 15) showed the lowest yield among the treatments. The trends observed in the grain yield were somewhat different according to the rice varieties. The orders of the mean yield in each variety were as follows:
      RD 7: P_1-3>P_2-1>P_1-1>P_1-2>P_2-2>P_2-3
      RD 11: P_2-1>P_1-1>P_1-3>P_1-2>P_2-3>P_2-2
   2) Relationships between yield and yield components
      A significant positive correlation between yield and number of spikelets per m^2 with reference to transplanting time was found (RD 7 $r = 0.970^{**}$, significant at 1% level; RD 11 $r = 0.736^{+}$, significant at 10% level), but there was

no significant correlation between yield and degree of ripening.

3) Relationship between yield and nitrogen absorption with reference to transplanting time

A significant positive correlation between yield and nitrogen absorption per m^2 at heading time was obtained in both the varieties (RD 7 $r = 0.886^*$; RD 11 $r = 0.848^*$, both significant at 5% level).

4) Relationships between yield or yield components and weather factors due to different transplanting time

In the variety of RD 11, a close positive correlation between degree of ripening and the average of difference between maximum and minimum air temperature during ripening period was found ($r = 0.996^{***}$, significant at 0.1% level). In the variety of RD 7, there was no significant correlation between degree of ripening and any weather factor; however, a close negative correlation between degree of ripening and number of spikelets per m^2 ($r = -0.863^*$), and a positive correlation between degree of ripening and nitrogen content of plants at heading time ($r = 0.939^*$), except P_1-1 which was somewhat damaged by birds, were obtained. In both the varieties, RD 7 and RD 11, a positive correlation between grain yield and average daily solar radiation during the period from transplanting to harvesting was observed (RD 7 $r = 0.723^+$ RD 11 $r = 0.728^+$, both significant at 10% level).

3. Relationship between yield and cultural practices

The effects of some cultural practices such as water management, rate of fertilizer application and planting density were examined. Judging from the analysis of variance, it can be said that drainage for 6 to 10 days in the middle growth stage decreased grain yield in P_1-2, P_1-3 and P_2-3, while in only P_2-2 increased the yield. The difference of grain yields due to different rates of fertilizer application was also clear in P_1-2, P_1-3, P_2-1 and P_2-3, where high level of fertilizer application yielded better. As for planting density a significant difference at 10% level was seen in P_1-3 and P_2-2.

4. Varietal differences

1) Growing period and heading time

Variety RD 7 took 115 to 133 days from seeding to harvesting and 91 to 108 days from transplanting to harvesting, while RD 11 took 132 to 139 days and 108 to 114 days, respectively (Table 4-3). The heading time of RD 11 was delayed 1 to 18 days as compared with RD 7. Thus, in case of triple cropping of rice there were only a few day intervals from harvesting to the transplanting of succeeding rice crop.

2) Yield and yield components

In the most plots, number of spikelets per unit area of RD 7 was more than that of RD 11 while the degree of ripening of RD 7 was less than RD 11. The total grain yield of the 1st, 2nd and 3rd crop of RD 11 in P_2 was slightly higher than that of RD 7 (significant at 10% level).

3) Nitrogen absorption

As compared with RD 7, RD 11 absorbed 40 percent more amount of nitrogen at heading time. Number of spikelets which were produced per mg of nitrogen absorbed by plant, was less in RD 11 than in RD 7. These two factors seemed effective on relatively higher values of the degree of ripening and grain yield of RD 11.

5. Water consumption

The amount of evaporation and transpiration have been checked during rice growing period in the plot of W_1-F_1-V_1-D_1.

1) Evaporation and transpiration

The total evaporation of P_1 was less than that of P_2; on the contrary, the total transpiration of P_1 was larger than P_2. The total evapotranspiration of the both were almost the same (Table 4-4).

2) Water requirement

The water requirement of P_1 which is defined as the water required to produce 1 gr. of dry matter, was less than P_2. Therefore, the efficiency of water utilization of P_1 might be higher in comparison with P_2.

The climatic conditions and water consumption in each crop are shown in Table 4-5 to 9 and 4-10 to 15, respectively.

Discussion

In this experiment, 15.87 ton per hectare of grain yield as a total of three crops in a year was obtained with the application of 40 to 60 kg per hectare of nitrogen to each crop which was similar to the amount recommended to farmers by the government. It suggested that there would be a possibility to gain higher yields in triple cropping of rice with application of more fertilizer.

Planting cycle is also very important factor to increase the total grain yield in triple cropping of rice. In decision of the planting cycle in this experiment, the weather conditions such as solar radiation and air temperature during ripening period were taken into consideration. Although the grain yield in P_1 cycle was higher than P_2, it is difficult in this experiment to conclude which cycle is better. However, it should be noted that P_1 cycle starting in January and ending in December coincides with the duration of the trial of four crops a year at IRRI (Yoshida et al. 1972) where high grain yield of 25.65 ton per hectare was obtained.

The difference between RD 7 and RD 11 was noticed in yield and other items. In the most cases, the grain yield of RD 11 was higher than RD 7; only in P_2-2 was the grain yield of RD 11 lower owing to severe prevalence of narrow brown leaf spot (*Cercospora oryzae* Miyake). In both the varieties positive correlations between grain yield and solar radiation during the period from transplanting to harvesting were observed (significant at 10% level).

The difference in degree of ripening between two varieties was prominent; the factors affecting the degree of ripening was different according to varieties. In case of RD 11, the degree of ripening was affected by the average difference between maximum and minimum air temperature during the ripening period; in case of RD 7 it was not affected by those factors but affected by the nitrogen content (positively) and the number of spikelets per m^2 (negatively). From these results it is most likely that the degree of ripening of RD 7 was affected by the level of nitrogen content as well as the competitive distribution of carbohydrates in rice plant which resulted from relatively abundant number of spikelets.

The varietal difference in the amount of nitrogen absorbed by top part of plant was also remarkable. The same trend was confirmed by authors among other RD varieties in another experiment; for example, the amount of nitrogen absorbed by RD 5 was around twice as much as that of RD 7. These facts lead to a question whether or not the same rate of nitrogenous fertilizer should be applied to different rice varieties in an experiment.

In both the varieties, RD 7 and RD 11, the significant correlation between solar radiation and degree of ripening was not observed. This strongly suggests the possibility that the sterility caused by high air temperature, as reported by Osada (1973) and Satake et al. (1977), disturbed the correlation. It was also observed in the experiments conducted at the same site that the percentage of empty grains of the variety RD 7 was the highest in the plot where heading time was on May 19, 1978* and the lowest in the plot where heading time was on January 6, 1978*.

Thus, the characteristics of rice varieties as mentioned above have to be referred to when the planting season and cultural practice for each variety are decided.

This experiment has proved the possibility of triple cropping of rice from the agronomic points of view focussing on its productivity and water efficiency. The comparison with other multiple cropping systems consisting of upland crops and rice in the aspect of productivity and water efficiency will be discussed in another chapter.

References

1) Yoshida, S. F. T. Parao, and H. M. Beachell:
A Maximum Annual Rice Production Trial in the Tropics. IRC Newsletter 21,(3)27-32 (1972)

2) Osada, A., V. Sasiprapa, M. Rahong, S. Dhammanuvong and H. Chakrabandhu: Abnormal occurrence of empty grains of indica rice plants in the dry, hot season in Thailand. Proc. Crop. Sci. Soc. Japan, 42(1): 103-109 (1973).

3) Satake, T. and S. Yoshida: Mechanism of sterility caused by high temperature at flowering time in indica rice, JARQ 9, 11(2): 127-128 (1977).

* The average maximum and minimum temperature for 10 days after both the dates was as follows:
May 19: Max: 33.8°C, Min: 25.9°C
Jan. 6: Max: 30.8°C, Min: 20.3°C

Table 4-1. Grain yield, number of spikelets, ripening degree and nitrogen absorption in relation to planting cycle, transplanting time and variety

Variety	Planting cycle and crop***	Grain Yield ton/ha	Number of spikelets /m²	Degree of ripening**** g/1,000 spikelets	Total nitrogen* g/m²	Total nitrogen* %	Number of spikelets per 1 mg nitrogen absorbed
Average of both Vareties	P_1-1	4.699	19948	23.8	6.16	0.77	2.95
	P_1-2	4.194	18159	23.1	6.09	0.80	2.58
	P_1-3	4.794	19462	24.9	6.40	0.85	2.76
	Total	13.687	57569	23.93*	18.65	0.81*	2.76*
	P_2-1	4.891	19966	24.6	6.75	0.67	2.99
	P_2-2	3.547	16169	22.0	5.15	0.81	2.92
	P_2-3	3.683	13957	26.5	5.39	0.92	2.40
	Total	12.121	50092	24.37*	17.29	0.78*	2.79*
RD 7	P_1-1	4.428	21714	20.4	4.90	0.72	4.10
	P_1-2	4.160	18719	22.2	4.52	0.64	3.23
	P_1-3	4.730	21467	22.1	5.69	0.76	3.51
	Total	13.318	61900	21.57*	15.11	0.71*	3.61*
	P_2-1	4.645	21125	21.9	5.29	0.57	3.99
	P_2-2	3.863	16778	23.0	4.41	0.73	3.41
	P_2-3	3.386	14376	23.6	4.73	0.99	2.60
	Total	11.894	52279	22.83*	14.43	0.71*	3.36*
RD 11	P_1-1	4.970	18182	27.2	7.42	0.80	2.20
	P_1-2	4.228	17599	24.0	7.65	0.94	2.19
	P_1-3	4.858	17457	27.8	7.11	0.94	2.15
	Total	14.056	53238	26.33*	22.18	0.89*	2.18*
	P_2-1	5.138	18807	27.3	8.21	0.76	2.34
	P_2-2	3.231	15560	20.9	5.89	0.89	2.56
	P_2-3	3.979	13538	29.4	6.04	0.88	2.25
	Total	12.348	47905	25.87*	20.14	0.83*	2.38*

Remarks:
- * : Values are expressed in an average.
- ** : Rice samples in the plots of W_1-F_1-D_1 at heading time were used for analyzing total nitrogen.
- *** : P_1-1 means 1st crop of planting cycle P_1.
- **** : Grain (unhusked full) yield per 1000 spikelets.

Table 4-2. Grain yield of rice in relation to planting cycle, transplanting time, water management, rate of fertilizer application, variety and planting density (ton/ha)

W	F	V	D	P_1-1	P_1-2	P_1-3	Total	P_2-1	P_2-2	P_2-3	Total
W_1	F_1	V_1	D_1	3.92	3.36	4.59	11.87	4.54	3.41	3.05	11.00
W_1	F_1	V_1	D_2	4.18	4.02	4.82	13.02	5.05	3.99	3.12	12.16
W_1	F_1	V_2	D_1	4.27	4.22	4.40	12.89	5.70	3.16	4.00	12.86
W_1	F_1	V_2	D_2	5.92	4.70	4.48	15.10	6.00	3.18	3.91	13.09
W_1	F_2	V_1	D_1	4.51	4.78	4.96	14.25	5.30	3.35	4.00	12.65
W_1	F_2	V_1	D_2	5.58	4.78	5.23	15.59	4.86	3.69	3.89	12.44
W_1	F_2	V_2	D_1	5.05	4.73	5.62	15.40	4.91	3.12	4.33	12.36
W_1	F_2	V_2	D_2	5.70	4.48	5.69	15.87*	5.46	3.25	4.46	13.17*
W_2	F_1	V_1	D_1	4.28	3.85	4.59	12.72	3.41	3.84	3.01	10.26
W_2	F_1	V_1	D_2	4.76	3.95	4.07	12.78	3.72	4.24	3.28	11.24
W_2	F_1	V_2	D_1	4.05	3.96	4.53	12.54	4.30	2.92	3.38	10.60
W_2	F_1	V_2	D_2	3.98	3.68	4.11	11.77	4.65	3.15	3.33	11.13
W_2	F_2	V_1	D_1	4.04	4.09	4.88	13.01	5.09	4.16	3.50	12.75
W_2	F_2	V_1	D_2	4.15	4.45	4.70	13.30	5.19	4.22	3.24	12.65
W_2	F_2	V_2	D_1	5.37	3.92	4.95	14.24	5.03	3.64	3.89	12.56
W_2	F_2	V_2	D_2	5.42	4.13	5.08	14.63	5.05	3.43	4.53	13.01

Remarks:
- * : Maximum grain yield among 16 plots.
- W : Watermanagement.
- W_1 : Continuously flooded.
- W_2 : Non-flooded for 6 to 10 days from 30 days after transplanting.
- F : Rate of fertilizer application
- F_1 : Standard, Basal N-20, P_2O_5-25.0, Top N-20 Kg/ha
- F_2 : High level, Basal N-30, P_2O_5-37.5, Top N-30 Kg/ha
- V : Variety
- V_1 : RD 7
- V_2 : RD 11
- D : Planting density
- D_1 : Standard, 16 hills/m^2
- D_2 : Dense, 20 hills/m^2

Table 4-3. Growing period in relation to planting cycle and variety

Planting cycle-crop	Variety	Seeding time	Trans-planting time	Heading time	Harvesting time	Growing Period, (days)				
						Seeding to heading	Trans-planting to heading	Heading to harvesting	Seeding to harvesting	Trans-planting to harvesting
P_1-1	RD7	Dec. 20	Jan. 13	Mar. 18	Apr. 14	88	64	27	115	91
	RD11	"	"	Apr. 2	May 2	103	79	30	133	109
P_1-2	RD7	Apr. 18	May 13	Jul. 27	Aug. 29	100	75	33	133	108
	RD11	"	"	Jul. 28	Sept. 2	101	76	36	137	112
P_1-3	RD7	Aug. 16	Sept. 9	Nov. 14	Dec. 19	90	66	35	125	101
	RD11	"	"	Nov. 23	Dec. 28	99	75	35	134	110
P_2-1	RD7	Feb. 18	Mar. 15	May 25	Jun. 24	96	71	30	126	101
	RD11	"	"	Jun. 8	Jul. 7	110	85	29	139	114
P_2-2	RD7	Jun. 21	Jul. 15	Sept. 24	Oct. 25	95	71	31	126	102
	RD11	"	"	Sept. 28	Oct. 31	99	75	33	132	108
P_2-3	RD7	Oct. 17	Nov. 10	Jan. 6	Feb. 15	81	57	40	121	97
	RD11	"	"	Jan. 24	Feb. 27	99	75	34	133	109

Table 4-4. Water consumption

	Evaporation		Transpiration		Evapotranspiration		Pan Evaporation			Water requirement
Planting cycle-crop	E_1 mm	E_2 mm	T_1 mm	T_2 mm	ET_1 mm	ET_2 mm	EP_1 mm	EP_2 mm	ET/EP	g/g
P_1-1	254.8	2.8	298.4	3.3	553.2	6.1	533.4	5.9	1.04	343.9
P_2-2	410.5	3.8	315.8	2.9	726.3	6.7	672.8	6.2	1.08	349.0
P_3-3	239.6	2.4	282.7	2.8	522.3	5.2	474.0	4.7	1.10	321.0
Total	904.9	3.01*	896.9	2.99*	1801.8	6.01*	1680.2	5.60*	1.07*	338.07*
P_2-1	331.6	3.3	398.3	3.9	729.9	7.2	689.8	6.8	1.06	381.5
P_2-2	344.3	3.4	216.8	2.1	561.1	5.5	499.6	4.9	1.12	277.1
P_2-3	240.9	2.5	240.2	2.5	481.1	5.0	447.5	4.6	1.08	411.3
Total	916.8	3.06*	855.3	2.85*	1772.1	5.91*	1636.9	5.46*	1.08*	354.86*

E_1, T_1, ET_1 and EP_1 are expressed as the total amount. E_2, T_2, ET_2 and EP_2 are expressed as a daily average value.
* : Value are expressed on an average.
Ep was measured by a evaporimeter 20 cm in diameter. The values may be about 10% more than evaporation from free water surface measured by evaporimeter 1 m in diameter.

Table 4-5. Average daily solar radiation during growing period

Planting cycle-crop	Variety	Seeding to heading		Transplanting to heading		Heading to harvesting		Seeding to harvesting		Transplanting to harvesting	
		A	Sr	A	Sr	A	Sr	A	Sr	A	Sr
P_1-1	RD 7	36052	409.7	26306	411.0	12027	445.4	48079	418.1	38333	421.2
	RD 11	42274	410.4	32528	411.7	14661	488.7	56935	428.1	47189	432.9
P_1-2	RD 7	45567	455.7	33734	449.8	13418	406.6	58985	443.5	47152	436.6
	RD 11	45941	454.9	34108	448.8	14859	412.8	60800	443.8	48967	437.2
P_1-3	RD 7	37577	417.5	28058	425.1	15650	447.1	53227	425.8	43708	432.8
	RD 11	41840	422.6	32321	430.9	15145	432.7	56985	425.3	47466	431.5
P_2-1	RD 7	43618	454.4	32917	463.6	14365	478.8	57983	460.2	47282	468.1
	RD 11	50343	457.7	39642	466.4	12738	439.2	63081	453.8	52380	459.5
P_2-2	RD 7	38859	409.0	28649	403.5	13650	440.3	52509	416.7	42299	414.7
	RD 11	40587	410.0	30377	405.0	14370	435.5	54957	416.3	44747	414.3
P_2-3	RD 7	35161	434.1	24520	430.2	14946	373.7	50107	414.1	39466	406.9
	RD 11	42159	425.8	31518	420.2	12152	357.4	54311	408.4	43670	400.6

Remarks: A: Accumulated value (cal/cm^2/period)
Sr: Average daily solar radiation (cal/cm^2/day)

Table 4-6. Average daily maximum air temperature during growing period

Planting cycle-crop	Variety	Seeding to heading		Transplanting to heading		Heading to harvesting		Seeding to harvesting		Transplanting to harvesting	
		A	Max.	A	Max.	A	Max.	A	Max.	A	Max.
P_1-1	RD 7	2806.8	31.9	2056.8	32.1	917.9	34.0	3724.7	32.4	2974.7	32.7
	RD 11	3305.9	32.1	2555.9	32.4	1061.1	35.4	4367.0	32.8	3617.0	33.2
P_1-2	RD 7	3454.4	34.5	2585.8	34.5	1085.2	32.9	4539.6	34.1	3671.0	34.0
	RD 11	3487.6	34.5	2619.0	34.5	1180.5	32.8	4668.1	34.1	3799.5	33.9
P_1-3	RD 7	2826.3	31.4	2046.2	31.0	997.4	28.5	3823.7	30.6	3043.6	30.1
	RD 11	3070.4	31.0	2290.3	30.5	1038.0	29.7	4108.4	30.7	3328.3	30.3
P_2-1	RD 7	3258.8	33.9	2449.8	34.5	1051.5	35.1	4310.3	34.2	3501.3	34.7
	RD 11	3743.7	34.0	2934.7	34.5	1014.5	35.0	4758.2	34.2	3949.2	34.6
P_2-2	RD 7	3135.8	33.0	2304.4	32.5	976.4	31.5	4112.2	32.6	3280.8	32.2
	RD 11	3267.3	33.0	2435.9	32.5	1027.5	31.1	4294.8	32.5	3463.4	32.1
P_2-3	RD 7	2405.2	29.7	1671.1	29.3	1295.5	32.4	3700.7	30.6	2966.6	30.6
	RD 11	2972.9	30.0	2238.8	29.9	1114.0	32.8	4086.9	30.7	3352.8	30.8

Remarks: A: Accumulated value (°C)
Max.: Average daily maximum air temperature (°C)

Table 4-7. Average daily minimum air temperature during growing period

Planting cycle-crop	Variety	Seeding to heading		Transplanting to heading		Heading to harvesting		Seeding to harvesting		Transplanting to harvesting	
		A	Min.	A	Min.	A	Min.	A	Min.	A	Min.
P_1-1	RD 7	1806.3	20.5	1303.9	20.4	659.7	24.4	2466.0	21.4	1963.6	21.6
	RD 11	2169.6	21.1	1667.2	21.1	775.5	25.9	2945.1	22.1	2442.7	22.4
P_1-2	RD 7	2526.9	25.3	1890.8	25.2	811.8	24.6	3338.7	25.1	2702.0	25.0
	RD 11	2551.4	25.3	1915.3	25.2	886.3	24.6	3437.7	25.1	2801.6	25.0
P_1-3	RD 7	2208.5	24.5	1613.2	24.4	661.0	18.9	2869.5	23.0	2274.2	22.5
	RD 11	2452.6	24.8	1857.3	24.8	694.2	19.8	3146.8	23.5	2551.5	23.2
P_2-1	RD 7	2292.0	23.7	1785.2	25.1	765.6	25.5	3057.6	24.3	2550.8	25.3
	RD 11	2645.9	24.1	2139.1	25.2	740.2	25.5	3386.1	24.4	2879.3	25.3
P_2-2	RD 7	2343.0	24.7	1742.2	24.5	771.6	24.9	3114.6	24.7	2513.8	24.6
	RD11	2443.7	24.7	1842.9	24.6	814.8	24.7	3258.5	24.7	2657.7	24.6
P_2-3	RD 7	1731.0	21.4	1148.8	20.2	851.3	21.3	2582.3	21.3	2000.1	20.6
	RD 11	2098.7	21.2	1516.5	20.2	749.4	22.0	2848.1	21.4	2265.9	20.8

Remarks: A : Accumulated value (°C)
Min. : Average daily minimum air temperature (°C).

Table 4-8. Average daily mean air temperature during growing period

Planting cycle-crop	Variety	Seeding to heading		Transplanting to heading		Heading to harvesting		Seeding to harvesting		Transplanting to harvesting	
		A	M	A	M	A	M	A	M	A	M
P_1-1	RD 7	2306.6	26.2	1680.4	26.3	788.8	29.2	3095.4	26.9	2469.2	27.1
	RD 11	2737.8	26.6	2111.6	26.7	918.3	30.6	3656.1	27.5	3029.9	27.8
P_1-2	RD 7	2990.7	29.9	2238.3	29.8	948.5	28.7	3939.2	29.6	3186.8	29.5
	RD 11	3019.5	29.9	2267.2	29.8	1033.4	28.7	4052.9	29.6	3300.6	29.5
P_1-3	RD 7	2517.4	28.0	1829.7	27.7	829.2	23.7	3346.6	26.8	2658.9	26.3
	RD 11	2761.5	27.9	2073.8	27.7	866.1	24.7	3627.6	27.1	2939.9	26.7
P_2-1	RD 7	2775.4	28.9	2117.5	29.8	908.6	30.3	3684.0	29.2	3026.1	30.0
	RD 11	3194.8	29.0	2536.9	29.8	877.4	30.3	4072.2	29.3	3414.3	30.0
P_2-2	RD 7	2739.4	28.8	2023.3	28.5	874.0	28.2	3613.4	28.7	2897.3	28.4
	RD 11	2855.5	28.8	2139.4	28.5	921.2	27.9	3776.7	28.6	3060.6	28.3
P_2-3	RD 7	2068.1	25.5	1410.0	24.7	1073.4	26.8	3141.5	26.0	2483.4	25.6
	RD 11	2535.8	25.6	1877.7	25.0	931.7	27.4	3467.5	26.1	2809.4	25.8

Remarks: A : Accumulated value (°C)
M. : Average daily mean air temperature (°C).

Table 4-9. Average difference between daily maximum and minimum air temperature during growing period (°C)

Planting cycle-crop	Variety	Seeding to heading	Transplanting to heading	Heading to harvesting	Seeding to harvesting	Transplanting to harvesting
P_1-1	RD 7	11.4	11.7	9.6	11.0	11.1
	RD 11	11.0	11.3	9.5	10.7	10.8
P_1-2	RD 7	9.2	9.3	8.3	9.0	9.0
	RD 11	9.2	9.3	8.2	9.0	8.9
P_1-3	Rd 7	6.9	6.6	9.6	7.6	7.6
	RD 11	6.2	5.7	9.9	7.2	7.1
P_2-1	RD 7	10.0	9.4	9.6	9.9	9.4
	RD 11	9.9	9.3	9.5	9.8	9.3
P_2-2	RD 7	8.3	8.0	6.6	7.9	7.6
	RD 11	8.3	7.9	6.4	7.8	7.5
P_2-3	RD 7	8.3	9.1	11.1	9.3	10.0
	RD 11	8.8	9.7	10.8	9.3	10.0

Table 4-10. Water consumption in P_1-1

Weeks after transplanting	Water requirement in depth (mm)	Evapo-ration (mm)	Trans-piration (mm)	Pan evaporation (mm)	T/EP (%)	Evapo-transpiration (mm)
1	5.8	3.6	0.8	4.4	18.2	4.4
2	5.0	3.8	0.3	4.2	7.0	4.1
3	5.9	3.7	1.0	5.1	19.6	4.7
4	6.0	3.2	1.8	5.2	34.6	5.0
5	5.6	3.0	2.2	5.6	39.3	5.2
6	7.8	3.2	3.1	6.8	45.6	6.3
7	7.3	2.4	3.7	5.9	62.7	6.1
8	6.8	1.9	4.4	5.8	75.9	6.3
9	7.5	1.6	5.7	6.8	83.8	7.3
10	7.0	1.9	4.7	6.3	74.6	6.6
11	7.6	2.3	5.1	6.0	85.0	7.4
12	6.8	3.0	3.6	6.3	57.1	6.6
13	8.7	2.8	6.2	7.8	79.5	9.0
Total (mm/91 days)	614.4	254.8	298.2	533.4	—	553.0
Mean (mm/day)	6.8	2.8	3.3	5.9	52.5	6.1

Remarks:
1) RD 7 in the plot of $W_1F_1D_1$ was used for measurement of water consumption.
2) Growing period (from transplanting to harvesting) in P_1-1 is 91 days. (Jan. 13 to Apr. 14)
3) T: Transpiration EP: Pan evaporation
4) Pan evaporation was measured by using a pan 20 cm in diameter: The values are supposedly around 10 percent more than that by using a pan 120 cm in diameter.
5) Water requirement in depth was not proportional to evapotranspiration because the former was influenced by the field conditions around the test field.

Table 4-11. Water consumption in P_1-2

Weeks after transplanting	Water requirement in depth (mm)	Evapo-ration (mm)	Trans-piration (mm)	Pan evaporation (mm)	T/EP (%)	Evapo-transpiration (mm)
1	7.3	6.6	0.9	6.6	13.6	7.5
2	4.9	4.7	0.6	6.3	9.5	5.3
3	6.3	4.6	1.0	6.1	16.4	5.6
4	11.0	5.7	1.1	7.8	14.1	6.8
5	10.0	4.1	2.9	6.1	47.5	7.0
6	13.1	4.4	3.7	8.2	45.1	8.1
7	12.3	3.4	5.5	8.0	68.8	8.9
8	12.0	2.9	5.9	6.3	93.7	8.8
9	16.6	4.9	2.8	7.3	38.4	7.7
10	10.6	3.2	4.5	6.2	72.6	7.7
11	9.9	1.9	5.0	3.8	131.6	6.9
12	11.5	2.4	3.6	4.7	76.6	6.0
13	9.0	2.7	4.1	5.7	71.9	6.8
14	7.8	2.7	2.7	6.2	43.5	5.4
15	4.6	2.8	0.8	4.5	17.8	3.6
16	6.2	3.8	0.0	5.4	0	3.8
Total (mm/108 days)	1,045.5	410.4	315.7	672.8	—	726.1
Mean (mm/day)	9.7	3.8	2.9	6.2	49.3	6.7

Remarks: Growing period in P_1-2 is 108 days (May 13 to Aug. 29).

Table 4-12. Water consumption in P_1-3

Weeks after transplanting	Water requirement in depth (mm)	Evapo-ration (mm)	Trans-piration (mm)	Pan evaporation (mm)	T/EP (%)	Evapo-transpiration (mm)
1	4.6	4.4	0	5.1	0	4.4
2	7.1	4.0	0	4.0	0	4.0
3	5.4	4.2	1.2	5.5	21.8	5.4
4	5.4	3.8	1.8	5.1	35.3	5.6
5	7.2	4.7	1.5	5.5	27.3	6.2
6	7.2	2.5	3.6	4.0	90.0	6.1
7	6.7	2.1	3.4	4.0	85.0	5.5
8	6.5	1.7	4.3	5.0	86.0	6.0
9	7.3	0.9	6.0	4.5	133.3	6.9
10	4.2	1.1	4.1	4.5	91.1	5.2
11	6.7	1.0	4.5	4.4	102.3	5.5
12	5.0	0.9	3.7	4.7	78.7	4.6
13	5.8	1.4	3.1	4.7	66.0	4.5
14	5.5	1.4	2.2	4.9	44.9	3.6
15	6.5	0.3	2.3	4.6	50.0	2.6
Total (mm/101 days)	611.5	239.6	282.7	474.0	—	522.3
Mean (mm/day)	6.1	2.4	2.8	4.7	61.2	5.2

Remarks: Growing period in P_1-3 is 101 days (Sept. 9 to Dec. 19).

Table 4-13. Water consumption in P_2-1

Weeks after transplanting	Water requirement in depth (mm)	Evaporation (mm)	Transpiration (mm)	Pan evaporation (mm)	T/EP (%)	Evapotranspiration (mm)
1	7.6	5.8	0	6.3	0	5.8
2	8.2	5.7	0.5	6.5	7.7	6.2
3	6.9	4.3	1.1	5.7	19.3	5.4
4	10.2	5.1	3.0	7.5	40.0	8.1
5	9.8	4.4	3.5	7.4	47.3	7.9
6	8.9	3.4	4.4	7.2	61.1	7.8
7	11.5	3.2	4.9	7.3	67.1	8.1
8	8.6	2.3	5.1	6.5	78.5	7.4
9	8.7	2.1	6.2	7.0	88.6	8.3
10	7.7	1.7	5.7	6.2	91.9	7.4
11	8.0	2.4	5.3	6.2	85.5	7.7
12	7.9	2.0	5.7	7.2	79.2	7.7
13	8.7	2.0	5.1	6.7	76.1	7.1
14	8.4	1.9	4.6	7.2	63.9	6.5
15	8.2	2.5	4.2	8.5	49.4	6.7
Total (mm/101 days)	872.3	331.6	389.3	689.8	—	729.9
Mean (mm/day)	8.6	3.3	3.9	6.8	53.3	7.2

Remarks: Growing period in P_2-1 is 101 days (Mar. 15 to Jun. 24).

Table 4-14. Water consumption in P_2-2

Weeks after transplanting	Water requirement in depth (mm)	Evaporation (mm)	Transpiration (mm)	Pan evaporation (mm)	T/EP (%)	Evapotranspiration (mm)
1	5.2	5.3	0	6.2	0	5.3
2	5.2	3.8	0.4	3.8	10.8	4.2
3	5.2	4.2	1.2	4.7	25.5	5.4
4	6.4	5.3	1.6	5.7	28.1	6.9
5	5.7	4.1	3.0	6.2	48.4	7.1
6	4.9	3.2	1.7	4.5	37.8	4.9
7	6.1	3.7	2.0	5.3	37.7	5.7
8	4.3	2.7	0.9	3.6	25.0	3.6
9	5.3	2.3	3.9	5.1	76.5	6.2
10	5.6	4.0	1.1	4.0	27.5	5.1
11	3.7	2.2	3.5	5.5	63.6	5.7
12	4.9	3.1	1.9	5.1	37.3	5.0
13	4.4	2.7	3.5	5.5	63.6	6.2
14	5.6	1.6	4.5	4.0	112.5	6.1
15	4.7	1.7	3.1	3.8	81.6	4.8
Total (mm/102 days)	525.4	344.2	216.8	499.6	—	561.0
Mean (mm/day)	5.2	3.4	2.1	4.9	44.0	5.5

Remarks: Growing period in P_2-2 is 102 days (July 15 to Oct. 25).

Table 4-15. Water consumption in P_2-3

Weeks after transplanting	Water requirement in depth (mm)	Evapo-ration (mm)	Trans-piration (mm)	Pan evaporation (mm)	T/EP (%)	Evapo-transpiration (mm)
1	2.9	3.9	0	4.7	0	3.9
2	6.8	3.7	0.4	4.5	8.9	4.1
3	3.8	3.2	0.9	4.6	19.6	4.1
4	8.0	4.0	1.7	4.6	37.0	5.7
5	8.7	3.3	2.1	4.9	42.9	5.4
6	6.7	2.3	2.6	4.6	56.9	4.9
7	6.6	2.4	2.9	4.4	65.9	5.3
8	7.0	1.8	3.9	4.7	83.0	5.7
9	7.5	1.7	3.9	4.4	88.6	5.6
10	4.8	1.3	3.7	4.1	90.2	5.0
11	6.8	1.4	3.9	4.2	92.9	5.3
12	5.2	1.7	2.5	3.9	64.1	4.2
13	4.8	1.3	2.9	5.1	56.9	4.2
14	6.0	2.8	3.4	6.1	55.7	6.2
Total (mm/97 day)	593.5	240.8	240.2	447.5	—	481.0
Mean (mm/day)	6.1	2.5	2.5	4.6	54.4	5.0

Remarks: Growing period in P_2-3 is 97 days (Nov. 10 to Feb. 15).