I. SOIL SCIENCE: STUDIES ON NUTRIENT UPTAKE OF RICE PLANTS IN RELATION TO THE PROPERTY OF SOILS

a. EFFECT OF TEMPERATURE ON NUTRIENT UPTAKE OF RICE

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The effect of temperatures on nutrient absorption levels were studied by rice plants grown in pots. One of the glass-houses with closed windows and the other opened windows are considered as the high and low temperature plots, respectively. In 1959, a Japonica variety, Taichung No. 65 was used. In 1960, both a Japonica and an Indica variety, Taichung no. 65 and Pai-mi-fun, were studied to examine how nutrient absorption and other agronsmic characters behave under the two conditions of temperature. In 1961, the effects of fertilization and different soils will be dealt with. The results of experiments in the past two years are presented below.

Experiment in 1959

The growth habit and nutrient absorption of Taichung no. 65 under different temperatures were investigated in this year. The average temperatures during the growing period in the two glass-houses were as follows.

Table 1. Average temperature in two glass-houses

	1st crop, 1959 (Mar. 26-Aug. 8)	2nd crop, 1969 (Aug 13-Dec. 18)
High temp. plot	30.9°C	29.8°C
Low temp. plot	27.9°C	27.0°C
Difference	3.0°C	2.8°C

Culm length, tiller number and dry plant weight were measured at various growing stages successively. The characters measured at maturity are shown in table 2.

Culm lengths in the first and sccond crops in the high temperature plot were apparently longer than those in the low temperature plot, but tiller number did not show a significant difference. It was found also that high temperatures advanced heading; heading date in the high temperature plot was 7 days earlier than that in the low temperature plot in the first crop, and 4 days earlier in the secoond crop. Total dry weights in the high temperature plot were higher than those in the low temperature plot, especially in the first crop.

Table 2. Growth and yield of rice plants grown under two different temperatures

	1st crop, 1959		2nd crop, 1959	
	High temp. plot	Low temp. plot	High temp. plot	Low temp. plot
Plant height (cm)	116.6	104.0	117.4	111.8
Tiller number	26.6	26.2	26.4	26.8
Total yield (g/pot)	92.2	76.9	101.7	98.1
Grain (g/pot)	13.7	27.2	40.8	31.3
Straw (g/pot)	78.5	49.7	60.9	66.3
Grain/Straw ratio	17/100	55/100	67/100	48/100

However, grain yields appeared to be more complicated. As shown in table 2, grain/straw ratios in the high and low temperature plots were 17% and 55% in the first crop and 67% and 48% in the second crop respectively. In the first crop, high temperatures decreased grain yield, but in the second crop increased on the contrary. This might be because that the high temperature plot in the first crop occasionally had maximum temperatures over 40°C which might have disturbed pollination. In fact, a high proportion of sterile grains resulted, 60% being empty. Grain yield would be thus reduced in the high temperature plot.

It was also found that the ripenning of grains was delayed for more than 10 days in the high temperature plot, letting the plants continue to grow vegetatively. The metabolism in the ripening period of rice plants Murayama (1957) stated that after heading, nutrients were translocated to panicles and the existence of panicles will cause yellowing of leaves and weakening of root activity. If the panicles are removed, the plant may continue to grow up and increase the dry matter weights of other organs to compensate for the loss of panicles.

In the second crop, the grain yields in the high temperature plot were higher than those in the low temperature plot. In the later stage of growth in November and December, since the temperature was too low for the fruiting process of rice, the high temperature plot might have a rather adequate condition for grain production.

The N, P and K contents in plants gradually increased after transplanting. The highest nutrient contents were reached about 50 days after transplanting in the first crop and 25 days in the second crop, and then the figures made a slow dropping till maturity. It was found that the K contents in the high temperature plot, especially in the first crop, were evidently higher than that in the low temperature plot.

In general, the absorption of the three elements by rice plants, especially of potassium, was greatly promoted under high temperatures. Moreover, potassium absorption was larger in the second crop than that in the first crop. This fact is of

interest with regard to the favourable availability of potash fertilizers in the second crop season in which the temperatures are high.

Table 3. Inorganic nutrient contents of rice plants at successive growing stages (% on oven dry basis), 1959

	High temp. plot				Low temp. plot			
	Date	N%	P_2O_5%	K_2O%	Date	N%	P_2O_5%	K_2O%
1st crop	Mar. 26 (planting)	1.14	0.868	1.56		1.14	0.368	1.56
	Apr. 28	3.21	0.860	4.30		3.74	0.875	2.80
	May 15	4.21	0.808	4.56		4.41	0.390	2.35
	June 1	3.23	0.800	3.65		3.71	0.938	1.58
	June 29	1.79	0.657	1.94	July 28	1.55	0.701	0.91
	Aug. 8 (maturity)	1.31	0.580	1.64		1.12	0.550	0.88
	Grain	1.32	0.615	0.64		1.32	0.611	0.62
	Stem	0.75	0.803	1.20		0.73	0.840	1.30
	Leaf	1.46	0.521	1.97		1.10	0.423	0.94
2nd crop	Aug. 13 (planting)	2.86	0.958	3.65		2.86	0.958	3.65
	Sep. 8	3.64	0.985	4.94		3.74	0.943	5.04
	Oct. 1	3.50	0.938	4.42		3.18	0.825	3.65
	Oct. 21	2.20	0.782	3.50		2.28	0.792	2.98
	Nov. 9	1.45	0.660	25.2		1.52	0.644	2.09
	Dec. 18 (maturity)	1.18	0.558	1.83		1.33	0.527	1.61
	Grain	1.40	0.702	0.65		1.58	0.698	0.67
	Stem	0.66	0.682	3.84		0.92	0.534	2.50
	Leaf	1.22	0.355	2.04		1.37	0.394	1.85

Table 4. Amounts of inorganic nutrients absorbed by rice plants at successive growting stages (mg/pot)

	High temp. plot				Low temp. plot			
	Date	N	P_2O_5	K_2O	Date	N	P_2O_5	K_2O
1st crop	Mar. 26 (planting)	1.0	6.7	1.3		1.0	0.7	1.3
	Apr. 28	31.1	8.3	42.1		24.7	5.8	18.5
	May 15	275.7	52.9	298.7		231.5	46.7	123.4
	June 1	699.9	170.7	778.9		671.8	169.9	286.1
	June 29	1,036.8	380.4	1,123.6		730.8	307.9	399.7
	Aug. 8 (maturity)	1,107.0	492.2	1,380.8	July 28	775.1	385.9	613.6
2nd crop	Aug. 13 (planting)	1.6	0.5	2.1		1.6	0.5	2.1
	Sep. 8	65.9	17.8	93.8		93.5	23.6	126.0
	Oct. 1	568.4	152.3	717.2		562.5	145.9	645.3
	Oct. 21	870.8	309.5	1,386.9		888.7	308.7	1,160.0
	Nov. 9	910.6	414.4	1,582.6		936.9	397.0	1,287.0
	Dec. 18 (maturity)	1,059.6	499.9	1,642.1		1,137.6	449.4	1,371.7

The average amounts and indices of N, P_2O_5, K_2O absorbed (per pot) were estimated as follows; N 1,019 mg. (100), P_2O_5 457 mg. (45), K_2O 1,252 mg. (123).

Experiment in 1960

In 1960, the pot experiment was continued in the same two glasvouses in order to find differences in the effect of temperatures on nutrient absorption between two rice varieties. A Japonica variety, Taichung 65 and an Indica variety pai-mi-fun were comparatively investigated.

Table 5. Average temperature in two glass-houses

	1st crop, 1960 (Feb. 24-July 12)	2nd crop, 1960 (July 30-Dec. 5)
High temp. plot	26.6°C	27.9°C
Low temp. plot	24.2°C	25.5°C
Difference	2.4°C	2.4°C

Table 6. Yield and other measurements at maturity

		Japonica (Taichung 65)		Indica (Pai-mi-fen)	
		High temp. plot	Low temp. plot	High temp. plot	Low temp. plot
1st crop	Plant height (cm)	128.6	120.6	153.6	146.0
	Tiller number	22.0	27.4	24.8	26.6
	Total yield (g/pot)	105.2	102.3	102.9	97.2
	Grain (g/pot)	39.6	40.9	45.6	39.8
	Straw (g/pot)	65.6	61.4	57.3	57.4
	Grain/Straw ratio	60/100	67/100	79/100	69/100
2nd crop	Plant height (cm)	123.5	124.3	168.3	162.5
	Tillers number	21.5	17.9	22.0	21.7
	Total yield (g/pot)	82.9	79.9	102.7	93.3
	Grain (g/pot)	36.9	33.5	44.1	37.9
	Straw (g/pot)	46.0	46.4	58.6	55.8
	Grain/Straw ratio	80/100	72/100	75/100	68/100

Elongation was apparently promoted in the high temperature plot, and the dry matter weight of plants was always larger than that in the low temperature plot. This trend was more significant in the first crop than in the second crop.

In the first crop, the high temperatures decreased both grain yield and grain/straw ratio in the Japonica variety, Taichung 65, but in the second crop the high temperatures increased them, in the same manner as in 1959. However, the grain yield of the Indica variety Pai-mi-fun was promoted under high temperatures in both the first and second crops; the two varieties thus seem to differ in temperature response.

The high temperature promoted heading of both varities in the first crop, but did not in the second crop.

Table 7. Heading date under different temperatures

		1st crop, 1960 Heading date	2nd crop, 1960 Heading date
Japonica variety	High temp.	June 8-16	Oct. 17-22
	Low temp.	June 16-25	Oct. 17-22
Indica variety	High temp.	June 2- 6	Oct. 15-22
	Low temp.	June 5- 9	Oct. 15-21

The amount of nutrients absorbed by the plants in the high temperature plot was larger than that in the low temperature plot, as shown in Table 9. In Pai-mi-fun, the increasing of nutrient absorption under high temperatures appeared to result in an increased transmission of nutrients to grains, but in Taichung No. 65, it did not. In this respect, the Japonica varity seemed to be less adaptive to high temperatures than the Indica variety.

Table 8a. Inorganic nutrient contents (% on oven dry basis), 1st crop, 1960

Varutty	Date	High temp. plot			Low temp. plot		
		N%	P_2O_5%	K_2O%	N%	P_2O_5%	K_2O%
Japonica, Taichung No. 65	Feb. 22 (planting)	4.628	2.280	4.464	4.628	2.280	4.464
	Mar. 17	4.324	1.055	5.904	4.660	1.297	5.930
	Mar. 31	4.280	1.075	6.048	4.420	1.010	5.520
	Apr. 14	3.898	1.048	5.222	3.892	1.062	5.356
	Apr. 28	3.803	1.196	5.254	4.278	1.119	4.835
	May 12	2.579	0.866	3.233	3.101	0.862	3.334
	June 2	1.592	0.643	2.155	1.604	0.758	1.818
	June 21	1.207	0.494	1.445	1.251	0.570	1.395
	July 12 (harvesting)	1.086	0.427	1.223	1.039	0.454	1.187
	Grain	1.341	0.610	0.592	1.371	0.581	0.594
	Stam & Sheath	0.630	0.330	1.368	0.609	0.396	1.440
	Leaf Blade	1.564	0.288	2.202	1.338	0.311	1.902
Indica, Pai-mi-fun	Feb. 22 (planting)	4.639	2.160	4.128	4.639	2.160	4.128
	Mar. 17	4.346	1.102	5.856	4.476	1.155	6.144
	Mar. 31	4.492	1.085	6.000	4.422	1.165	6.384
	Apr. 14	3.574	0.950	5.201	3.798	0.999	5.821
	Apr. 28	3.482	0.994	4.239	3.724	0.988	4.630
	May 12	2.448	0.752	2.673	2.254	0.808	2.656
	June 2	1.381	0.485	1.722	1.528	0.650	2.098
	June 21	1.144	0.471	1.370	1.115	0.452	1.314
	July 4 (harvesting)	1.152	0.479	1.302	1.112	0.450	1.269
	Grain	1.591	0.790	0.560	1.532	0.798	0.568
	Stem & Sheath	0.621	0.253	2.060	0.585	0.207	1.886
	Leaf Blade	1.151	0.192	1.572	1.362	0.211	1.401

Table 8b. Inorganic nutrient contents (% on oven dry basis), 2nd crop, 1960

Variety	Date	High temp. plot			Low temp. plot		
		N%	P_2O_5%	K_2O%	N%	P_2O_5%	K_2O%
Japonica, Taichung No. 65	July 30 (planting)	3.000	0.846	3.360	3.000	0.846	3.360
	Aug. 29	3.576	0.814	4.903	3.127	0.785	5.238
	Sep. 20	3.146	0.650	3.855	3.121	0.651	3.926
	Oct. 12	2.324	0.739	2.886	2.254	0.712	2.920
	Nov. 1	1.674	0.651	2.072	1.623	0.569	2.020
	Dec. 5 (harvesting)	1.581	0.580	1.730	1.414	0.531	1.707
	Grain	1.690	0.740	0.552	1.650	0.708	0.588
	Stem & Sheath	1.260	0.495	2.808	1.010	0.448	2.628
	Leaf Balde	2.080	0.345	1.730	1.800	0.299	2.244
Indica, Pai-mi-fun	July 30 (planting)	3.310	0.958	3.984	3.310	0.958	3.984
	Aug. 29	3.995	0.590	5.771	3.734	0.471	5.279
	Sep. 20	3.128	0.593	3.715	2.891	0.858	3.142
	Oct. 12	1.672	0.506	2.391	1.591	0.575	2.008
	Nov. 1	1.196	0.484	1.654	1.145	0.543	1.676
	Nov. 22 (harvesting)	1.107	0.411	1.412	0.974	0.425	1.298
	Grain	1.470	0.602	0.576	1.370	0.685	0.600
	Stem & Sheath	0.700	0.279	2.352	0.580	0.270	1.992
	Leaf Blade	1.130	0.244	1.356	0.960	0.243	1.272

Table 9a. Distribution of inorganic nutrients in the plant, 1st crop, 1960

Variety	Plot	Part	N	P_2O_5	K_2O
			mg/pot (Index)	mg/pot (Index)	mg/pot (Index)
Japonica, Taichung No. 65	High temp. plot	Grain	531.0 (47)	241.5 (54)	234.4 (18)
		Stem & Sheath	281.0 (25)	147.2 (33)	610.1 (47)
		Leaf Blade	328.4 (29)	60.5 (13)	442.6 (35)
		Total (Index)	1,140.4(100) (100)	449.2(100) (39)	1,287.1(100) (113)
	Low temp. plot	Grain	550.5 (52)	237.6 (51)	242.9 (20)
		Stem & Sheath	258.2 (24)	167.9 (36)	610.6 (50)
		Leaf Blade	254.2 (24)	59.1 (13)	331.4 (30)
		Total (Index)	1,062.9(100) (100)	464.6(100) (44)	1,214.9(100) (114)
Indica, Pai-mi-fun	High temp. plot	Grain	725.5 (61)	360.2 (73)	255.4 (19)
		Stem & Sheath	234.1 (20)	95.4 (19)	776.6 (58)
		Leaf Blade	225.6 (19)	37.6 (8)	308.1 (23)
		Total (Index)	1,185.2(100) (100)	493.2(100) (42)	1,340.1(100) (113)
	Low temp. plot	Grain	609.7 (56)	317.6 (73)	226.1 (18)
		Stem & Sheath	233.4 (22)	82.6 (19)	762.5 (62)
		Leaf Blade	238.4 (22)	36.9 (8)	245.1 (20)
		Total (Index)	1,081.5(100) (100)	437.1(100) (40)	1,233.7(100) (114)

Table 9b. Distribution of inorganic nutrients in the plant, 2nd crop, 1960

Variety	Plot	Part	N	P_2O_5	K_2O
			mg/pot (Index)	mg/pot (Index)	mg/pot (Index)
Japonica, Taichung No. 65	High temp. plot	Grain	632.6 (48)	273.1 (56)	203.7 (14)
		Stem & Sheath	414.2 (32)	162.7 (34)	923.1 (64)
		Leaf Blade	273.0 (21)	45.3 (9)	307.1 (21)
		Total (Index)	1,310.8(100) (100)	481.1(100) (37)	1,433.9(100) (109)
	Low temp. plot	Grain	552.1 (49)	236.9 (56)	196.7 (14)
		Stem & Sheath	329.5 (29)	146.2 (34)	857.5 (63)
		Leaf Blade	247.7 (22)	41.1 (10)	308.8 (23)
		Total (Index)	1,129.3(100) (100)	424.2(100) (38)	1,363.0(100) (121)
Indica, Pai-mi-fun	High temp. plot	Grain	647.5 (57)	265.2 (63)	253.7 (17)
		Stem & Sheath	282.3 (25)	112.5 (27)	948.4 (65)
		Leaf Blade	207.1 (18)	44.7 (10)	248.5 (17)
		Total (Index)	1,136.9(100) (100)	422.4(100) (37)	1,450.6(100) (128)
	Low temp. plot	Grain	560.3 (58)	269.1 (64)	254.4 (20)
		Stem & Sheath	234.8 (24)	109.3 (26)	806.3 (63)
		Leaf Bade	171.8 (18)	43.5 (10)	227.7 (18)
		Total (Index)	966.9(100) (100)	421.9(100) (44)	1,288.4(100) (133)

DISCUSSION

Oka: It might be desired to investigate the assimilation rate of plants to find whether or not there are varietal differences in such specific growing characters between the two varieties and between temperature treatments. The method of measuring assimilation rate, so called "growth analysis" was reported in detail by J. Tsunoda (Agr. & Hort, Janan, Vol. 33, 1958)

Hsu: Mr. Chiu and Mr. Wu may adopt the growth analysis method as suggested in future.

Oka: I wonder why the growing periods were so long, especially, in the second crop the maturity in the middle of December. The date obtained could not be applied for explaining of those from field experiments.

Chiu: According to our experiences, pot culture in a glass-house brings about a longer growing period than field culture. I will try to start experiments earlier in future.

Ku: The temperatures in the glass-house, even in the low temperature plot, were higher than those in the field condition. The temperatures in the high temperature plot were extremely high, which might be undoubtedly an abnormal condition for plant growth. The installation of air-conditioner, or water spraying on the roof of glasshouse, would be necessary for realizing field temperatures.

Chiu: Owing to the lack of installations for lowering temperature, we could only

used the present two glass-houses.

Tan: You didn't give any statististical analysis of the data for interpretation, Differences in absorbed nutrients between temperature treatments may be doubtful if no statistical methods are taken.

Chiu: We haven't had enough time. I wish you can help me.

Hsu: Your experiment showed that high temperatures increased dry weights and nutrient absorption, but the absorbed nutrients might be consumed for straw formation leaving little for the production of grains. That is a point of interest in relation to low yield of rice in tropical countries. I hope that more penetrating researchs on the mechanism of yield determination from the view-point of nutriophysiology be carried out.

Chiu: High temperatures are harmful for grain formation in the Japonica variety, Taichung no. 65. However, the Indica variety, Pai-mi-fun appeared to be adapted to higher temperatures. Transmission of absorbed nutrients under high temperatures should be studied.

Hsu: The status of nutrients in soils under different temperatures is also important to be investigated in future.