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Physiological Studies of Rice Tillers
II. Productivity of Varieties Differing in Grain Volume[1]

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Abstract : Amount of dry matter, total nitrogen and total nonstructural carbohydrates (TNC) in the leaf blades, leaf sheaths and stems from various node positions, as well as panicles, of rice tillers were analyzed at stages of grain development. The purpose of this study was to compare the potential of productivity between a large-grain variety Mira and a medium-grain variety Tainung No. 67. Nitrogen concentrations in various organs of Mira tillers were significantly higher, whereas TNC concentrations were lower, than those of Tainung No. 67 tillers. When compared to Mira on a per tiller basis, Tainung No. 67 produced 14-55% less dry matter and 36-39% less TNC during the test period. For a mature panicle from a single tiller, the amounts of dry matter and TNC accumulated by Tainung No. 67 were only 61-74% and 63-80%, respectively, of those accumulated by Mira. Those results indicated that the productivity per tiller was greater for the large-grain variety. As panicle number per hill was very low for Mira, community productivity was 50% higher for Tainung No. 67 in the first crop but was comparable between varieties in the second crop. No difference in the increase rates of major components in panicles was found between varieties, indicating the absolute amount of translocation into panicles was greater for Mira. Results suggested that yield increase through enlarging grain size was possible. However, responses of the large-grain rice to the environmental factors should be further understood.

In a previous report [13] we found that for the first crop rice grown in Taichung area, up to 20% of total nonstructural carbohydrates in rice tillers remained in the vegetative organs at maturity. We therefore hypothesized that the limitation to the yield of the first crop rice was sink size rather than source capacity, and yield increase of 20% was possible providing that panicle volume could be enlarged to accept the more than enough photosynthates produced by the leaf blades during grain-filling.

Rice yield can be enhanced by increasing the value of any one of the four yield components without simultaneously affecting the performance of the others. Panicle number per hill, which was the main factor in causing the low yield of the second crop rice [14], has been considered as adequate for rice grown in the first crop season. Further improvement might be difficult especially for the machine-transplanted rice with a na-

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rrow spacing of 30×15cm.

Spikelet number per panicle and the percentage of seed-setting are usually negatively correlated[6]. According to Ishizuka[3], 80 spikelets per panicle and seed-setting rate of 85%, along with 400 panicles/m^2 and 1,000-grain-weight of 22g, were ideal for rice yield of 6 t/ha. In Taiwan, it is not uncommon that rice panicle has 100-150 skikelets and over 90% of them are able to bear well-developed seeds in the first crop season. In other words, yield increase through increasing spikelet number per panicle and seed-setting percentage would not be very effective.

The size of rice grains is limited by the surrounding hulls[6]. Thousand-grain-weight of most commercial varieties is around 23-25g. However. seed weight of many large-grain varieties is as high as 40-45mg. Theoretically, an increase of seed weight from 25mg to 30mg means 20% increase in grain yield. The problems remain as whether or not the photosynthetic productivity during the period of grain-filling can meet the demands by the large-volume panicles.

The objective of this study was to examine the potential of dry matter production of a large-grain rice variety on a per tiller and community basis. The distribution of total nonstructural carbohydrates and nitogen among different tiller fractions was studied. A medium-grain commercial variety was also included for comparison.

Materials and Methods

A japonica, large-grain (1, 000-grain-weight about 37g) rice cultivar introduced from the Philippines, Mira, and a japonica, medium-grain cultivar, Tainung No. 67 were grown at the experimental farm of Taiwan Agricultural Research Institute in 1981. In the first crop, transplanting date was Feb. 20 and heading date was April 28 for Mira and May 11 for Tainung No. 67. In the second crop, transplanting was on Aug. 10 and heading on Sept. 25 and Oct. 13 for Mira and Tainung No. 67 respectively. Maturity date was 5 weeks after heading in the first crop and harvest was made 4 weeks after heading in the second crop. The early harvest of the second crop rice wsa due to the heavy infestation of brown plant hopper.

Seedlings were raised in the field until at the leaf age of 4.5-5.0 and transplanted by hand at a spacing of 25×25cm. Plots, sized at 7.5×5m, were arranged in a randomized complete block design with three replications. Before transplanting, N, P_2O_5 and K_2O were applied to all plots at, respectively, 60, 60 and 50kg/ha in the first and 65, 60 and 50kg/ha in the second crop. Additional nitrogen at a rate of 30kg/ha each was topdressed twice in both crops.

At least 8 hills of rice plants including roots were harvest from each plot at a week's interval between heading and maturity. The collected plants were cleaned with tap water and 80 large tillers of each variety were selected and combined. Only the above-ground portion was kept and the samples were further divided according to the position of the nodes on a basipetal basis. The uppermost node was designated as the first node. Leaf blade, leaf sheath and stem from ther same node were separated as individual samples. Tose samples from the 4th and lower nodes were combined. Panicle was divided separately.

Samples were dried in a forced draft oven at 100°C for 2 hrs follwed by 70°C for 24 hrs. After dry weight had been determined, the samples were ground with a Wiley mill through a 40-mesh screen. Concentration of total nonstructural carbohydrates was then determined according to Smith[11]. Nitrogen was determined by the Kjeldahl procedures.

Results on the dry weight of the same plant fraction (leaf blade, leaf sheath or stem) from various node positions were pooled and reported. Comparison between the developmental stages of heading and maturity was emphasized. Changes in concentrations of N and total nonstructural carbohydrates of different plant parts during grain-filling were also discussed in terms of physiological importance.

Results

I. N concentrations in tiller organs during grain-filling

N concentrations of the leaf blades, leaf sheaths. stems and panicles at stages of grain development were indicated in Table 1. It was generally true that the upper leaf blades had higher N concentrations than the lower ones. Leaf blade N percentages were highest at heading and decreased continuously thereafter for either variety in both crops. For rice tillers grown in the first crop season, Mira contained more N in the leaf blades than Tainung No. 67 during the first two weeks of grain development. However, the concentrations were higher in Tainung No. 67 leaves during the subsequent period of grain-filling. In contrary, leaf N was consistently higher for Mira than for Tainung No. 67 up to three weeks after heading in the second crop.

Table 1 also showed that at the stage of heading, leaf N was higher in the first (2.24—3.14%) than in the second (2.20-2.16%) crop for Tainung No. 67 and was comparable between the two crops (2.88-3.52%) for Mira tillers. N concenrtations decreased faster thereafter in the first crop season as they were higher in the second crop between one and four weeks after heading. Final concentrations of N in the leaf blades at four weeks after heading were, respectively, 0.51-1.62% and 1.10 1.99% in the first and second crops for Tainung No. 67. Corresponding values for Mira were 0.85-0.93% and 0.94-1.89%.

Similar pattern of changing N concentrations in the leaf sheaths and stems was recorded (Table l). N concentrations were higher in the leaf sheaths than in the stems and decreased continuously in both organs towards maturity. The second crop and Mira variety had higher N concentrationts than the first crop and Tainung No. 67, respectively.

Panicle N concentrations showed little fluctuation during grain-filling. The only exception was Tainung No. 67 in the second crop which decreased from 1.22% at heading to 0.88% at harvest. The concentrations at matruity were around 1.3% for Mira which was significantly higher than the 0.88-0.99 % of Tainung No. 67 tillers.

Table 1. Nitrogen concentrations (%, dry basis) in different plant fractions of Tainung No. 67 and Mira rice tillers at stages (weeks after heading) of grain-filling.

Variety	Tiller Fraction[a]	First Crop						Second Crop				
		0	1	2	3	4	5	0	1	2	3	4
Tainung No. 67	1st leaf	3.14	2.70	2.27	1.91	1.62	1.30	2.61	2.89	2.77	2.30	1.99
	2nd leaf	2.69	2.21	1.93	1.51	0.82	0.55	2.50	2.33	2.30	2.06	1.58
	3rd leaf	2.24	1.90	1.56	1.09	0.51	0.50	2.20	2.06	1.95	1.77	1.10
	Leaf sheath	0.64	0.57	0.51	0.43	0.35	0.39	0.69	0.67	0.59	0.49	0.51
	Stem	0.55	0.40	0.32	0.28	0.26	0.31	0.58	0.47	0.37	0.35	0.31
	Panicle	1.04	0.96	0.98	0.96	0.97	0.99	1.22	1.08	1.00	0.93	0.88
Mira	1st leaf	3.36	3.31	2.44	1.22	0.93	0.93	3.52	3.45	3.23	2.72	1.89
	2nd leaf	3.41	2.80	2.34	1.22	0.92	0.87	3.36	3.34	2.83	2.36	1.60
	3rd leaf	2.88	2.41	1.97	0.91	0.85	0.77	2.88	2.73	2.43	1.82	0.94
	Leaf sheath	1.02	0.77	0.71	0.53	0.50	0.51	1.29	1.05	0.85	0.73	0.62
	Stem	0.93	0.58	0.38	0.36	0.41	0.39	1.36	1.25	0.67	0.58	0.51
	Panicle	1.46	1.36	1.35	1.29	1.35	1.38	1.28	1.25	1.35	1.38	1.37

[a]Leaf blades were sequenced basipetally according to the position of nodes on tillers; combined data of leaf sheaths and stems from various node positions were presented.

II. TNC concentrations in tiller organs during grain-filling

Table 2 showed that concentrations of total nonstructural carbohydrates (TNC) in the leaf blades decreased slowly but continuously during the whole period of grain development. Mira had higher TNC percentages (5.5% and 8.3% in the first and second crops, respectively) than Tainung No. 67 (3.9% and 4.1%) at heading. However, final concentrations at harvest were similar between the two varieties in the first crop (about 2%). It was much higher foe Tainung No. 67 (4.2%) than for Mira (2%) in the second crop.

TNC concentrations were lower in the uppermost and lowest leaf sheaths than in the middle (2nd and 3rd from top) leaf sheaths at any stage of grain-filling. The decreases in TNC concentrations were most pronounced between the first and second weeks after heading in both crops. It was also found that the first crop contained more TNC in the leaf sheaths than the second crop. Tainung No. 67 tillers were also higher in sheath TNC than Mira, especially in the second crop season.

Stems had very high TNC concentrations at heading (Table 2). Highest values were recorded in the lower stem sections, e. g., 40% for Tainung No. 67 and 30% for Mira in the first crop. Those values in the second crop were around 30% and from 13% to 27% for the two varieties, respectively. Marked decreases in stem TNC were also found between the first and second weeks after heading which coincided with the period of rapid grain-filling.

Table 2. Concentrations of total nonstructural carbohydrates (%, dry basis) in different plant fractions of Tainung No. 67 and Mira rice tillers at stages (weeks after heading) of grain-filling.

Variety	Tiller Fraction[a]	First Crop						Second Crop				
		0	1	2	3	4	5	0	1	2	3	4
Tainung No. 67	Leaf blade	3.9	3.4	2.9	1.9	2.3	1.6	4.1	3.8	3.0	2.0	4.2
	1st sheath	6.8	5.3	3.1	1.0	2.0	2.1	6.5	3.5	3.2	1.2	3.1
	2nd sheath	16.1	11.3	6.6	1.6	2.3	1.8	11.5	10.5	6.0	2.5	2.7
	3rd sheath	20.0	13.6	5.4	1.4	1.6	1.0	13.5	13.0	6.5	1.5	1.9
	4th sheath	15.0	9.0	2.8	0.7	1.4	0.6	6.3	6.4	2.8	1.5	1.2
	1st stem	17.1	18.3	7.0	2.3	3.0	2.5	12.3	10.0	10.0	2.8	3.2
	2nd stem	34.5	32.2	25.1	5.8	5.5	9.5	25.2	25.9	25.2	8.2	6.4
	3rd stem	40.3	32.0	25.3	3.8	4.7	11.1	30.2	31.9	25.0	6.6	4.6
	4th stem	40.6	29.1	23.3	2.7	3.5	10.6	31.8	32.3	22.4	4.8	3.0
	Panicle	5.0	26.4	50.5	58.4	61.5	61.6	4.5	9.6	40.6	51.4	58.1
Mira	Leaf blade	5.5	6.4	3.2	3.0	2.6	2.1	8.3	7.1	4.1	3.7	2.0
	1st sheath	6.8	5.4	4.1	4.2	5.3	4.8	5.4	5.0	2.6	2.0	1.6
	2nd sheath	10.8	10.3	6.5	3.3	2.7	2.1	6.8	8.2	2.5	1.8	1.4
	3rd sheath	14.2	15.0	10.1	2.5	3.2	2.6	6.3	6.3	2.6	1.5	1.0
	4th sheath	14.4	12.4	8.2	1.6	1.0	1.0	3.0	3.2	1.5	1.3	0.8
	1st stem	12.2	27.3	9.4	3.2	3.0	2.5	13.0	23.8	5.0	2.1	1.6
	2nd stem	22.5	37.8	19.4	5.5	6.2	5.7	27.6	35.8	7.1	2.4	2.1
	3rd stem	29.8	36.8	24.8	5.3	7.3	7.1	26.7	35.7	7.5	2.7	1.6
	4th stem	31.0	34.4	24.9	6.5	12.7	12.8	13.4	25.1	5.9	2.4	1.2
	Panicle	4.7	22.1	46.2	55.7	55.9	56.0	5.9	10.4	42.7	57.4	58.3

[a]Leaf sheaths and stems were sequenced basipetally according to the position of nodes on tillers; combined data of leaf blades from various node positions were presented.

Panicles just extruded from the embedding leaf sheaths possessed only 5% of their dry matter as TNC. In one week, the concentrations increased to 22-26% in the first but only 10% in the second crop. TNC deposition into panicles of Tainung No. 67 tillers was completed within a duration of 4 weeks in both crops (Table 2). The mature panicle contained 61% of TNC in the first crop and 56% in the second crop. The duration of grain filling for the large-grain Mira tillers was shorter (3 weeks) than that of Tainung No. 67. Final concentrations were 56% and 58% for the first and second crop, respectively.

III. Changes in the amounts of dry matter, N and TNC during-filling

Dry weights of different plant fractions of rice tillers at heading and maturity were shown in Table 3. For the variety Tainung No. 67, total dry weight per tiller at heading was 3,140mg in the first crop and 2,990mg in the second crop. Dry weight increased to 4,480mg at maturity, or a net dry matter accumulation of 1,340mg, for the first crop. The increase was 1,550mg, or 210mg higher, for tillers grown in the second crop season. For Mira, dry weight increased from 3,290mg at heading to 6,250mg at maturity in the first crop and from 4,100mg to 5,900mg in the second crop. Those results indicated that net dry matter production of Mira tillers during grain-filling was higher in the first (2,960mg) than in the second crop (1,800mg).

Table 3. Changes in dry weight (mg/tiller) of Tainung No. 67 and Mira rice tillers from heading to maturity

Variety	Tiller Fraction	First Crop			Second Crop		
		Heading	Maturity	Difference	Heading	Maturity	Difference
Tainung No. 67	Leaf blade	670	550	− 120	820	820	0
	Leaf sheath	1,040	800	− 240	980	990	+ 10
	Stem	870	620	− 250	750	690	− 60
	Panicle	540	2,510	+ 1,970	440	2,040	+ 1,600
	Small tiller[a]	20	0	− 20	0	0	0
	Total	3,140	4,480	+ 1,340	2,990	4,540	+ 1,550
Mira	Leaf blade	830	610	− 220	1,050	770	− 280
	Leaf sheath	1,100	870	− 230	1,100	900	− 200
	Stem	870	1,020	+ 150	1,060	900	− 160
	Panicle	490	3,410	+ 2,920	670	3,330	+ 2,660
	Small tiller[a]	0	340	+ 340	220	0	− 220
	Total	3,290	6,250	+ 2,960	4,100	5,900	+ 1,800

[a]Small tillers originated from above-ground nodes of the sampled large tillers.

Despite the similar total tiller dry weight at heading of the two varieties in the first crop. Mira accumulated 40% more dry matter than Tainung No. 67 at the time of maturity. Panicle weight was also 36% higher for Mira (3,410mg vs. 2,510mg). Average panicle weight of Tainung No. 67 tillers in the second crop was 2,040mg or 470mg lower thna that in the first crop. However, the difference was only 80mg per panicle for Mira tillers between the two rice crops.

The amounts of N present in different plant fractions were shown in Table 4. For either crop or variety, the largest amount of N was recovered in the leaf blades at heading and in the panicles for the mature rice tillers. There was a consistent loss of N from leaf blades, sheaths and stems and a significant N deposition into panicles during the test period. The loss of N from vegetative organs was 11.8-19.0mg per tiller

for Tainung No. 67 and 29.4-37.7mg for Mira. On the other hand, grain of N by developing panicles was 12.6-18.8mg for Tainung No. 67 and 37.0-38.8mg for the large-grain Mira. Comparison between heading and maturity showed that rice tillers contained similar amount of N with the exception of Mira in the first crop where an increase of 12.8mg per tillers was recorded.

Table 4. Changes in the amount of nitrogen (mg/tiller) in Tainung No. 67 and Mira rice tillers from heading to maturity.

Variety	Tiller Fraction	First Crop			Second Crop		
		Heading	Maturity	Difference	Heading	Maturity	Difference
Tainung No. 67	Leaf blade	16.4	4.8	− 11.6	18.3	10.6	− 7.7
	Leaf sheath	6.6	2.8	− 3.8	6.8	5.0	− 1.8
	Stem	4.8	1.6	− 3.2	4.4	2.1	− 2.3
	Panicle	5.6	24.4	+ 18.8	5.4	18.0	+ 12.6
	Small tiller[a]	0.4	0.0	− 0.4	0.0	0.0	0.0
	Total	33.8	33.6	− 0.2	34.9	35.7	+ 0.8
Mira	Leaf blade	23.6	5.1	− 18.5	31.0	10.8	− 20.2
	Leaf sheath	11.3	4.4	− 6.9	12.5	6.1	− 6.4
	Stem	8.1	4.1	− 4.0	10.1	3.6	− 6.5
	Panicle	7.1	46.0	+ 38.9	8.6	45.6	+ 37.0
	Small tiller[a]	0.0	3.3	+ 3.3	4.6	0.0	− 4.6
	Total	50.1	62.9	+ 12.8	66.8	66.1	− 0.7

[a]Small tillers originated from above-ground nodes of the sample large tillers.

The production and distribution of TNC in rice tillers were shown in Table 5. It was obvious that Tainung No. 67 contained more TNC in the mature panicles in the first crop (1,528mg per panicle) than in the second crop (1,184mg). Panicles of Mira, on the other hand, possessed 25% more TNC than those of Tainung No. 67 in the first crop and 59% more in the second crop. Net accumulation of TNC in the whole tiller was also significantly higher for Mira rice, especially in the second crop season. Results also showed that at the time of harvest, 92-98% of TNC present in the tillers had been deposited into panicles, suggesting hign efficieny of utilizing TNC for economic production of the rice varieties tested. Contribution of pre-heading storage to panicle TNC was, respectively. 20% and 15% for Tainung No. 67, and 11% and 13% for Mira in the first and second crops under the assumption that the translocation efficiency was 70%.

Table 5. Changes in the amount of total nonstructural carbohydrates (mg/tiller) in Tainung No. 67 and Mira rice tillers from heading to maturity

Variety	Tiller Fraction	First Crop			Second Crop		
		Heading	Maturity	Difference	Heading	Maturity	Difference
Tainung No. 67	Leaf blade	26	13	− 13	34	34	0
	Leaf sheath	148	15	− 133	85	20	− 65
	Stem	310	26	− 284	211	29	− 182
	Panicle	28	1,528	+ 1,500	20	1,184	+ 1,164
	Small tiller[a]	3	0	− 3	0	0	0
	Total	515	1,582	+ 1,067	350	1,267	+ 917
Mira	Leaf blade	45	16	− 29	88	16	− 72
	Leaf sheath	131	29	− 102	58	11	− 47
	Stem	246	85	− 161	221	15	− 206
	Panicle	23	1,906	+ 1,883	40	1,878	+ 1,838
	Small tiller[a]	0	71	+ 71	15	0	− 15
	Total	445	2,107	+ 1,662	422	1,920	+ 1,498

[a]Small tillers originated from above-ground nodes of the sample large tillers.

IV. Comparison on productivity between varieties on single tiller and community bases

Numbers of panicle per hill at harvest were 16.1 and 14.9 for Tainung No. 67 in the first and second crops, respectively. Corresponding values for Mira were 7.6 and 9.8 (data not shown). Multiplication of the results in Tables 3-5 (based on single tiller study) by panicle number per hill was presumed to be the performance of whole plant. Taking the figures of Mira as 1.00, the ratios of some characters between the medium-grain Tainung No. 67 and large-grain Mira were shown in Table 6.

Table 6. Comparisons on the ratios of some characters between single-tiller and community performances of Tainung No. 67 and Mira rice at maturity[a]

Crop Season	Tiller Fraction	Dry Matter Accumulated		Amount of N Absorbed		Amount of TNC Produced	
		Single tiller	Community	Single tiller	Community	Single tiller	Community
First	Panicle	0.74	1.55	0.53	1.13	0.80	1.70
	Total	0.72	1.51	0.53	1.13	0.75	1.58
Second	Panicle	0.61	0.94	0.40	0.60	0.63	0.97
	Total	0.77	1.16	0.54	0.82	0.66	1.00

[a]Amount of dry matter (N, TNC) in Mira divided by amount of dry matter (N, TNC) in Tainung No. 67.

One Tainung No. 67 tiller yielded 72-77% of dry matter and 66-75% of TNC when compared with Mira tiller. The amount of N present in a Tainung No. 67 tiller at harvest was only 53-54% of that in a Mira tiller. The community performances were reversed. For example, production of dry matter and TNC per hill of plant was 50% more for Tainung No. 67 in the first crop and about the same as Mira in the second crop. Those results indicated higher potential of productivity for single Mira tiller but less production in the actual field circumstance.

Discussion

Generally, N concentrations in the leaf blades were higher in the second than in the first crop during the whole period of grain-filling (Table 1). This was in accordance with the results of Chen *et al*[1] and Wei *et al*[13]. Oritani *et al*[10] reported that photosynthetic rate of rice leaves was positively correlated with concentrations of total N, soluble protein and fraction-I protein. For rice grown in Taiwan, Chen *et al.*[1] also suggested that the composition of N-containing compounds was more important than N concentration to the physiological activity of rice plant.

Although Yoshida[15] estimated that the critical N concentration for a high leaf photosynthetic rate was 2%, the fact that Mira contained more N in the leaf blades and culms than Tainung No. 67 indicated varietal difference in the ability of obtaining N from soils. Table 3 showed that the potential of dry matter production during grain-filling was significantly higher for Mira tillers. Whether or not the two phenomena were interrelated has yet to be determined. However, Tanaka[12] reported that photosynthetic rate of rice leaves was curvilinearly correlated to N concentration up to 3% or higher.

In contrast to the results on N, concentrations of TNC in the leaf sheaths and stems were significantly higher for Tainung No. 67 at the stage of heading, especially in the first crop. Many reports[7,15] indicated an inverse correlation between N and TNC accumulation. However, in view of the marked increase in TNC concentration in Mira stems during the first week of grain development, the relationship between N and TNC was more complex and subjected to the influences of rice growth and differentiation *per se*.

The rapid decline of TNC concentrations in the vegetative organs between 2 and 4 weeks after heading was in good agreement with the rate of TNC accumulation in the panicles. In other words, a relatively large amount of TNC was retranslocated from culms to the developing panicles during this period, as reported by Cock and Yoshida [2]. In the first crop season, TNC concentration of the lower stem sections increased gradually starting from the third week after heading. The continued deposition of TNC into stems indicated clearly that stems had replaced panicles as sink demanding photosynthates from the still active leaf blades. Similar result has been obtained by this laboratory (unpublished data) which has led to the conclusion that the limitation to grain yield was different between the first and second rice crops.

According to Murata and Matsushima[9], all vegetative parts stopped growing after flowering. For Mira rice grown in the first crop of this study, it was found that depo-

sition of dry matter into stems continued during grain-filling. A possible explanation was that TNC transport to the panicles was limited by some unknown factors and TNC accumulation in the stems occurred. The increase in total dry weight during grain-filling usually showed a close correlation with grain yield[8]. Unpublished data of this laboratory found exceptions against such rule, suggesting the distribution efficiency of dry matter was important to the yield performance of rice crops. However, comparison between the two varieties (Table 3) did show a parallel relationship between dry weight increase in whole tiller after heading and panicle weight at harvest. In other words, the large-grain Mira rice possessed a pronounced higher potential in dry matter production on a per tiller basis than the medium-grain Tainung No. 67.

The net production of TNC per tiller during grain development was also significantly higher for Mira (Table 5). Difference between varieties was more pronounced in the second crop season. Those facts, along with the performances of dry matter accumulation mentioned above, clearly indicated that the productivity of single tiller was higher for Mira rice with large panicle volume. It was also suggested that yield potential of the commercial varieties was able to be increased through the improvement of genetic backgrounds.

Table 6 showed different results when productivity of the two varieties were compared on community basis. The poor performance of the large-grain Mira in the field was due mainly to the fewer panicle number per hill, or the low tillering ability. It might be possible to enhance its productivity by narrowing the planting spacing from 25×25cm to, for example, 30×15cm or even narrower. However, the responses of this variety or other large-grain rice varieties to the environmental conditions remained to studied. On the other hand, if panicle number per hill of Tainung No. 67 at heading was reduced artificially from 14-16 to 7-9, one would expect higher production per tiller of dry matter and TNC during the period of grain-filling. However, as the sink volume of this medium-grain variety was limited, significant increase in productivity could not be expected. In other words, panicle size was an important factor in determining the amount of photosynthates produced by the vegetative organs.

The amount of TNC in the panicles at harvest was about 45-90 times higher than that at heading (Table 5), indicating extremely active translocation of TNC into the panicles. When the rate was expressed as per cent of the amount at maturity, TNC deposition was generally slower than dry matter and N deposition. The results of this study were also in accordance with those of MacGregor *et al.*[5] which showed that total Kjeldahl N increased at the same rate as dry matter in barley kernels. Based on the above information, it was found that the translocation of N was faster and earlier than that of TNC, at least during the early grain-filling period.

The increase rates of major components in the large-grain Mira panicles were comparable or higher than those of the medium-grain Tainung No. 67. However, the demand of various constituents by single grain or grains per panicle of Mira rice was certainly higher than those of Tainung No. 67. In addition to total dry matter and N, Liu *et al.*[4] found the naked, largekernel (40-56mg) barley varieties Hiproly and CI-4362 required

more mineral elements for kernel development that the commercial varieties (kernel weight about 30mg). It was thus important to study the balance between supply and demand of various components in terms of obtaining high productivity of large-grain rice varieties.

In conclusion, we found that the panicle volume, or sink size, of the large-grain variety Mira was at least 30% greater than that of the commercial variety Tainung No. 67. The potential of producing dry matter and TNC and absorbing N during the period of grain-filling on a per tiller basis was also significant higher for Mira. As the tillering ability was very poor, community productivity was 50% lower than that of Tainung No. 67 in the first crop. We suggested that the productivity of commercial rice varieties could be further increased by enlarging the panicle size, mainly through increasing grain size. However, the responses of such ideal rice type to environmental factors, e. g., temperature, spacing, N requirement, etc., should be further understood.

Literature Cited

1. Chen, C. S., D. D. Huang, M. C. Shen and D. J. Liu. 1980. Carbohydrate, N, P and K status of developing rice (*Oryza sativa* L.) plants grown in the first and second crop seasons in Taiwan. J. Agri. Res. China 29 : 81-92.
2. Cock, J. H. and S. Yoshida. 1972. Accumulation of ^{14}C-labelled carbohydrate before flowering and its subsequent redistribution and respiration in the rice plant. Proc. Crop Sci. Soc. Japan 41 : 226-234.
3. Ishizuka, Y. 1969. Engineering for higher yields. *In* Physiological aspects of crop yield (J. D. Eastin, F. A. Haskins, C. Y. Sullivan and C. H. M. van Baveleds.). Amer. Soc. Agron., Madison.
4. Liu, D. J., Y. Pomeranz and G. S. Robbins. 1975. Mineral content of developing and malted barley. Cereal Chem. 52 : 678-686.
5. MacGregor, A. W., D. E. Laberge and W. O. S. Meredith. 1971. Changes in barley kernels during growth and maturation. Cereal Chem. 48 : 255-259.
6. Matsushima, S. 1975. Crop science in rice-theory of yield determination and its application. pp. 237, 255-256, 263-264. Fuji Publ. Co., Tokyo.
7. Matsushima, S. 1975. High-yielding rice cultivation. pp. . 316-317, 323-324. Univ. of Tokyo Press, Tokyo.
8. Murata, Y. and Y. Togari. 1972. Analysis of the effect of climatic factors upon the productivity of rice at different localities in Japan. Proc. Crop Sci. Soc. Japan 41 : 372-387.
9. Murata, Y. and S. Matsushima. 1975. Rice. *In* Crop physiology some case histories (L. T. Evans ed.). Cambridge Univ. Press, London.
10. Oritani, T., T. Enbutsu and R. Yoshida. 1979. Studies on nitrogen metabolism in crop plants. XVI. Changes in photosynthesis and nitrogen metabolism in relation to leaf area growth of several rice varieties. Japan J. Crop Sci. 48 : 10-16.
11. Smith, D. 1969. Removing and analyzing total nonstructural carbohydrates from plant tissue. Wis. Agri. Exp. Sta. Res. Rep. 41. 11p.
12. Tanaka, A. 1961. Studies on the nutrio-physiology of leaves of rice. plant. J. Fac. Agri., Hokkaido

Univ. 51 : 449-550.

13. Wei, M. L., M. C. Shen, C. S. Chen and D. J. Liu. 1982. Physiological studies of rice tillers. I. Partition of dry matter, nitrogen and total nonstructural carbohydrates during grain-filling. Proc. Natl. Sci. Counc. ROC (A) 6 : 190-196.

14. Wu, H. P., I. Y. Liao, M. H. Chien, T. L. Lin, Y. S. Chen, Y. P. Wang, K. H. Tsai. L. K. Wu, W. I. Chang, F. H. Lin and Y. L. Wu. 1975. The investigation on the causes of low yielding in the second crop of rice. Natl. Sci. Council Monthly 3(10) : 5-39.

15. Yoshida, S. 1981. Fundamentals of rice crop science. pp. 60-62, 140, 242. International Rice Resecarh Institute, Los Banos, Philippines.

水稻分蘖之生理研究
II. 不同穗部容積品種的生產力比較[1]

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摘　要

以大粒種水稻品種 Mira（千粒重約 37g）及中粒型水稻品種臺農67號（千粒重約 25g）爲材料，自抽穗起每週以分蘖爲單位取樣，測定源自不同節位之葉片、葉鞘、莖及穗部的乾物重，全氮及非構造性碳水化合物（TNC）含量的變化，目的在比較兩型水稻的生產能力。試驗結果發現 Mira 各器官內之全氮濃度顯著較臺農67號爲高，每一分蘖吸收的氮量亦超出臺農67號40%以上。在穀粒充實過程的淨乾物質與 TNC 生成量比較，如以單一分蘖爲單位，臺農67號分別較 Mira 少14—55%與36—39%；成熟期時，臺農67號水稻之單一穗重僅爲 Mira 之 61—74%，單一穗內 TNC 含量僅爲63—80%，顯示大粒型水稻單一分蘖的生產力較高，而推廣品種亦有再加改良的可能。由於大粒型水稻的穗數太少，故就羣落生產力而言，一期作臺農67號較 Mira 高50%，二期作則兩品種相似，即 Mira 在第二期作有較優良的表現。兩品種穗部主要成份的累積速率相當，表示絕對轉流量以大粒型品種爲高。本試驗結果建議，經由增大穀粒體積謀求稻作增產或有可能，但較大粒型水稻品種（系）對各項環境因子一諸如溫度，栽植密度、氮需要量等之反應，仍應先加以深入的瞭解。

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