Accumulation of ^{14}C-labelled Carbohydrate Before Flowering and its Subsequent Redistribution and Respiration in the Rice Plant

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イネにおける開花前の炭水化物の蓄積とその移行および呼吸

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日本作物学会紀事第41巻第2号別刷

Reprinted from

Proceedings of the Crop Science Society of Japan, Vol. XXXXI. No. 2.

昭和47年6月 June, 1972

Plant Breeding), Ser. III, No. 5, 103 pp., illus. In Russian English Summary, p. 103.

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〔和 文 摘 要〕

大豆の化学成分組成と栽培地の関係について
第2報 カリ・リン・マグネシウムおよびカルシウム含量

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大豆の30品種を石岡・塩尻および熊本の大豆育種試験地の圃場でそれぞれ栽培し，得られた大豆について，カリ，リン，マグネシウムおよびカルシウムの含量をしらべた．これら種子の無機成分含量と，各地域における生育特性（開花まで，登熟および成熟までの日数），栽培環境（開花まで，登熟および成熟までの積算平均気温，積算日照時間，積算降水量），一株粒重，千粒重および一般成分（タンパク質，脂質，炭水化物，灰分）などとの関係について検討を加えた．

これら栽培地を異にした大豆の無機成分含量の地域的変動は乾物中の含量において，カリは石岡，塩尻，熊本間に変動が認められないが，リン，マグネシウム，カルシウムは三地域間において変動が認められた．一方，これら無機成分の灰分中の含量においては，カリ，リン，マグネシウム，カルシウムにおいて地域的変動が認められた．これら無機成分含量の品種間の変動は，乾物中および灰分中のカルシウムの変動が，カリ，リン，マグネシウムの変動に比べて大きいことが認められた．

これら無機成分含量の変動におよぼす生育特性・栽培環境との相関は，石岡，塩尻および3地域総合において同じ傾向を示した．すなわち，乾物中の含量においてはカリとの間には相関が認められないが，リン，マグネシウム，カルシウムとの間に負の相関が認められた．一方，灰分中の含量においては，カリが前記条件との間に正の，リン，カルシウムにおいて負の相関が認められた．なお，マグネシウムにおいては，これら上記諸要因との間に全く相関が認められなかつた．また，これら上記の諸相関は，熊本においては異なつた傾向が認められた．

一般成分含量と無機成分含量間の相関は，石岡，塩尻，熊本および3地域総合においてほとんど同じ傾向が認められた．すなわち，カリが炭水化物との間に負の，灰分のと間に正の相関が認められ，リン，マグネシウムにおいては，タンパク質，灰分との間に正の相関が，脂質，炭水化物との間に負の相関が認められた．また，カルシウムにおいては，タンパク質，灰分との間に正の，炭水化物との間に負の相関が認められた．また，無機成分含量間の相関では，カリがリンとの間に正の，カルシウムとの間に負の，リンがマグネシウム，カルシウムとの間に正の，マグネシウムがカルシウムとの間に正の各相関が認められた．一方，灰分中の各無機成分含量と一般成分含量との間の相関は，カリにおいてはタンパク質，灰分との間に負の，脂質，炭水化物との間に正の，リンにおいては，タンパク質，灰分との間に正の，脂質，炭水化物との間に負の相関がそれぞれ認められた．また，マグネシウムにおいては，タンパク質との間に正の，脂質，炭水化物，灰分との間に負の，カルシウムにおいては，灰分，脂質との間に正の，炭水化物との間に負の相関がそれぞれ認められた．また，灰分中各無機成分含量間の相関においては，カリはリン，マグネシウム，カルシウムとの間に負の，リンはマグネシウム，カルシウムとの間に正の各相関が認められた．

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Introduction

The rice plant (*Oryza sativa* L.) accumulates carbohydrate in the form of starch and sugar in the leaf and culm during the 2 weeks before flowering[4,5,7,12,14,16]. At harvest most of the carbohydrate is no longer present in the leaf and culm.

Murayama *et al.*[7] labelled the accumulated carbohydrate with ^{14}C and found that the increase in activity of the grains was almost equal to the loss in activity of carbohydrate in the leaf and culm. They concluded that the stored carbohydrate was very efficiently translocated to the grain. In a similar experiment Oshima[8] found that 89% of the accumulated starch was translocated to the grain. Lian and Tanaka[6], in a field experiment, also found that the accumulated carbohydrate was translocated to the grain. Although they did not assess the efficiency of translocation, they stated that a considerable amount of carbohydrate might be lost through respiration. Hence the data available on efficiency of translocation are not conclusive. The reason is that the measurement of efficiency depends on the difference in ^{14}C activity in carbohydrate at flowering and at harvest. If translocation is very efficient, as is indicated by the experiments of Murayama *et al.*[7] reported above, then the difference in total ^{14}C activity in the carbohydrate fraction at flowering and at harvest will be difficult to assess, as they acknowledged in their report.

Archbold[1] estimated the loss of carbohydrate from barley stems caused by respiration. She observed that respiration accounted for about 50% of the loss in dry weight of the stems between flowering and harvest. She assumed however that none of the carbohydrate in the stem was translocated to the grain. Stoy[11] calculated the maximum respiratory loss in the stems of the wheat variety, Dala. His data show a maximum loss of carbohydrate due to respiration that is equivalent to 58% of the stored carbohydrate loss. He states however "the actual respiration loss was presumably considerably smaller."

Yoshida and Ahn[16] assessed the contribution of accumulated carbohydrate to grain carbohydrate in several rice varieties by measuring the change in carbohydrate content of leaf blades plus sheath plus culm between flowering and harvest. They found that the accumulated carbohydrate could account for up to 38% of grain carbohydrate and that the contribution varied considerably among varieties. Archbold and Mukerjee[2] found that not more than 14% of the ear weight of barley can be accounted for by stored sugars. Stoy[10] showed that in wheat at least a fraction of carbohydrate assimilated before flowering is translacated to the grain. He[11] also found that wheat varieties differ in their ability to accumulate carbohydrate in the stem. Lian and Tanaka[6] suggested that in rice, carbon assimilated before flowering is used for grain filling with relatively low efficiency. Thorne[13] reviewed the factors influencing grain production in cereals and concluded that carbohydrate that accumulated before flowering was relatively unimportant in wheat and barley, but in rice it might make up one-third of the grain carbohydrate.

Thus estimates of the efficiency of use of

* Received for publication on October 27, 1971.

accumulated carbohydrate range from extreme efficiency in rice to more than 50% loss by respiration in wheat, while estimates for their contribution to grain carbohydrate range from less than 14% in barley under most conditions and up to 38% in rice.

We assessed the contribution of stored carbohydrate to grain carbohydrate by chemical analyses of the plant tissue and by measuring the redistribution of carbohydrates labelled with ^{14}C. The respiration losses during translocation from the sheath plus culm to the ear were estimated by measuring $^{14}CO_2$ output.

Materials and Methods

IR8 was sown on January 1, 1970 and transplanted in four plots on January 21 at the International Rice Research Institute, Los Baños, Philippines. The plants were spaced at 30×30 cm and received 100 kg/ha N, 40 kg/ha P_2O_5, and 40 kg/ha K_2O. Routine applications of insecticide were made. On March 31, 10 days before flowering, four groups of four plants in each plot were enclosed in mylar plant chambers measuring 60×60×100 cm. Each chamber had a small electric fan to circulate the air. Two hundred microcuries of $NaH^{14}CO_3$ were placed in each chamber and $^{14}CO_2$ was released by acidifying the $NaH^{14}CO_3$ with lactic acid. After 2 hours excess $^{14}CO_2$ was absorbed in KOH and the chambers were removed.

On April 10 and 17, and May 10, four treated plants from each plot were harvested and separated into panicle, sheath plus clum of the upper five leaves (sheath plus culm), upper five leaf blades (leaves), other leaves (dead leaves), and dead tillers. The plant parts were placed in a forced draft oven at 100°C for 2 hours and then at 75°C for 4 days. The panicles of the plants harvested on May 10 were separated into husk plus rachis and dehulled grains, and then dried. All samples were ground in Wiley mill and then in a ball mill.

The total activity of ^{14}C in each plant part was determined by burning 50 mg of dried tissue in a Coleman carbon-hydrogen analyzer, Model 33, at 800°C and collecting the carbon dioxide released in 10 m*l* of hyamine hydroxide. Two milliliters of the hydroxide were then mixed with 10 m*l* of toluene ethanol scintillator (70 parts toluene with 0.4% PPO and 0.01% POPOP mixed with 30 parts ehtanol) and the activity determined in a Packard TriCard 314 Ex Liquid Scintillation Counter.

For samples taken on April 10 and May 10 the activity in the sugar fraction and in the starch fraction was determined according to the procedure of Yoshida, Forno and Cock[17]. Briefly, 100 mg dried tissue were extracted with 80% ethanol at 80°C, most of the ethanol evaporated off and the solution diluted with water and passed through Amberlite IRA 400 in the Cl^- form and Amberlite 120 in the H^+ form to remove amino acids and sugar phosphates. Two milliliters of filtrate were added to 10 m*l* of Brays Scintillator[3] and counted in the liquid scintillation counter.

The residue from the ethanol extract was extracted with 4.6*N* $HClO_4$. The starch was purified by iodine precipitation[15], redissolved in water and mixed with Brays scintillator before counting.

Sugar and starch were determned by the anthrone method[17]. Starch was measured before and after precipitation with iodine. The starch content in the grain was determined only on unpurified starch due to the difficulty of collecting all the starch after iodine precipitation in this case. Specific activity of starch was determined on purified starch in the grain.

Respiration was measured on April 13, 17, 21, 24 and 31, and May 7. Two hours after sunset, one group of four plants per replicate was enclosed in a 60×60×100 cm mylar chamber with electric fans to circulate the air. At the same time two blank chambers were set up in the field. After 2 hours, 2 liters of air were drawn from the chambers and discarded. The following 10 liters of air were passed successively through two bottles each containing 200 m*l* of 0.1% KOH. The CO_2 absorption was determined by measuring the change in conductivity of the KOH.

Then the two portions of KOH were mixed. A 200 m*l* sample was taken and acidified with 1*N* HCl. The carbon dioxide that was liberated was trapped in 3 m*l* of hyamine hydroxide. Two milliliters of the hydroxide was added to 10 m*l* of toluene ethanol scintillator and the activity was determined in the liquid scintillation counter.

Grain yield was determined from four 6 m^2 areas.

Nitrogen content was determined by the Kjeldahl method.

Results

At the first harvest on April 10, 85% of the tillers had flowered. By May 10 none of the panicles were still green. The yield of rough rice was 7.8 t/ha at 14% moisture (6.7 t/ha dry matter).

The total dry weight of the plants increased from 96 g/hill at flowering to 122 g/hill on May 10. The weight of the culm plus sheath decreased from 52.3 g/hill at flowering to 34.8 g/hill at harvest. The leaf blades decreased from 22.3 g/hill to 17.5 g/hill. Changes in the weights of dead leaves and dead tillers were small and inconsistent (table 1). The panicle weight increased from 14.5 g/hill to 64.5 g/hill. This increase of 50.0 g was similar to the weight of dehulled grains—46.1 g/hill—suggesting that most of the increase in panicle weight after flowering resulted from the increase in the weight of the dehulled grains. The weight of the husk plus rachis at harvest (17.0 g/hill) was slightly greater than the

Table 1. Dry weight (g/hill) of IR8 (on April 10, 85% flowering).

	Sheath+culm	Leaf blade	Dehulled grains	Husk+rachis	Panicle	Dead Tillers and leaves	Total
April 10	52.3	22.3	—	—	14.5	6.7	95.8
April 17	43.8	19.6	—	—	28.5	7.0	98.9
May 10	35.8	17.5	46.1	17.0	64.5*	4.8	121.6
Difference							
April 10~May 10	17.5	4.8			50.0	1.9	25.8

* The sum of dehulled grains and husk plus rachis is 1.4 g less than the panicle weight due to losses during the process of dehulling.

Table 2. Carbohydrate content of plant parts of IR8 at flowering and harvest in the dry season, 1970.

	Sheat+culm		Leaf blade		Panicle		Dehulled grains		Total without dehulled grain (g/hill)
	%	g/hill	%	g/hill	%	g/hill	%	g/hill	
Sugar									
April 10	14.6	7.7	7.2	1.6	2.1	0.3	--	—	9.6
May 10	1.6	0.5	1.4	0.3	—	—	2.1	1.0	0.8
Starch									
April 10	11.8	6.2	0.5	0.1	5.6	0.9	—	—	7.2
May 10	2.0	0.7	0.4	0.1	—	—	90	41.5	0.8
Total									
April 10	26.4	13.9	7.9	1.7	7.7	1.2	—	—	16.8
May 10	3.6	1.2	1.8	0.4	—	—	92.1	42.5	1.6
Change in carbohydrate									
(April 10~May 10)		12.7		1.3					15.2

panicle weight at flowering (14.5 g/hill) indicating that the the husk plus rachis increased in weight by a small amount (2.5 to 3.9 g/hill) after flowering.

The decrease in the weight of the sheath plus culm plus leaf blade (22.3 g/hill) was 48% of the weight of the dehulled grains suggesting that the maximum possible contribution of stored material to dehulled grains is about 50%. This measurement however discounts the possibility of loss of material in the field and of respiration losses. It is also influenced strongly by small sampling errors because the change in weight of the sheath plus culm plus leaf blade is relatively small compared with the total weight of these parts.

The total carbohydrate in the sheath plus culm at flowering was 13.9 g/hill. At harvest it was 1.2 g/hill. The leaf blade contained relatively little carbohydrate: 1.7 g/hill at flowering and 0.4 g/hill at harvest. The panicle had 1.2 g/hill carbohydrate at flowering and the dehulled grains had 42.5 g/hill at harvest. These results are summarized in table 2 which also shows that the amounts of sugar and starch in the sheath plus clum are similar, that starch is present in the leaf blade in extremely small amounts (less than 0.5%), and that starch is, as expected, the major constituent of the dehulled grains.

The contribution of stored carbohydrate to grain yield as assessed by comparing the change in carbohydrate content of the sheath plus culm plus leaf blade (14.0 g/hill) with the change in carbohydrate content of the dehulled grains (41.3 g/hill) is 34% of total grain carbohydrate. This method of assessment overestimates the contribution of stored carbohydrate to grain yield because it disregards the possibility of losses due to respiration during translocation.

Respiration was greatest at flowering (1.8 g/m² CO_2) and gradually decreased untill 2 days before harvest (0.2 g/m² CO_2 (fig. 1). Ambient temperature during measurement was 27.5°C±1°C, so temperature correction was not necessary. The rate of release of ^{14}C decreased almost linearly with time (fig. 2). The linear regression $Y=13.8-0.48t$ ($r=0.91$) was used to estimate total ^{14}C loss by respiration, where $Y=10^{-3}\times$dpm/hill/hr and t=time in days from the first harvest. Total respiration loss from flowering to harvest was 4.8×10^6 dpm/hill and for the 7 days after flowering it was 2.1×10^6 dpm/hill.

The amount of ^{14}C per hill was 93.8 dpm $\times10^6$ at flowering; 100.2 dpm $\times10^6$, 7 days after; and 94.8 dpm $\times16^6$, at final harvest. When the respiration loss was added, the total ^{14}C was 93.8, 102.3, and 99.6 dpm $\times10^6$/hill. The total ^{14}C values do not differ significantly ($F=0.4$ with six and two degrees of freedom for error and treatment, respectively). The distribution of ^{14}C to different plant parts was calculated with the assumption that the total ^{14}C in the plants plus the respiration loss up to a particular harvest were the same as the mean value of the three harvest (fig. 3).

The difference between the content of ^{14}C in the sheath plus culm plus leaf blade plus panicle at flowering and the content in the sheath plus culm plus leaf blade plus husk and rachis at harvest was 20.3% of the total ^{14}C. The ^{14}C

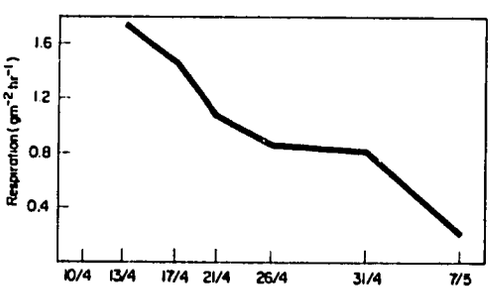

Fig. 1. Respiration of IR8 from flowering (10/4) to harvest (10/5).

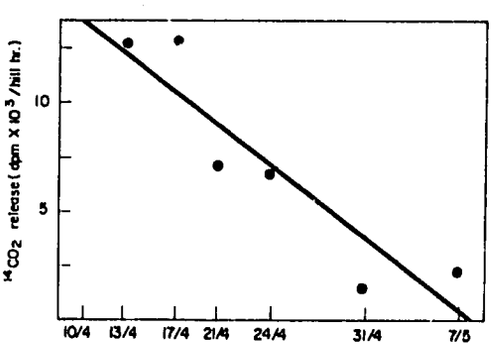

Fig. 2. Release of ^{14}C from IR8 from flowering (10/4) to harvest (10/5).

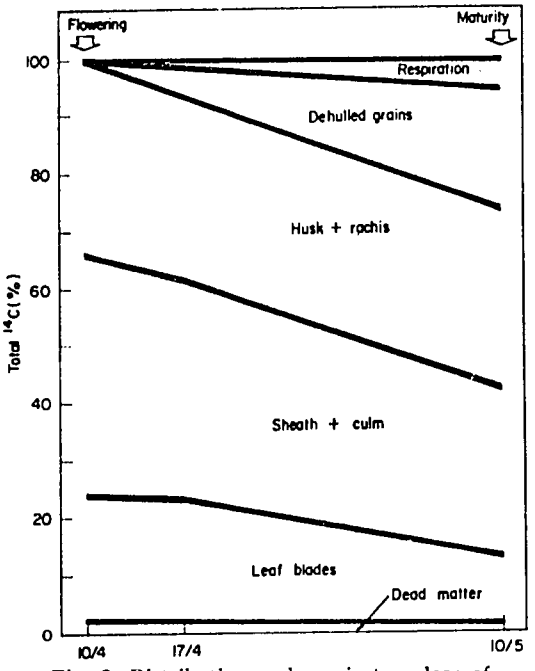

Fig. 3. Distribution and respiratory loss of total ^{14}C in different plant parts between flowering (10/4) and harvest (10/5).

present in the sheath plus culm was translocated to the grain with 79% efficiency. The respiration loss was 4.8% of the total ^{14}C at final harvest. Hence respiration accounts for 24% of the change in total ^{14}C, indicating a translocation efficiency of 76%. These two methods closely agree. A decrease of 0.4% of total activity in dead matter accounts for the small difference between the two.

At flowering most of the ^{14}C incorporated in carbohydrate was present in the sheath plus culm (13.3×10^6 dpm/hill) (table 3). Smaller amounts were present in the panicle (1.8×10^6 dpm/hill) and the leaf blades (3.6×10^6 dpm/hill). At final harvest most of the ^{14}C present as carbohydrate was in panicles (13.2×10^6 dpm/hill) while the activity has decreased to 1.2×10^6 dpm/hill in the sheath plus culm plus leaf blade. The increase in ^{14}C in carbohydrate activity in the panicle was 11.4×10^6 dpm/hill while the decrease in activity of sheath plus leaf blade was 14.9×10^6 dpm/hill which indicates that 77% of the carbohydrate lost from the vegatative parts was translocated and 28% was lost by respiration.

From table 3 the efficiency of use of the total carbohydrate present in the vegetative parts can be calculated. Of the total carbohydrate 68% was translocated to the grain, 20% was lost by respiration and 12% remained in the vegetative parts at harvest (fig. 4). Hence the stored carbohydrate translocated at 68% efficiency to the grain accounts for 10.6 g/hill of grain carbohydrate or

Table 3. ^{14}C in the carbohydrate fraction of IR8 in the dry season 1970. April 10 was date of flowering.

	^{14}C content, 1×10^6 dpm/hill			
	Sheath plus culm	Leaf blade	Panicle	Dehulled grains
Sugar				
April 10	8.75	3.54	0.93	—
May 10	1.21	0.68	—	0.27
Starch				
April 10	4.57	0.07	0.88	—
May 10	0.00	0.13	—	12.98
Total				
April 10	13.32	3.61	1.81	—
May 10	1.21	0.81	—	13.21
Change	12.11	2.80		

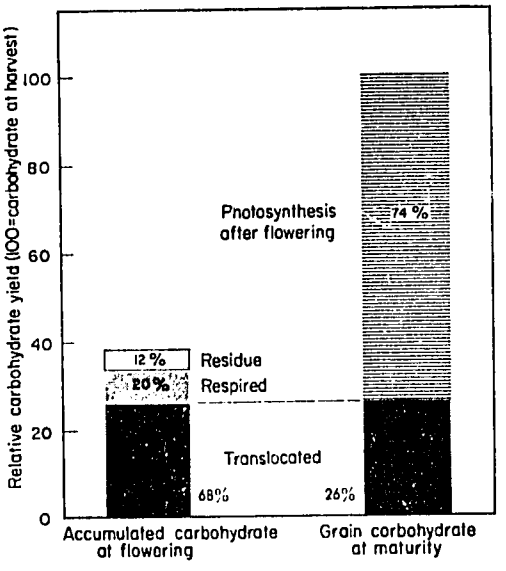

Fig. 4. The contribution of accumulated carbohydrate in the vegetative parts at flowering to grain yield.

Table 4. Carbohydrate content of plant parts in g/hill of IR8 by two methods. Dry season 1970.

	Carbohydrate content, g/hill					
	Sheath+culm		Leaf blade		Panicle	
	I-KI	Standard	I-KI	Standard	I-KI	Standard
Starch						
April 10	6.2	8.4	—	—	0.9	1.3
May 10	0.7	1.5	0.1	—	—	—
Change	5.5	6.9	0.1	—	—	—
Total carbohydrate						
April 10	13.9	16.1	1.7	1.6	1.2	1.6
May 10	1.2	2.1	0.4	0.3	—	—
Change	12.7	14.0	1.3	1.3	—	—

26% of the increase in grain carbohydrate between flowering and harvest.

The loss of ^{14}C in carbohydrate between flowering and harvest was 3.5×10^6 dpm/hill. That is somewhat less than the estimate of respiration of 4.8×10^6 dpm/hill.

Total carbohydrate was also determined without using I-KI precipitation of starch in the sheath plus culm so that these results could be compared with those obtained by Yoshida and Ahn[16]. The values for starch are slightly less with I-KI precipitation, possibly because starch was lost during precipitation or because of hydrolysis of hemicellulose which was later measured as sugar when the starch was not purified. Nevertheless, the two methods give similar results (table 4).

The contribution of stored carbohydrate to grain carbohydrate assessed by the change in carbohydrate weight of sheath plus culm plus leaf blades was 34% with I-KI precipitation and 40% without it.

Discussion

The loss in total ^{14}C activity in the sheath plus culm was 12.4×10^6 dpm/hill while the loss in the carbohydrate was 12.1×10^6 dpm/hill. Hence carbohydrate appears to be the only labelled material that was translocated from the sheath plus clum. In the leaf blade, the change in total ^{14}C activity was 9.4×10^6 dpm/hill; the change in carbohydrate activity was only 2.8×10^6 dpm/hill. Thus, not only was carbohydrate lost from the leaf but other labelled materials, possibly proteins, apparently were broken down in the aging leaves and were translocated elsewhere. Since carbohydrate is the primary substrate for respiration, it is unlikely that the loss in activity of the non-carbohydrate fraction was due to respiration.

The total activity of the panicle increased by 20.1×10^6 dpm/hill, whill carbohydrate activity in the dehulled grains was 13.2×10^6 dpm/hill at flowering. The increase in non-carbohydrate activity of the panicle was 6.9×10^6 dpm/hill of which 2.9×10^6 dpm/hilll were in the dehulled grains and 4.0×10^6 dpm/hill in the husk plus rachis. Hence the increase in non-carbohydrate activity of the panicle (6.9×10^6 dpm/hill) almost equalled the loss in non-carbohydrate activity from the leaves (6.6×10^6 dpm/hill). Between flowering and harvest, the nitrogen content of the panicle increased by 0.51 g/hill while that of the leaf blade decreased by 0.27 g/hill, while, at the same time, total nitrogen content increased by only 0.11 g/hill. That suggests that a large amount of nitrogenous compounds was translocated from the leaf blade to the panicle. If these compounds account for the loss in activity in the non-carbohydrate fraction of the leaf, they must be translocated to the panicle with great efficiency.

The increase in total activity of the dehulled

grains was 79% of the loss in total activity of the other plant parts. However because some of this increase was due to very efficient translocation of compounds other than carbohydrates, the efficiency of translocation of carbohydrates must be somewhat less. In fact, we estimated the efficiency of translocation of carbohydrate to be 77% by comparing the increase in activity of the grain carbohydrate with the loss in activity of carbohydrate from the leaf blade, shath, and culm. The respiratory loss estimated by this method was only 3.5×10^6 dpm/hill. The loss by respiration, however, was estimated from direct measurement to be 4.8×10^6 dpm/hill. This difference may be due to re-assimilation of previously respired ^{14}C. If so, and if 4.8×16^6 dpm/hill is the true measure of respiration, then respiration accounts for 32% of the loss in carbohydrate activity of the sheath plus culm plus leaf blade, i.e., translocation is 68% efficient. As can be seen from figure 1 however, the direct measurement of ^{14}C respiration gave somewhat variable results. Consequently, the final estimate of total ^{14}C loss by precipiration may be subject to large errors.

We feel the efficiency of translocation of carbohydrate accumulated before flowering for grain filling is probably not less than 65% and is certainly not greater than 80%.

Hence the chemical method of estimation, which suggested that 34% of grain carbohydrate came from the stored carbohydrate, probably overestimates the true percentage. Nevertheless the magnitude of this overestimation is less than it seems at first. The starch content of the sheath plus culm decreased from 11.8% at flowering to 2.0% at harvest (6.2 and 0.7 g/hill, respectively). At harvest however, no activity could be detected in the starch in the sheath and culm. Thus it appears that all the starch was translocated to the grain or lost by respiration and that later more starch was deposited. Hence the amount of carbohydrate lost from the stem will be 0.7 g/hill greater than the amount suggested by the chemical method which corresponds to a 35% contribution. This underestimate is negligible, especially when compared with different methods of starch determination and the losses due to respiration.

The chemical method does not take into account respiration losses or the possibility of complete translocation of starch followed by accumulation just before harvest. The ^{14}C labelling method enables us to assess both of these factors, however in this experiment respiration measurement was not sufficiently accurate to enable us to assess accurately how much ^{14}C was respired and re-assimilated. Nevertheless the two methods can be compared, the chemical method based on the difference in carbohydrate content af flowering and harvest overestimates the contribution of storage carbohydrate by 28~47%.

Allowing for 68 to 77% translocation efficiency and the complete translocation or loss by respiration of accumulated starch, 24 to 27% of grain carbohydrate was accounted for by accumulated carbohydrate. This is equivaent to 1.1 to 1.2 t/ha of carbohydrate.

In our experiment, the nitrogen supply was less than the optimum for again yield of IR8. When less nitrogen is applied to the crop, the percentage of carbohydrate is greater, hence in experiment of this type can be carried out with greater accuracy. However, Yoshida and Ahn[16] found that although the apparent contribution in IR8 was less at higher nitrogen levels, the actual contribution in terms of carbohydrate per unit ground area increased with increasing levels of nitrogen. So at greater levels of nitrogen the accumulated carbohydrate may account for more than the 1.1 t/ha carbohydrate.

Since carbohydrate is only part of the composition of rough rice, the accumulated carbohydrate is equivalent to 1.9 to 2.1 t/ha of rough rice at 14% moisture.

In this experiment the equivalent of 1.9 to 2.1 t/ha grain yield came from stored carbohydrate. Soga and Nozaki[9] shaded rice plants during the ripening period and found that translocation of stored carbohydrates from the vegetative parts to the panicles were enhanced, and the percentage

contribution of the stored carbohydrate to grain carbohydrate was greatly increased. Hence in farmers' fields where yields may be low due to disease and pest attacks and shortage of water, the contribution of stored carbohydrate may be even more significant and may tend to stabilize yields.

Summary

Rice plants (*Oryza sativa* L., variety IR8) were grown in the field at the International Rice Research Institute, Philippines in the dry season 1970. Ten days before flowering 200 μCi of $^{14}CO_2$ were fed to groups of four plants. At flowering, 7 days after flowering, and at maturity, the activity of ^{14}C was determined. The activity of ^{14}C present in starch and suger was determined at flowering and at maturity. Respiration of $^{14}CO_2$ was measured in the field six times between flowering and harvest. The loss in ^{14}C activity in the carbohydrate fraction was less than the ^{14}C respiration, indicating that some respired $^{14}CO_2$ were re-assimilated by the plant. The overall efficiency of translocation of ^{14}C from the vegetative parts to the panicle was 79%. The non-carbohydrate fraction apparently was translocated without loss. The efficiency of carbohydrate translocation was 68% and 77% with and without taking into account the re-assimilation of $^{14}CO_2$, respectively. With a translocation efficiency of 68 to 77%, the contribution of stored carbohydrate to grain carbohydrate is 24 to 27%, which is equivalent to 1.9 to 2.1 t/ha of rough rice at 14% moisture.

Acknowledgement

The authors are grateful to Miss P. H. Perez for doing much of the chemical analysis. The senior author was supported by a research grant from Shell International.

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〔和 文 摘 要〕

イネにおける開花前の炭水化物の蓄積とその移行および呼吸

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1970年乾季作に国際稲研究所圃場に稲（品種 IR8）を栽培した．開花10日前に200 μCi の $^{14}CO_2$ を4株を単位とするいくつかの群に与えた．全 ^{14}C 活性は開花期，開花後7日および収かく期に測定した．でんぷんと砂糖中の ^{14}C 活性は開花期と収かく期にのみ測定した．開花期と収かく期の間に6回，圃場で呼吸として放出される $^{14}CO_2$ を測定した．炭水化物分画からの ^{14}C の活性の減少は呼吸による ^{14}C の放出より少く，これは呼吸によって放出される $^{14}CO_2$ の一部が再同化されることを示している．栄養体から穂へ移る ^{14}C のみかけの効率は 79% であつた．非炭水化物画分は損失しないで移行したようにみえる．炭水化物の移行効率は $^{14}CO_2$ の再同化を考慮した場合 68%，考慮しない場合 77% であつた．この効率から計算すると，開花前蓄積炭水化物の穂炭水化物に対する貢献度合は 24～27% で，これは 14% 水分における籾 1.9～2.1 トン/ヘクタールに相当する．