Photosynthesis of Rice Plants

(IV) Plant factors constituting photosynthetic ability of the rice plants growing on paddy field*

Yoshio MURATA, Akio OSADA, Junichiro IYAMA, and Noboru YAMADA
(National Institute of agricultural Sciences)

Introduction

In the previous paper¹⁾, we reported that light intensity is the most important factor in determining the photosynthetic activity of the rice plants growing on paddy field.

But, in the other hand, the photosynthetic ability to be shown under a definite intensity of sunlight shows a large variation according to the growth stages of the plant.

In this paper, we pursued first the change of photosynthetic ability of the rice plants grown at four different periods, and secondly tried to find out what are the composing factors of the ability. And thirdly we searched for the relation between the changes of the composing factors and the conditions in the plant side.

Material and Methods

Two varieties of rice plants, Norin No. 17 (early, panicle-weight type) and Norin No. 29 (medium, intermediate type), were grown at four successive periods on paddy field.

And their photosynthetic activities at various growing stages were measured both in the field using the whole plant under natural conditions and in the laboratory using cut leaves under controlled conditions. The apparatus used was the same as the previous

Fig. 1 Changes of photosynthetic activity on field area basis.

report.

Results

1. Changes of the photosynthetic ability in the field.

Fig. 1 shows the changes of the photosynthetic ability on unit field area. Two points are clear in the figure; (a) The ability attains its highest value during the period from fulltiller stage to just before heading, declining slowly thereafter, and (b)

Fig. 2 Light-photosynthesis curve of individual leaves.

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Fig. 3 Changes of photosynthetic activity on leaf area basis (Norin 29)

the difference in the ability at the low light level and at the high one becomes greater with the advance in growth stage.

2. Factors constituting photosynthetic ability of a rice community

When the air temperature is not extreme (18–33°C) and the supply of water or mineral nutrients is not limiting, the photosynthetic activity of the rice plants forming a community in the field can be expressed as follows:

$$P = \sum pa = \sum g(i) a \dots \dots \dots (1)$$

Where, P denotes the photosynthetic activity on field area basis at a constant light intensity; p , the photosynthetic activity of the individual leaves of the plants on leaf area basis at light intensity i ; and g , a function of i , respectively.

Now, as we have shown already¹⁾, the photosynthetic activity of the individual leaves belonging to a community in the field is almost exclusively determined by the light intensity on their surface, irrespective of the age or the position on the plant. Thus, the same function $g(i)$ in equation (1) can be equally applied to all the leaves in the community.

So, if we take $\bar{i}$ instead of i (here, $\bar{i}$ means the "effective mean" of i , a theoretical mean calculated from the values of i , with the treatment that when i is larger than $\bar{i}$, the approximate light intensity in Fig. 2, it is reckoned to be equal to $\bar{i}$ considering its effect to photosynthesis), we get the following approximate equation.

$$\sum g(i) a = \sum g(\bar{i}) a =$$

$$g(\bar{i}) \sum a = g(\bar{i}) A \dots \dots (2)$$

here, A means the total leaf area of the community.

From (1) and (2),

$$P = g(\bar{i}) A \dots \dots (3)$$

And from Fig. 2:

$$\frac{g(\bar{i})}{g(i_0)} = \frac{i}{i_0} \text{ that is,}$$

$$g(\bar{i}) = \frac{i}{i_0} g(i_0) \dots \dots (4)$$

therefore, from (3) and

$$(4), P = \frac{i}{i_0} g(i_0) A \dots \dots (5)$$

Then, if we replace

$$\frac{i}{i_0} = f, g(i_0) = p_0,$$

equation (5) can be

Fig. 4 Changes of total leaf area (Norin 29)

Fig. 5 Changes of light-receiving coefficient (Norin 29, at 70 kilo-lux) saturating light intensity, and light-receiving coefficient.

3. Changes of the three factors constituting the photosynthetic ability of a rice community

The above analyzed three factors show the following changes respectively with progress of growth stage and the time of culture.

(1) *Mean photosynthetic ability on leaf area basis*—The mean photosynthetic activity on leaf area

Fig. 7 Photosynthetic activity and water content (all 8 plots mixed)

rewritten as follows:

$$P = A f p_0 \dots (6)$$

As f in the above equation means something an efficiency in the photosynthetic activity of the community determined mainly from its thickness and the way to

receive light, we propose here to call this factor the "light-receiving coefficient". And this coefficient is, and must be, in the range: $0 < f \leq 1$.

In this way we have come to the conclusion that the photosynthetic ability of a rice community under a definite light intensity can be approximately represented by the product of the three factors; total leaf area, mean photosynthetic ability of individual leaves per leaf area under

Fig. 6 Light-receiving coefficient and total leaf area (all 8 plots mixed)

basis of each plot, measured in the laboratory under saturating light intensity (50 kilo-lux) and normal CO_2

conc. (0.03%) using cut leaves, shows an ever-descending tendency except the earliest stages as is seen in Fig. 3.

(2) *Total leaf area*—The total leaf area of each plot on 1 m² field shows the changes as are shown in

Fig. 8 Photosynthetic activity and potassium content (all 8 plots mixed)

Fig. 9 Photosynthetic activity and protein-N content (Norin 29)

Fig. 10 Photosynthetic activity and chlorophyll content (Morin 29)

find a fair support in Fig. 6; it indicates that there really exists a functional relation—a hyperbolic one—between the two.

And as a due result of this, the above equation (6) can be once more rewritten in the following form, using two factors only:

$$P \pm F(A) p_o \dots\dots\dots (7)$$

where, F means a function of A .

4. Relation between the photosynthetic activity on leaf area basis and the internal factors of the leaves

The change of some leaf constituents was also studied to correlate it with the above described changes of the leaf-area-basis-photosynthetic activity.

(1) Water content (% of fresh weight) has generally a high positive correlation with photosynthetic activity (Fig. 7) as our previous report²⁾, but at early stages, the correlation is reversed, showing the existence of a positive correlation between dry matter content and photosynthetic activity.

(2) Potassium content of the leaf also shows an intimate correlation with photosynthetic activity, with some exceptional points at very early stages (Fig. 8).

(3) Protein-N content also shows similar tendency but there is no exceptional points seen and the correlation becomes closer if it is taken within each plot (Fig. 9).

(4) In the case of chlorophyll, too, the situation is roughly the same with the former, only the correlation being somewhat weaker (Fig. 10).

In short, it has a high possibility that, at very early stages of growth, the content of proto-

Fig. 4 in semilogarithmic scale, and reaches its largest value at about the heading stage.

(3) *Light-receiving coefficient*—This coefficient shows the change to make something a concave curve as is seen in Fig. 5.

Now, it will be quite natural that one supposes an intimate relation between this change and the total leaf area. This supposition will

plasm or some other factor accompanying with this, and, at other stages of growth, the content of one or some of water, potassium, protein-N, or chlorophyll, may respectively well become limiting, directly or indirectly, in the course of photosynthesis.

Literature cited

- 1) YAMADA, N., Y. MURATA, A. OSADA & J. IYAMA : Proc. Crop Sci. Soc. Japan. **24**, 246-253, 1956.
- 2) ———, ———, ——— & ——— : ibid. Crop Soc. Soc. Japan. **23**, 112-118, 1955.

水稻の光合成に関する研究

(第4報) 圃場光合成能力構成因子とその時期的変化*

村田吉男・長田 夫・猪山純一郎・山田 登

(農林省農業技術研究所)

摘 要 どの生育段階でも、水稻の圃場同化作用の大いさを支配する第一の因子は光の強さであるが(前報)、光の強さが同じ場合の圃場同化能力は、生育時期や栽培時期により大きな変化を示す。

本報では、このような圃場同化能力の変化がどんな因子によつて支配されるかを解析し、その解析を通じて圃場同化能力の構成因子を明かにし、更にそれらの因子の時期的な変化及びそれと体内諸条件との関連を明かにした。すなわち、

(1) 水稻の単位圃場面積当りの同化能力は、早播、晩播に拘わらず最高分けつ期過ぎから出穂直前までの間に最高値を示す。

(2) この圃場同化能力は、受光能率(f)と、総葉面積(A)と、単位葉面積当りの各葉の平均同化能力(p_0)との三つの因子の積、 Afp_0 によつて表わすことが出来るが、このうち f は A と一定の函数関係をもつことが分つたので、結局、圃場同化能力は A 及び p_0 を独立変数とする一つの函数を以て近似的に表わすことが出来る。

(3) 二つの構成因子のうち、(イ) 総葉面積は栽培時期の如何に拘わらず出穂期頃に最大となり、(ロ) 単位同化能力は生育の初めに高く以後漸減するが、その変化は生育の初期には葉内の乾物及び蛋白態含量と、その後は水分、蛋白態 N , K 及び葉緑素含量の何れとも密接な正の相関を示す。

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