GROWTH DURATION IN RELATION TO YIELD
AND NITROGEN RESPONSE IN THE RICE PLANT*

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Synopsis. There exists an optimum growth duration in obtaining the highest grain yield of the rice plant under a given set of environmental conditions. The optimum growth duration is shorter under high than low nitrogen levels.

Rice plant can be grown any time of the year in the tropics, while in the temperate areas, such as in Japan, it is grown only in the seasons free from frost because of temperature limitation. Therefore, in the tropics the growth duration of the rice plant varies more than in the temperate area.

The growth duration differs significantly depending on the genotypes and the environmental conditions under which the plants grow. The differences, whether these are caused genetically or environmentally, are mainly in the duration of the basic vegetative growth period rather than in the duration of reproductive growth period (TANAKA et al., 1964).

Plant characters such as leaf area, light transmission ratio, panicle-straw ratio, total plant weight, nitrogen content of the plant, and grain yield are influenced by the growth duration. There seems to exist an optimum growth duration for obtaining the highest grain yield under a given set of environmental conditions and the optimum is the function of various factors (VERGARA et al., 1964 and 1966).

Starch in rice grain comes from two sources: one assimilated before flowering and accumulated in the straw, and the other assimilated during ripening (ISHIZUKA and TANAKA, 1963; VERGARA et al., 1964). Starch coming from the former and that from the latter sources are herein called “accumulated” and “assimilated”, respectively.

A short duration variety has a smaller proportion of the accumulated starch than a long duration variety. At high nitrogen levels, the proportion of the accumulated starch is smaller than at low nitrogen levels (MURAYAMA and YOSHINO, 1956).

OKA (1956) reported that “varieties non-sensitive to daylength, and those with shorter growing periods, tend to be high in the rate of increase of panicle number due to fertilizing”.

There is a positive relation between the LAI and the photosynthetic rate of field population, although the relationship is not linear. However, the photosynthetic rate of field populations with a big LAI decreases markedly, if these were kept under a mutually shaded condition for a long period. Respiration regresses to the plant weight except at very late growth stages. Because of these reasons the balance between photosynthesis and respiration generally decreases with the increase of plant size (TANAKA and KAWANO, 1866).

In this report, the meaning of growth duration in rice plants will be discussed through the viewpoint of dry matter production of rice population.

Materials and Methods

Experiment 1

Randomly chosen eighteen varieties were used. The varieties and the countries of their origin are as follows:

<table>
<thead>
<tr>
<th>Variety</th>
<th>Origin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tainan-3</td>
<td>Taiwan</td>
</tr>
<tr>
<td>Peta</td>
<td>Philippines</td>
</tr>
<tr>
<td>Bluebonnet x PI 215936</td>
<td>USA</td>
</tr>
</tbody>
</table>
Taichung Native-1 Taiwan
Hung China
81-B25 Surinam
Hyb. Mix × Ped. CP-231 USA
PI 215936 × CI 9214 USA
H.D. 19 Australia
PI 160891 China
Shen Li Sien China
B36-8 Burma
Kindandang Puti Philippines
10022 India
Century Patna 231 USA
BPI-76 Philippines
59-368 Ceylon

On July 1, 1963, 20-day old seedlings were transplanted using 30 × 30 cm spacing with one plant per hill. The field was uniformly fertilized with 50 kg/ha of P₂O₅ and K₂O. Two nitrogen levels, 0 and 100 kg/ha, were made. The layout of the plots followed a split plot design, with nitrogen as the main plot and varieties as the sub-plots. The experiment contained two replications.

Experiment 2

Six varieties, i.e., Tainan–3, Peta, Bluebonnet × PI 215936, Taichung Native–1, Hung, and 81–B25, were used. Twenty-day old seedlings were transplanted on December 20, 1963, one plant per hill at 30 × 30 cm spacing in a field which received a uniform application of 40 kg/ha P₂O₅ and K₂O, and 0 and 150 kg/ha of N. The field layout was a split plot design with variety as the sub-plot, replicated twice. In both Experiments 1 and 2, data were collected on leaf area, plant weight, plant height, and grain yield. Occasional measurements of photosynthesis and respiration were made in the field. The experimental technics used in these experiments were described previously (TANAKA and KAWANO, 1965).

Experiment 3

Peta, a leafy tropical variety in the Philippines, was used. Twenty-day old seedlings were transplanted at 30 × 30 cm spacing with one plant per hill on November 10, 1964. The field received a uniform application of 100 kg of N and 50 kg each of P₂O₅ and K₂O per hectare. Leaf area and plant weight were measured at 10 days intervals. Diurnal changes of apparent assimilation rate was measured at 65, 80, and 95 days after transplanting (more or could days less) by the same technics less as described in the previous paper (TANAKA and KAWANO, 1966).

Results

Variance analyses of Experiment 1 (Table 1.) show that the effects of variety and nitrogen application were highly significant in dry weight of the plant and ratio of the grain weight to the total plant weight. In grain yield, however, the interaction between variety and nitrogen application was highly significant while the effects of variety and nitrogen application alone were not so.

Table 1. Variance analyses for the characters of discussion.

<table>
<thead>
<tr>
<th>Character</th>
<th>Variance source</th>
<th>d.f.</th>
<th>Mean square</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain yield</td>
<td>Variety</td>
<td>17</td>
<td>237.63</td>
<td>2.052</td>
</tr>
<tr>
<td></td>
<td>Nitrogen</td>
<td>1</td>
<td>25.68</td>
<td>0.222</td>
</tr>
<tr>
<td></td>
<td>Variety × Nitrogen</td>
<td>17</td>
<td>115.78</td>
<td>4.417**</td>
</tr>
<tr>
<td></td>
<td>Error</td>
<td>36</td>
<td>26.21</td>
<td></td>
</tr>
<tr>
<td>Total dry weight at flowering stage</td>
<td>Variety</td>
<td>17</td>
<td>5154.1</td>
<td>16.562**</td>
</tr>
<tr>
<td></td>
<td>Nitrogen</td>
<td>1</td>
<td>17020.3</td>
<td>54.692**</td>
</tr>
<tr>
<td></td>
<td>Variety × Nitrogen</td>
<td>17</td>
<td>311.2</td>
<td>1.997*</td>
</tr>
<tr>
<td></td>
<td>Error</td>
<td>36</td>
<td>155.8</td>
<td></td>
</tr>
<tr>
<td>Total day weight at harvest</td>
<td>Variety</td>
<td>17</td>
<td>2736.5</td>
<td>3.220*</td>
</tr>
<tr>
<td></td>
<td>Nitrogen</td>
<td>1</td>
<td>7812.3</td>
<td>9.192**</td>
</tr>
<tr>
<td></td>
<td>Variety × Nitrogen</td>
<td>17</td>
<td>849.9</td>
<td>2.082*</td>
</tr>
<tr>
<td></td>
<td>Error</td>
<td>36</td>
<td>408.3</td>
<td></td>
</tr>
<tr>
<td>Ratio of grain weight to total weight (inversed sine)</td>
<td>Variety</td>
<td>17</td>
<td>83.06</td>
<td>13.594**</td>
</tr>
<tr>
<td></td>
<td>Nitrogen</td>
<td>1</td>
<td>245.31</td>
<td>40.149**</td>
</tr>
<tr>
<td></td>
<td>Variety × Nitrogen</td>
<td>17</td>
<td>8.10</td>
<td>1.326</td>
</tr>
<tr>
<td></td>
<td>Error</td>
<td>36</td>
<td>6.11</td>
<td></td>
</tr>
</tbody>
</table>

Statistical significances are shown by * (5%) and **(1%).

With a heavy nitrogen application, the grain yield per unit field area was maximum when the duration is around 70 days (transplanting to flowering), which is approximately equivalent to the total growth duration of 120 days (Fig. 1). The grain yield lowered as the duration became longer or shorter than 70 days. With no-nitrogen application, however, the grain yield increased with increase in growth duration up to 110 days (approximately equivalent to the total growth duration of 160 days) and was then maintained more or less constant above 110 days.
transplanting, the gain, the release, and the net gain were 61, 28, and 33 g CO₂, respectively. At 95 days after transplanting, the gain,

Fig. 1. Relation between varietal growth duration and grain yield.

The crops with short growth duration seemed to have more chances to respond to nitrogen (as expressed by the yield difference between with and without nitrogen) than those with long growth duration (Fig. 2).

Fig. 2. Relation between varietal growth duration and nitrogen response.

At high nitrogen levels the plant weight increased as the duration increased until about 100 days and there was no further increase above that. On the other hand, at no-nitrogen level the plant weight increased constantly with growth duration (Fig. 3).

The grain–total weight ratio decreased as the growth duration increased and the extent to which the ratio decreased was more marked at high nitrogen levels (Fig. 4).

Diurnal CO₂ exchange in the field population of Peta at 100 kg/ha N at different growth stages is given in Fig. 5. At 65 days after transplanting, the population gained 46 g of CO₂ through photosynthesis and released 16 g of CO₂ through respiration so that the net gain was 30 g CO₂ per day. At 80 days after

Fig. 3. Relation between varietal growth duration and plant weight at flowering stage (Symbols are the same as in Fig. 1.)

Fig. 4. Relation between varietal growth duration and ratio of grain weight to total weight. (Symbols are the same as in Fig. 1.)

Fig. 5. Diurnal gas exchange of Peta population at different growth stages.
the release, and the net gain were 65, 36, and 29 g, respectively.

The photosynthesis as well as respiration of populations increased with increase of growth duration (Fig. 6). The ratio of the diurnal CO₂ release by respiration to the diurnal CO₂ gain by photosynthesis increased with the decrease of leaf area per unit plant weight which accompanied the growth (Fig. 7).

![Diurnal photosynthesis and respiration](image)

**Fig. 6.** Diurnal photosynthesis and respiration at different growth stages.

![Leaf area vs. days](image)

**Fig. 7.** Leaf per area plant weight and ratio of diurnal respiration to photosynthesis at different growth stages.

At high nitrogen levels LAI at flowering increased with increase of growth duration up to 70 days and then decreased slightly above that duration, whereas at no-nitrogen level it continued to increase with increase of duration (Fig. 8).

The populations with 80-day growth duration had the highest photosynthetic rate at high nitrogen levels (Fig. 9). This photosynthetic activity declined markedly as the duration deviated from 70 days in both direc-

![Relation between LAI and days](image)

**Fig. 8.** Relation between varietal growth duration and LAI at flowering stage. (Symbols are the same as in Fig. 1)

![Photosynthetic activity vs. days](image)

**Fig. 9.** Relation between varietal growth duration and Photosynthetic activity at flowering stage. (Symbols are the same as in Fig. 1.)
However, among the varieties of more than 70-day growth duration, the photosynthetic rate at flowering declines markedly with increase in growth duration. This is because there is no more increase in LAI and the population suffers longer from mutual shading and the photosynthetic rate of individual leaves decreases with increase of growth duration.

The lower photosynthetic rates of population at flowering of both short and long growth duration populations at no-nitrogen level are due to a small LAI of the former and a low nitrogen content of the leaves of the latter (VERGARA et al., 1964).

The respiratory rate at flowering increases with growth duration, but then decreases after the duration reaches a certain period at both nitrogen levels. A small plant weight of short duration populations and a low nitrogen content of straw of long duration populations are the causes of the low respiratory rate.

At high nitrogen levels the net assimilation rate at flowering is the highest with populations of about 70-day growth duration from transplanting to flowering, but it drops as the duration exceeds 70 days because of a low photosynthetic and a high respiratory rates. Thus, the grain-total weight ratio declines remarkably with increase of growth duration.

At no-nitrogen level the net assimilation rate at flowering does not vary with growth duration as significantly as at high nitrogen levels. Populations with long growth duration have more of the accumulated starch than those with short growth duration. Thus, the longer the growth duration, the higher is the grain yield.

The prolonged vegetative growth and mutual shading cause the elongation of culm. As such, there is no case of short stature with long growth duration. Naturally, populations with long growth duration, are apt to lodge when grown with a heavy nitrogen application.

In these experiments mentioned above, the cause of differences in growth duration was genetical. The results obtained here go parallel with the results obtained in a similar experiment where environmental condition (i.e., photoperiod) was the cause of differences in growth durations in one variety (VERGARA

--- 50 ---
et al., 1964).

There exists an optimum growth duration in obtaining the highest grain yield, but it varies with the environmental condition under which the plants are grown. The optimum growth duration is shorter under high than low nitrogen levels. Populations with total growth duration of about 120 days would give the highest yield under high nitrogen levels and those with 150–160 days would yield highest under low nitrogen under a set of conditions in these experiments described in this paper.

Although 30 × 30 cm spacing is one of the ordinary farmer’s practices in contemporary Southeast Asia, further discussion of optimum growth duration ought to be made with all the spacings probable.

The deviations of varietal performances from the main regression of grain yield on the growth duration would be accounted for by the varietal differences in leaf characters or plant type (Tanaka and Kawano, 1965). The difference in these characters of varieties included in these experiments introduces difficulties in drawing definite conclusions. Because of this reason a similar type of experiment using isogenic lines with different growth durations is desirable.

Summary

Rice varieties with different growth durations were tested in Los Banos, Laguna, Philippines, using 30 × 30 cm spacing in order to obtain information of the effects of growth duration on plant characters, especially on the yielding ability and yield nitrogen response.

Plant weight at harvest increased with increase in growth duration, but under high nitrogen levels it did not increase after the growth duration exceeded 150 days. The ratio of grain weight to total weight decreased with growth duration and the trend was more marked under high nitrogen levels.

Grain yield was at maximum value with about 120 days growth duration under high nitrogen levels, while under low nitrogen levels it was highest with 150–160 days growth duration. The populations with long growth duration had little chances to respond in grain yield to nitrogen application.

Under high nitrogen levels the photosynthetic rate at flowering was highest with 120 days growth duration, and the respiratory rate at flowering increased with growth duration except for the cases of very long duration. Under low nitrogen level the photosynthetic rate at flowering was the highest with 130–150 days growth duration, while the respiratory rate did not vary markedly with growth duration. The low assimilation rate after flowering was the cause of low grain yield in long growth duration populations with high nitrogen levels. With a larger amount of the accumulated starch, a higher grain yield was obtained with a longer growth duration under low nitrogen level.

Literature Cited

稲の生育期間と収量および肥料反応との関係

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フィリピン国、ラグナ州、ロスバニオスにおいて、少窒素条件では、120日の生育期間を持つ品種が、また少窒素条件では150〜160日の品種がともに最高の収量をもたらした。

多窒素条件での開花時光合成能力は、生育期間120日の品種において最も高く、また同時期の呼吸量は、通常の生育期間の長いものを除いては、生育期間の長いものがほど大きい。少窒素条件での開花時光合成能力は生育期間130〜150日の品種が最も高く、同じく呼吸量については、品種の生育期間長にともなう変化はあまりない。

多窒素条件では、開花期以後の同化能力が収量と密接な関連を持ち、生育期間の長い品種では、これが低い事がそれら品種の収量が低い理由である。少窒素条件では、開花以前における炭水化物の貯蔵されがとと開花以後の同化能力が高い事が、生育期間の比較的長い培種が高収量となる理由である。

一般的に説の事がいえよう、すなわち最高収量をあげる為の最適生育期間長は、与えられた環境条件で異なり、多窒素条件下では少窒素条件下よりも短かい。非常に長い生育期間を持つ品種が、収量において窒素肥料によく反応する可能性はまずあり得ない。