Short Report

PROPAGULE SIZE AND GROWTH OF PLANT
PHENOMENON OF GAINING IN GROWTH BY PLANTS HANDICAPPED
BY SMALL INITIAL SIZE

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Introduction

The energy amount of a single propagule plays an important role in plant populations, and thus it is necessary to determine its initial size of productive structure, the speed of its development and the number of propagules of the next generation. The dry weight of seeds, which are the main propagules of plants, has been found to exceed ten orders of magnitude (Harper et al., 1970). Nishioaka et al. (1969) and Nishioaka & Hozumi (1970) grew Gladiolus Gandavensis of various corm size at various plant densities and showed that plants grown from small corms redoubled their weight faster. Similarly, Stebbins (1976) showed a negative correlation between seed size and the amount of growth relative to seed size in five Vicia species which varied approximately 20-fold in seed weight. Also, Nishioaka & Hozumi (1970) succeeded in approximating plant weight by a function of corm size. Shinozaki (1980) analyzed theoretically the initial weight of plants as a growth factor. The above mentioned findings suggest that species with smaller propagules have greater advantage in dry matter production in an open habitat than those with larger propagules. The phenomenon of a plant grown from a small propagule gaining upon that grown from a large propagule in dry weight offers a clue to the study of vegetation ecology. This phenomenon will be discussed using Helianthus tuberosus.

Materials and Methods

H. tuberosus is a perennial plant which reproduces mainly with tubers. The tuber's dry weight spans a wide range from 0.2 g to over 20 g. The experimental site was the Koishikawa Botanical Gardens in Tokyo. Tubers were stored at 4°C until planting to prevent germination. Four different sizes of the tubers were planted on May 4, 1978 in a regular square disposition (Table 1). The deviation of each tuber's fresh weight from the mean value was limited within the range of ±10%. In an ascending order of tuber weight, a spacing of 20, 20, 30 and 100 cm in both directions was employed. The plants were thinned when mutual shading was observed. Sampling was made at about 10 days’ intervals until 62 days after planting when the tubers were almost decayed. At harvesting, the plants were separated into component parts and dried at 80°C. The dry weights of the leaf, petiole, stem, root, tuber, stolon and leaf area were measured.

Results and Discussion

As in Nishioaka & Hozumi (1970)'s report, the plant weight could be approximated by the recip-
Table 1. The dry weights of planted tubers.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry weight (g)</td>
<td>0.347</td>
<td>0.608</td>
<td>3.29</td>
<td>10.1</td>
</tr>
</tbody>
</table>

rational function of the initial dry weight of plants, except for the data obtained at 12 days after planting (Fig. 1).

\[
1/w = C/w_0 + D
\]

where \( w, w_0, C \) and \( D \) are the mean and initial dry weights of plants and constants respectively.

On the other hand, the distribution ratio is one of the useful tools to analyze dry weight growth. Here, the distribution ratio of newly produced organs was defined as follows:

\[
\text{Distribution ratio} = \frac{\text{dry weight increment of the organ}}{\text{sum of dry weight increment of newly produced organs per unit time}}
\]

where the unit time was three days.

This is a simplified formula to analyze dry matter economy. The distribution ratio was calculated with the values read from the smoothed growth curve of each organ. In the initial stage of growth, the ratio of distribution to the photosynthetic organs increased as the tubers decreased in size (Fig. 2).

Among the factors which affected the rate of redoubling dry weight, the following were important when the tuber size varied:
1. the photosynthetic activity of new leaves;
2. the efficiency to convert reserve substances into new organs;
3. the speed of translocation from reserve substances to new organs;
4. and the ratio of distribution to photosynthetic organs.

The first factor probably did not vary with tuber size, although there are no other reports to verify it. A few papers have shown that the economic ratio (Midorikawa, 1959) is independent of tuber

![Fig. 1. The relation between initial dry weight and the ratio of mean dry weight to initial dry weight. The data of 12 days after planting; ○ and others; □. Solid lines are given by Eq. 1; broken line is not.](image)

![Fig. 2. The ratio of distribution to leaves of each treatment. See the text.](image)
size (Hogetsu et al., 1960 and Hayashi et al., 1967) and have proved that tuber size does not affect the efficiency of conversion. Consequently, the third and/or fourth factor above may explain the phenomenon of gaining in growth. Hogetsu et al. (1960) and Hayashi et al. (1967) reported that the small tubers translocated reserve substances into new organs more rapidly, although this tendency was not clearly observed in this experiment. Also, in this study, the plant grown from small tubers tended to allocate more energy to photosynthetic organs (Fig. 2). Because of the high distribution to leaves and rapid translocation of the reserve substances, the small plants could exceed the larger plant in growth. Stebbins (1976) also attributed his results to the transfer of stored materials in seeds.

Ecological characteristics such as dispersibility depend primarily on the weight of propagules and growth depends on the amount of energy present. When one considers the significance of propagule size among different species, it should be noted that the propagule's weight and its immediately available energy for growth cannot be discussed in parallel. The ratio of energy to the weight of propagules varies with their chemical composition and morphology. Fatty seeds have a higher value than starch seeds (Yokoi, 1966) and seeds containing a dispersal structure have a lower value. In the following rough discussion, however, the weight and energy of propagules are not distinguished.

The phenomenon of gaining in growth is considered to be common to plant. Different species germinated in different environments have, of course, different redoubling rates of initial growth which can be detected if the effects of environment and proper photosynthetic activity are reasonably considered. Our method of determining dry matter economy makes it possible to analyze the classical work of Salisbury (1942). It is well known that plants with small propagules generally have high dispersibility and are thus handicapped in terms of competitive ability. It is probable among species other than H. tuberosus that the distribution to photosynthetic organs and the speed of translocation are negatively correlated to propagule size. Therefore, the following general tendency is expected among different species: plant with small propagules rapidly form leaves with poor productive structure after germination and these contribute to the phenomenon of gaining in growth. In an open habitat, even small plants receive sufficient solar radiation for photosynthesis, while in a closed habitat where light intensity at the soil surface is low, most solar energy is absorbed by plants with a well developed productive structure which is guaranteed by rich stored material. Consequently, in an open habitat, plants with small propagules increase their weight more rapidly whereas in a closed habitat, those with large propagules do so more rapidly.

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References


* Japanese only. The titles of the papers in parentheses have been translated from the original Japanese titles by the author of this paper.