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# OBSERVATIONS ON GROWTH AND DEVELOPMENT RATES OF TOMATO SEEDLINGS

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## Summary

For the various seasons of the year, under greenhouse conditions in The Netherlands, growth and development rates of tomato seedlings were determined. Improvements in the rooting-medium resulted in considerably better growth. Weight increase rates observed were sometimes as high as 50% per day. During most months of the year these very high rates were found. This indicates that, with the present cultural procedures, summer light intensities cannot be properly used for growth.

A complicating factor of these fast growth rates is that individual plants within a sowing will differ in weight quite considerably. And this is the more so a troublesome fact since differences in weight of upto 100% cannot be seen.

## Introduction

Summer and winter have their own quite specific possibilities and difficulties with respect to growth of plants in greenhouses. Determining potential growth rates a year round under greenhouse conditions prevailing in The Netherlands seemed worthwhile. Especially when these observations were to be accompanied by determination of quality of growth.

## Materials and methods

Tomatoes cv. 'Moneymaker', and the selfstopping cv. 'Pipo' were sown directly into pots. Standardized procedures were adopted with respect to pot medium, seed quality, sowing, pot size, fertilization and watering. Plants that germinated on one specific day were maintained. Early and late ones were discarded. Pots were filled with commercial potting-soil, or with a coarse type of sphagnum peat. A variety of pot types and pot sizes was used. Pot sizes varied from about 0. 8 l to 10 l for plastic pots. In some experiments soil blocks were used. The cv. 'Pipo' was grown in 3 l plastic pots exclusively. Watering and application of fertilizer was also quite different from one experiment to the next, from hand watering to a practically full-automatic hydroponic procedure.

Light and temperature conditions varied with the season. The conditioning of the greenhouse climate was as much as possible according to practice prescription (thermohydrograph data are available). Distances between plants were such that mutual shading remained very limited when the plants grew larger. Normally plants of 100 g (beginning of flowering-stage) were placed 8 plants in 1. 5 m2 trays.

At harvest, plants were cut off just below the cotyledons for weighing. For very young stages some 25 plants were used per treatment, whereas

for the later stages usually 4 plants were taken.

The data were collected during a period of six years, from 1965 to 1970. Initially procedures were gradually improved, but for the last two years data of the various sowings are comparable with respect to cultural procedures.

Results

Over a period of two years tomatoes have been sown every three weeks. Plants were grown in 3 l buckets, placed in a greenhouse in The Netherlands. Through Volmatic capillary drip watering, plants were amply supplied with water. Nutrients were constantly added with the water.

Data collected of plants of these 34 sowings, among other observations, were sowing-date, date of flowering and date of ripeness of the fruit of the first flower. These data are presented in figure 1, as days from sowing till flowering, days from flowering till ripeness and days from sowing till ripeness for each of the sowings.

Clearly, the yearly natural light cycle is not reflected in these developmental rates. The intervals are essentially constant for sowings from February through September. Only in winter a considerable lengthening of these time intervals is seen. For some of these winter sowings, the first flowers did not even open.

A second series of data on rate of flowering is presented in Table 1. These data are a compilation of observations on a variety of experiments. The first group of data is obtained from plants growing in plastic pots on an automatic system of irrigation and fertilization. The third column in table 1 are data from experiments in other years, but with, as much as possible, a parallel series of sowing-dates.

If we assume the yearly natural light cycle to have not been too different for these years, one can conclude that in all seasons flowering was faster on the automatic system. As in figure 1, from March to September the rate of flowering is constant. Again in winter a considerable retardation is seen.

In an attempt to connect the data on the rate of flowering with other growth characteristics, periodic harvests of earlier stages of plants of the sowings of figure 1 and table 1 have been taken to determine fresh and dry weight growth rates. A selection of sowings from the available data is presented in figure 2. Fresh weight is presented on a log. scale against age.

From this figure it can be seen that, in summer, all sowings initially grow at idential rates for about two weeks. The initial rate is very close to a 50% per day increase. After this period the growth rates gradually fall off to lower values. The moment at which this reduction begins depends mainly on the cultural procedure. Especially water and nutrient supply and pot size seem to be controlling factors in obtaining continued growth along the 50% per day line. Clearly, larger plants can be grown in pot at fast rates, however, with intensive care only.

Differences due to prolonged optimal growth result in very large differences in weight. Viz. 30 days after germination, in 1965, plants had reached fresh weights of 20 g. After improvements on the rooting-medium, at the same age fresh weights were as high as 240 g in an experiment

in 1970. Thus, a relatively short period of only 2-3 weeks of slightly sub-optimal growth will cause plant weight to be reduced to 1/10 of what it can be (20 versus 240 g).

Another presentation of the data in figure 2 is given in figure 3, where fresh weight is given on a linear scale, but for the observations from the third to seventh week after sowing only. It is evident again that with more or less commercial procedures (1965 experiments), growth is by far not ideal with respect to growth rate. Summer sowings in 1965 took about 45 days from sowing to reach plant fresh weights of 100 g. The best sowing upto now (6 May 1970) reached that weight already after 30 days. If the time for germination is subtracted from these figures, it may be concluded that an actual growth period of 40 days can be reduced to 25 days. The line drawn vertically through 35 days after sowing is the one discussed with figure 2. Fast plants can have reached a fresh weight which is about 10 times heavier than is obtained with the normal measures common in horticultural practice.

The graphs presented in figures 2 and 3 were all obtained with summer sowings. In winter, growth potentials evidently are limited considerably, most likely due to the low influx of light energy. From figure 4, it is seen that growth rate differences are evident immediately from germination, but that the period of the year during which sub-maximal rates are found indeed (see also figure 1) is confined to a few months in midwinter.

The data on flowering of the experiments discussed with figure 3 are combined with some fresh weight data in table 2. These data indicate that, for the various experiments, the age that the plants reach fresh weights of 100 g is parallel with age of the plants at the moment of first flowering, and that they are negatively correlated with plant weight at 35 days after sowing.

Interpolation of these data (figure 4) shows that plants begin to flower when weighing 40-80 g fresh, almost irrespective of growth rate.

However, the above data being a rather rough approach, since fresh weight is determined as average of 4-8 plants and flowering as the first flower to open on each group of plants, some more detailed observations were produced. Plant fresh weights and flowering-stages for individual plants were determined.

These data are presented in figure 5, where numbers of open flowers per plant are given against the plant fresh weights, for three sowings. The zero-flowers data should not be considered, since it is unknown exactly when these would have flowered. Clearly, the three sowings are different and within one sowing considerable variation is seen.

It is most unpleasant to find such large variation within selected groups of plants of one sowing. However, it seems unavoidable since evidently the human eye is not able to evaluate plant size adequately, as is demonstrated by the following data. In the experiment presented in table 3, three men were asked to select 100 plants of equal weight from a group of 300 plants. The results are, as expected on earlier experience, very poor and indicate that if one wants to select groups of plants of which the average fresh weights are to be different less than 5%,

these groups have to contain over 100 plants. There is some difference of accuracy between the three persons, but at the 5% confidence level 100 plants or more seem unavoidable.

Discussion

The data presented in this paper can be discussed somewhat further with the following remarks.

With respect to figure 1 and table 1, it seems justified to conclude that the yearly cycle of growth rates as presented in figure 1, can be altered by manipulating the conditions in the rooting-medium (table 1), not so much resulting in a change of shape of the curve but in an overall shift in its position. It seems remarkable that the yearly response curve to light is not found to be altered in the saturation level to light of the response curve. However, the number of dates of sowing is limited, so that this preliminary conclusion needs further confirmation.

Evaluation of the graphs in figure 2 comprises two remarks. First, it is evident that prolonged growth at the maximal rate, if only for a few days, is very profitable. It has been shown that improvements of this type can be realized (difference between 1965 and 1971). Secondly, the question arises whether or not the initial rate would be maximal. It might be possible, e. g. with higher temperatures, to increase the slope of the steep initial rates. However, should the optimal temperature regime have been applied already, then it will become very difficult to realize an improvement of this type. In that case, it seems logic to assume that we are dealing with internal biochemical limitations with respect to the reproduction level of plasma and cells in the apex of the young seedling. If so, the 1,000 fold weight increase in 17 days found as a maximum up to now in our experimental series, would be the ultimated obtainable value.

With respect to figure 5, three characteristics of these data seem noteworthy. First, plants with more open flowers are heavier and this relation is about equal for the three sowings. Secondly, in relation to the age of the plants when harvested, it is seen that plants of sowings that flower earlier are heavier when they flower. Thus, when sowings have a faster rate of development, growth is even more speeded up. Fast growing plants flower a little late relative to fresh weight, but they flower much earlier relative to their age. The third aspect of the graphs in figure 5 is the variation in weight between plants of one sowing.

In all experiments, a sharp selection with respect to plant weight and stage of development was performed by sorting out deviating plants. At germination, seedlings of only one specific day are maintained to form the experimental plants. However, of course, at growth rates of around 50% per day, even a one day germination period, at first glance a rather sharp criterium, allows weight differences of plus or minus 25%. In figure 5, weights varied about 100%. The various 'flowering stage' group averages within one experiment are about 60-80% apart, viz. : 42-75; 64-118 and 71-105.

It may be concluded that better selection procedures are necessary, or that one has to ask for less accurate information. Or, growing procedures resulting in more equal groups of plants might be employed. It

seems worthwhile to look for these, since the present situation is rather unsatisfactory.

Aknowledgement

We thank Miss Brenda van Beek for her accurate assistance in collecting most of the data mentioned in this paper.

Table 1 - Tomato, cv. 'Moneymaker'. Development rate in days from sowing till flowering for sowing in various periods of the year, and as a function of cultural procedures with respect to the rooting-medium.

| Automatic irrigation and nutrition | | Commercial propagation method | |
|---|---|---|---|
| sowing-date | days till anthesis | sowing-date | days till anthesis |
| 19- 3-1970 | 33 | 12- 3-1965 | 44 |
| 6- 5-1970 | 29 | 7- 5-1965 | 39 |
| 15- 6-1970 | 33 | 2- 6-1967 | 39 |
| 13- 8-1970 | 33 | 16- 8-1967 | 39 |
| 1-10-1970 | 50 | 29- 9-1965 | 54 |
| 3-12-1970 | 74 | 18-11-1970 | 92 |

Table 2 - Tomato, cv. 'Moneymaker'. Fresh weight growth and development rates in nine experiments under greenhouse conditions. Fresh weight (g/plant) 35 days after sowing, age (days after sowing) when the plants reach fresh weights of 100 g/plant and age (days after sowing) when the first flower had opened.

| Sowing-date | Fresh weight (g) at 35 days | Age (days) when 100 g | Age (days) when flowering |
|---|---|---|---|
| 7-5-1965 | 20 | 49 | 39 |
| 30-7-1965 | 30 | 46 | 46 |
| 16-8-1967 | 35 | 44 | 39 |
| 3-6-1967 | 56 | 39 | 39 |
| 1-8-1969 | 75 | 37 | 34 |
| 19-3-1970<br>13-8-1970 | 133 | 33 | 33 |
| 15-6-1970 | 160 | 32 | 33 |
| 6-5-1970 | 215 | 30 | 29 |

Table 3 - Selection of idential groups of tomato plants. Three men selected 100 plants out of a group of 300 plants for homogeneity. Selected plants were weighed individually.

| Person | 1 | 2 | 3 |
|---|---|---|---|
| Mean fresh weight (g) | 1. 86 | 1. 83 | 2. 15 |
| Deviation of mean (g) | 1. 81-1. 91 | 1. 78-1. 87 | 2. 08-2. 22 |
| Number of plants at 95% confidence limit | 129 | 94 | 153 |

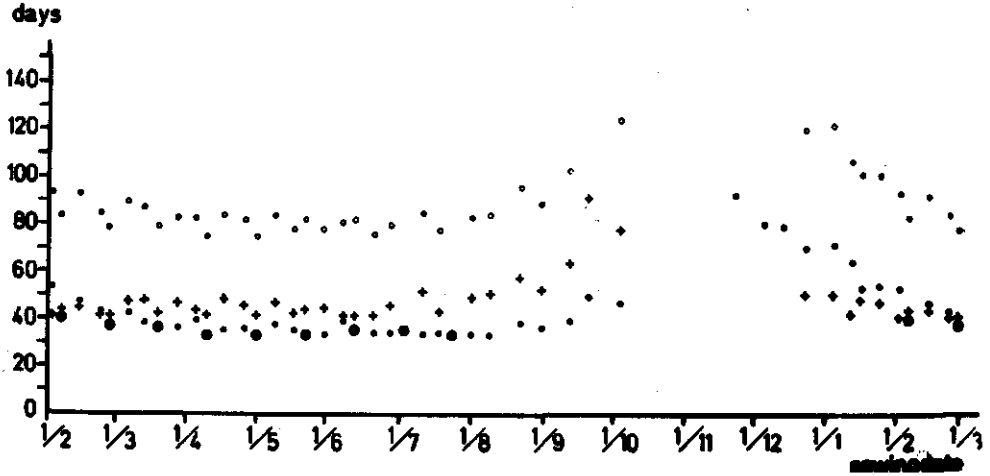


Figure 1 - Tomato, cv. 'Pipo'. Data on development and fruits of 34 sowings during two years (3 week intervals), grown in a greenhouse on automatic water and nutrient supply (hanging bucket experiment).
• and ◉ days from sowing to flowering; + days from flowering to ripeness; o days from sowing to ripeness.

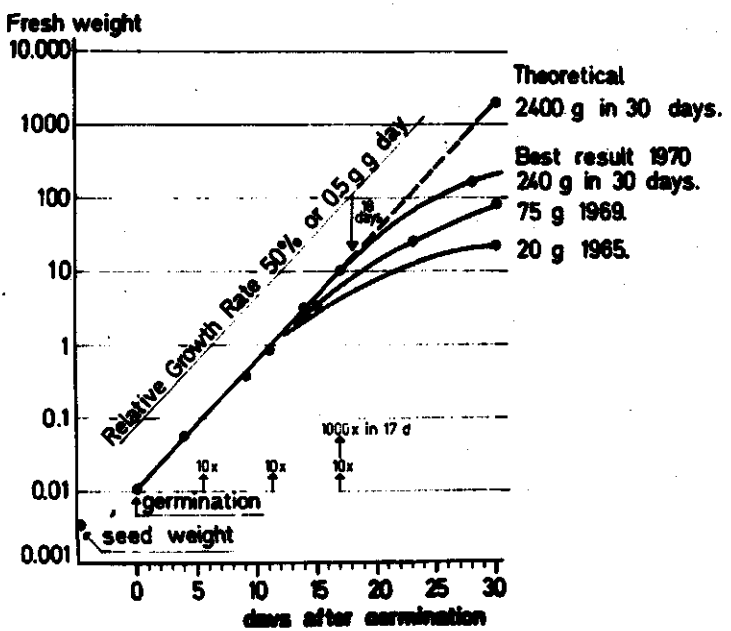


Figure 2 - Tomato, cv. 'Moneymaker'. Fresh weight growth (g/plant) under summer greenhouse conditions. 1965 to 1970: improvements in the rooting-medium (pot volume, potting-mixture, watering and nutrion procedures).

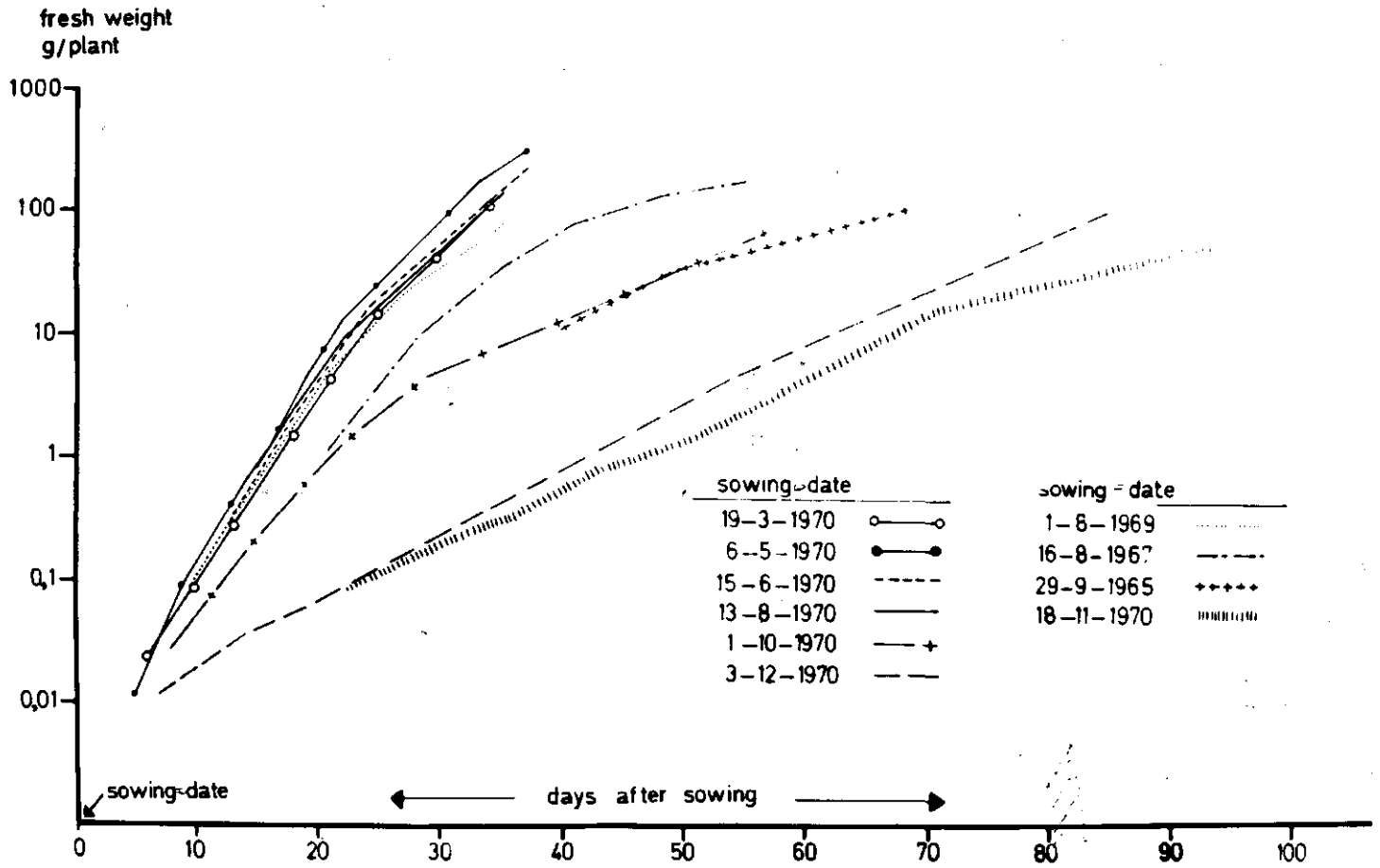


Figure 4 - Tomato, cv. 'Moneymaker'. Fresh weight growth (g/plant). Summer and winter greenhouse conditions.

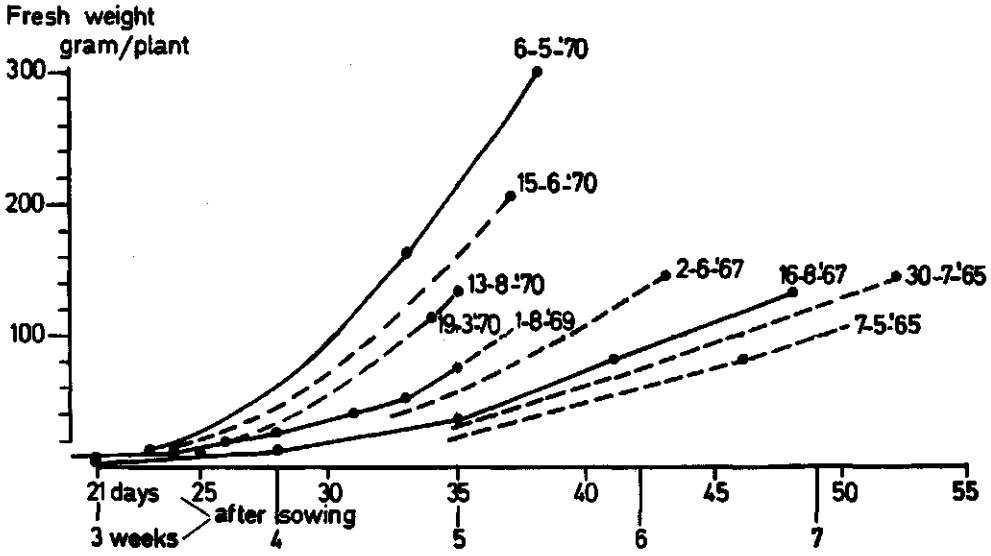


Figure 3 - Tomato, cv. 'Moneymaker'. Fresh weight growth from three weeks after sowing (g/plant) under summer greenhouse conditions. 1965–1970: improvements in the rooting-medium (see Fig. 2).

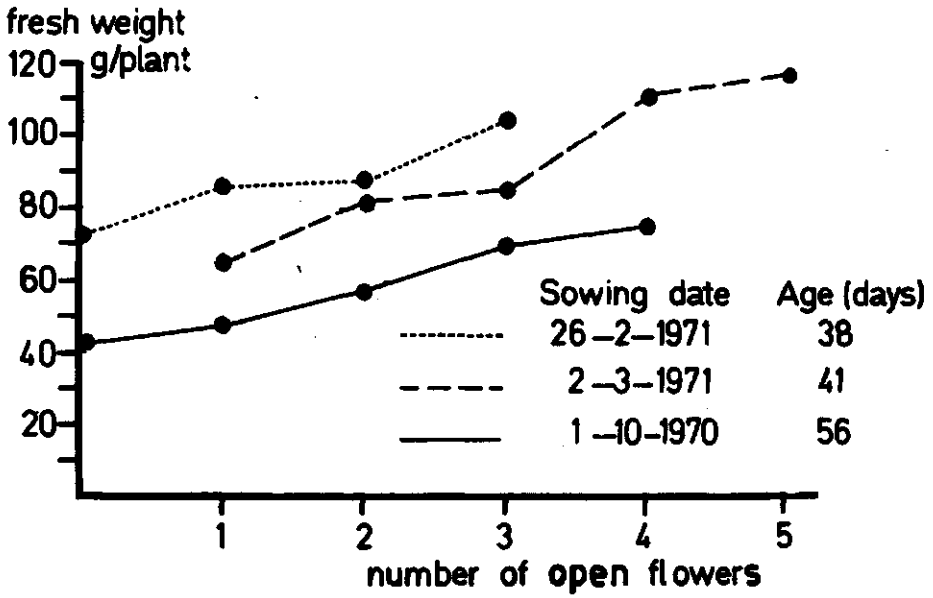


Figure 5 - Tomato, cv. 'Moneymaker'. Relation between plant fresh weight and number of open flowers, for three experiments with different growth rates (experiments harvested after 38, 41 and 56 days).