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Elongation of Strawberry Runners in Relation to Length and Number of Cells

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Summary

This study was conducted to elucidate contribution of cell division and cell elongation to the the growth of internodes of strawberry runners varying with their different parts. Immature internodes of runners from 'Toyonoka' stock plants were marked with Indian ink at one tenth intervals and the separation of adjacent marks was measured daily. A rapid elongation was detected at first in the proximal internode, while the distal internode reached the maximum elongation rate when the proximal internode had almost ceased to elongate. The early elongation of internodes was mainly due to the increase in cell length all along the internodal length and partly due to the increase in cell number particularly at the distal parts, while, the subsequent elongation was exclusively due to the cell elongation at the most distal parts. Thus, the internodes showed the acropetal growth pattern.

The growth of stolons (runners) in strawberry plants is the result of elongation of 2 internodes, that is, proximal (I-1) and distal (I-2) ones (2). Previously, it was shown that the elongation of runners first occurred exclusively in I-1, while the rapid elongation of I-2 started when I-1 attained near the highest elongation rate. The elongation of strawberry runners was regarded as a product mostly of cell division and cell expansion (7). The cell division in each internode continued until the internode attained about one third to half of their final length (7). However, it was not clear how cell division and cell elongation differed with the parts of each internode.

The purpose of this study is to elucidate the changes in the length and number of cells varying with different parts of internodes during the internodal growth.

Materials and Methods

In May 1991, strawberry plants (*Fragaria* × *ananassa* cv. Toyonoka) were planted one per 1 l plastic pot containing 5 soil : 3 vermiculite : 2 peat (by volume) medium amended with 1.0 g of a controlled release fertilizer (15N : 15 P_2O_5 : 15 K_2O), and grown in an unheated plastic film greenhouse. On August 5, plants in which a runner apex just appeared in the axil of the 9th leaf (L-9) from the basal one were selected and L-9 was removed. The proximal internode (I-1) was marked with Indian ink at one tenth intervals along its length, and then the plants were transferred to a growth chamber kept at day/night temperatures of 25°/20°C under a 14-hr photoperiod. Light in the growth chamber was provided from 6 : 00 to 20 : 00 by 20W white fluorescent lamps and 20W incandescent lamps at photosynthetic photon flux of 260 and 20 μmol m^{-2} s^{-1} at the leaf surface, respectively. Seven days after transfer, the distal internode (I-2) was also marked at one tenth intervals as in I-1. In both internodes, the segments between adjacent marks were designated as I, II, III etc. from the proximal one. The lengths of serial segments were assumed to show the growth pattern of internodes (5, 6). RGR was calculated on every two successive segments as $[\ln(X_2)-\ln(X_1)]/(t_2-t_1)$, where X_1 and X_2 were the length of two successive segments at time t_1 and t_2 (days) after the emergence of runner, respectively.

Runners were harvested 0, 5, 7, and 20 days after their emergence. Segments shorter than 10 mm were cut into 3 sections with equal length and fixed in 3.5% glutalaldehyde in 0.25M phosphate buffer. The sections were then dehydrated in a graded ethanol series, embedded in Acrytron's resin (Mitsubishi Rayon Inc.), sliced longitudinally at 5 to 10 μm in thickness with a microtome and stained with 1% toluidin blue. Segments longer than 11 mm were cut into 10 sections with equal length and fixed in a FAA solution (5 formaldehyde : 5 acetic acid : 90 50% ethanol by volume). Epidermal tissues were then stripped off from the mid-portion of each section and stained with 1% ruthenium red. Lengths of 15 epidermal cells on the central part of each section were measured as described previously (7, 8, 9). The number of epidermal cells of each segment along its length (abbreviated merely as the cell number) was calculated by dividing the length of segment by the mean epidermal cell length (the cell length) of the segment.

Results and Discussion

The elongation of each internode was represented by a single sigmoid curve as indicated previously (7), and reached the maximum rate 7 and 12 days after the emergence of runner in I-1 and I-2, respectively. When I-1 had almost ceased to elongate, I-2 attained the maximum rate (Fig. 1).

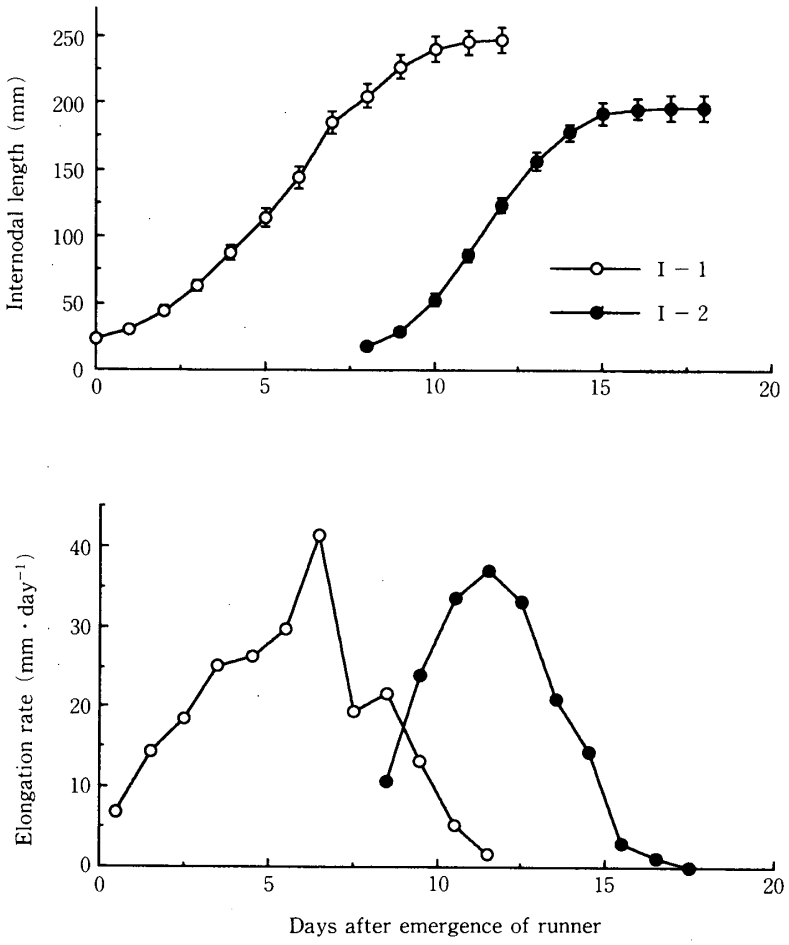

FIG. 1. Changes in length and elongation rate of internodes at day/night temperatures of 25°/20°C under a 14-hr photoperiod. I-1, proximal internode; I-2, distal internode. Values represent means of 7 plants±S.E.

The segments increased their length in different degrees with their position on the internode. In both I-1 and I-2, the lower segments, I to V, elongated actively only for 5 days after the beginning of their elongation and their final lengths were small, while the elongation of upper segments, VI to X, was more rapid and continued longer, resulting in greater final lengths (Fig. 2)

In I-1, the highest value of RGR in each segment was higher at upper segments, while in I-2 it differed little with the position of segments. However, in both I-1 and I-2, the date when the maximum value of RGR was attained was delayed at upper segments, and at segments VII+VIII and/or IX+X, a second peak of RGR was detected (Fig. 3).

In I-1, the cell length was greater at lower segments, while the cell number was greater at upper segments at the emergence of runner. During the subsequent 5 and 20 days, the cell number increased little except at IX and X, where a great increase was found during the first 5 days. On the other hand, the cell length

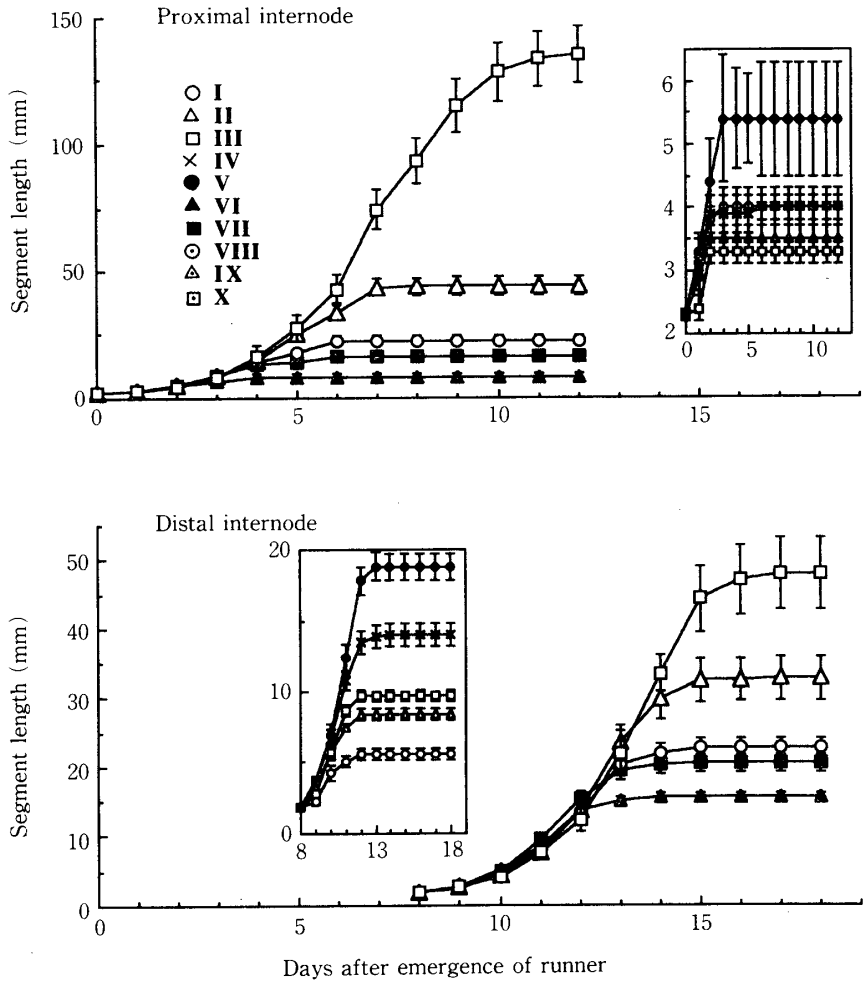

FIG. 2. Changes in length of respective segments. At the emergence of runner and 7 days after, proximal and distal internodes, respectively, were marked with Indian ink at one 10th intervals along their length, and segments separated by adjacent marks were designated as I, II, III, etc. from the proximal one. Insets indicate the changes in length of segments I to V. Values represent means of 7 plants±S.E.

increased greatly at III to IX during the first 5 days and at IX and X during the following 15 days (Fig. 4). Thus, it appeared that the great increase in elongation of I-1 during 5 days after the emergence of runner was mainly due to the increase in the cell length of central and proximal segments, in particular, of III to IX, while, contribution of the cell number was small except for IX and X. The elongation of I-1 during the period from 5 to 20 days after the emergence of runner was exclusively due to the increase in cell length of IX and X. It was probable that this increase occurred soon after 5 days after the emergence of runner and brought about the second peak of RGR. The circumstances were also true of I-2. Seven days after the emergence of runner, that is, at the beginning of elongation,

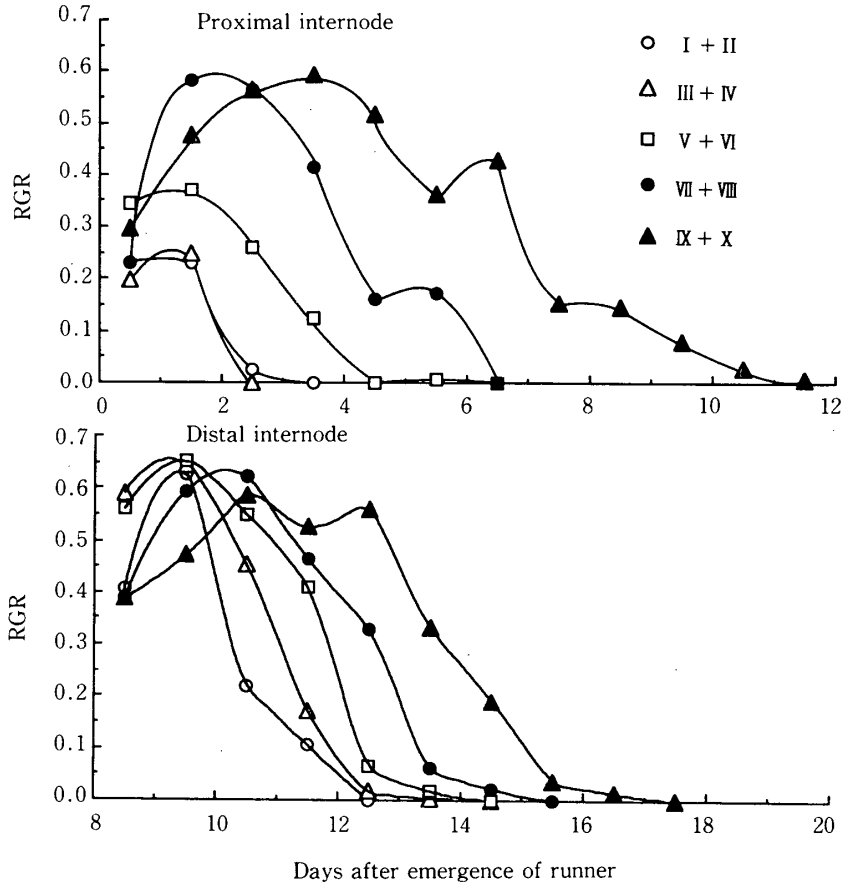

FIG. 3. Changes in relative growth rate of every two successive segments. As to the position of segments, refer to Fig. 2.

the cell length was greater at lower segments, while the cell number was greater at upper segments. During the subsequent 13 days, the cell length increased greatly at upper segments, but the increase in the cell number was comparatively small except at X (Fig. 4). Thus, the elongation of I-2 during 13 days after the beginning of its elongation, was mainly due to the increase in cell length at all segments, and partly due to the increase in cell number particularly at the uppermost segment. The latter increase seemed to explain the second peak of RGR.

Our results show the acropetal growth pattern in the internodal elongation of strawberry runners, that is, cell division have almost ceased at the beginning of internodal elongation except at the distal parts, while the cell length increases greatly for a short time after the beginning of internodal elongation at the central to distal parts and still thereafter at the most distal parts. Thus, the early elongation of internodes is almost due to the cell length and partly due to the cell number particularly at the distal parts. On the other hand, the subsequent elongation was exclusively due to the increase in the cell length at the distal parts.

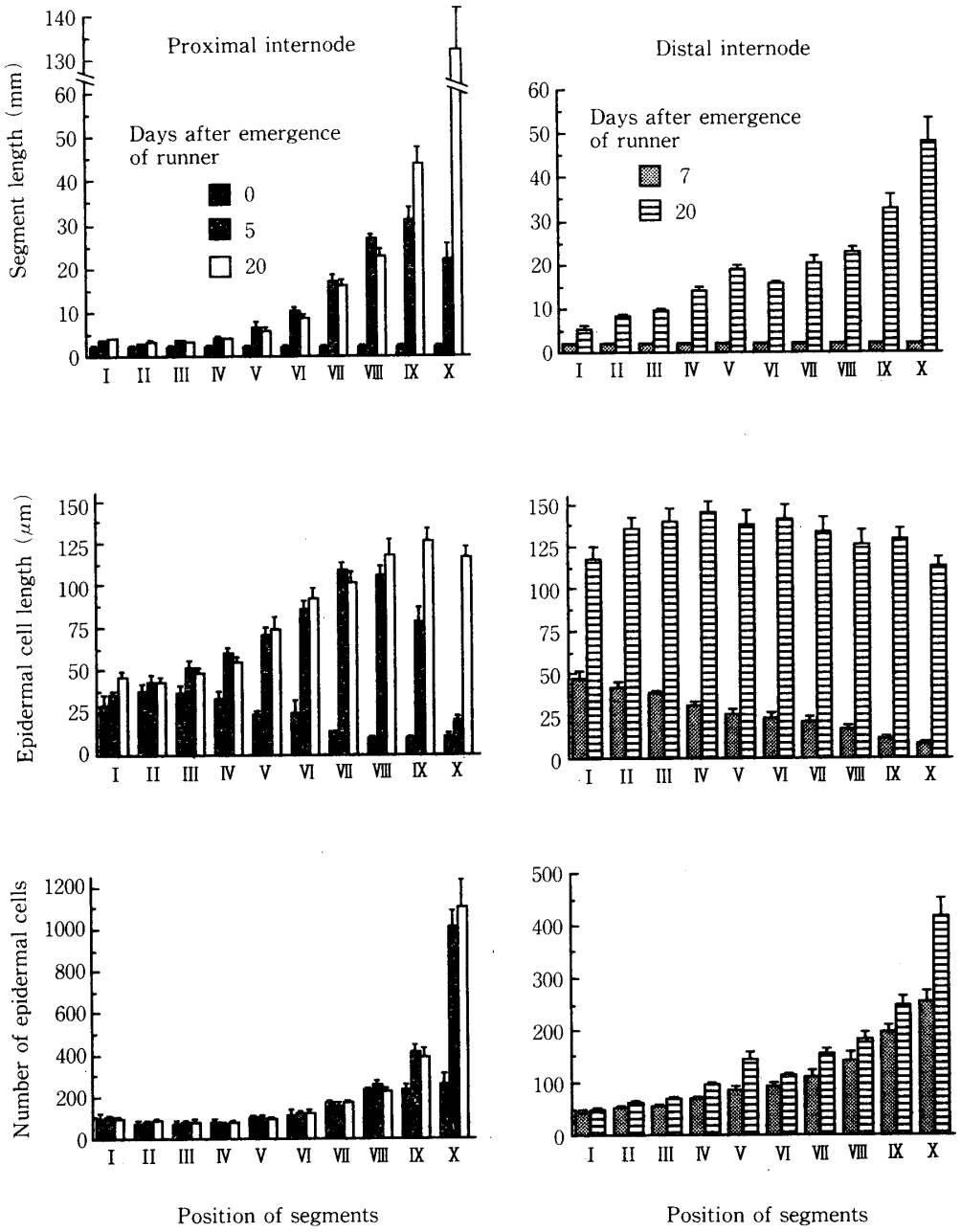

FIG. 4. Changes in length and number of epidermal cells in respective segments. Vertical bars represent S.E. As to the position of segments, refer to Fig. 2.

Internodal elongation can be found in many species inclusive of cereals and grasses. Kaufman *et al.* (4) indicated the basipetal growth pattern in the stem internodes of *Avena sativa*, where cell division and cell elongation ceased first at the distal part in opposite to our results. The acropetal growth pattern of internodes in strawberry runners seemed to be similar to that in *Helianthus* (3) and *Xanthium* (6).

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