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THE EFFECT OF ALTERNATING PERIODS OF LIGHT AND DARKNESS ON THE TISSUE OF PHASEOLUS VULGARIS L.

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Abstract

A study has been made on bean plants (*Phaseolus vulgaris* L cv. Harvester) grown under three different treatments wirh periods of 16—8, 1—0.5, and 8—4 hours of light and darkness resp., light intensity 35 Watt/m², temperature 22 ± 1 °C, and relative humidity 65 ± 5%, were the same in all the three treatment.

As compared to the control 16—8 hours it was found that dry weight was the greatest for 5 week plants under a cycle of 8—4 hours of light and darkness.

Primordia leaves grown under 1—0.5 hour rhythm show a decrease in thickness as compared to the 8—4 hours and 16—8 hours of light and darkness.

There was a slight difference in the stomata number of upper leaf surface for plants grown under the treatments, while for the lower stomata number there was found an increase in the rhythm of 1—0.5 hour as compared to the 8—4 hours and 16—8 hours.

The growth of vascular bundles of stem and root was the best under 16—8, and 8—4 hours, and the poorest growth took place under 1—0.5 hours.

Introduction

Light exerts a considerable effect on the growth and development of plants. It is well-known, e.g., that the growth of the leaf, the elongation of the stem are generally stimulated by light.

The strength of illumination, apart from its effect on the organic matter production, has an effect on growth and development, as well. As a result of the low strength of illumination, the stem grows longer, becomes thinner, the leaves are smaller, the lamina of leaves are thinner.

The quality of light and the distribution of spectral energy has also an influence on the morphological properties and the tissue structure (HORVÁTH, 1965). It is for example, demonstrated that growth and leaf surface are increased under the influence of the red but particularly the blue-red spectral ranges.

The occurrence of light and dark cycles of a short period on certain plants exerts a considerable effect on the morphology and the accumulation of dry-matter. It was found by several investigators that the very short alternate periods of light and darkness have pronounced inhibitory effect on growth and development. The effect of light and dark cycles between 1-min. and 12-hours was observed in Cucumber by PORTSMOUTH (1937) and in *Salvinia* by RAJAN et al. (1971), and it was found that plants subjected to 1-min. cycle were greatly reduced in height and over-all leaf area.

HORVÁTH and co-workers (1976, 1977) have found in *Phaseolus* and *Sinapis* grown in 4-hours' light and 2-hours' dark, the utilization of photosynthetic energy and dry weight was about 20% higher than the treatment of 16—8 hours light and darkness.

In the course of our investigations, we have dealt with the effect of alternating periods of light and darkness on the tissue structure of the leaf, stem and root.

Materials and Methods

Our experiments were carried out in the phytotron of the Botanical Garden of Attila József University, Szeged. HORVÁTH (1972). The used plants were *Phaseolus vulgaris* L., cv. Harvester grown in pots containing coarse sand and perlite. At the beginning of the experiment the 70% water capacity of sand was set on with KNOP's nutrient solution. The plants were watered daily with distilled water and once a week with KNOP's nutrient solution.

Three chambers were used in the experiment one of them is the control with a 16-hours' light and 8-hours' dark, and the other two supplied with a short rhythm of 1—0.5 and 8—4 hours of light and darkness, respectively, and the total daylength in both rhythms was 16-hours' light. In the three treatments light intensity was 35 Watt/m² (supplied with 40 W F 29 fluorescent tubes)., temperature was 22 ± 1 °C, and relative humidity was maintained between 65 ± 5%.

The investigation was repeated on the three occasions, in each case 18 plants were elaborated. The elaboration took place 2, 3, 4, and 5 weeks after sowing. Fresh materials from each plant were placed in an electric oven in 105 °C and then dried 70 °C until it attained the constant weight.

For anatomical study, the primordia, the 2nd internodium of stem and about 2 cm from the apices of roots were collected and fixed in 70% alcohol. The epidermis and cross-sections were prepared from the middle part of the leaf. Several sections were made by hand and others by hand microtome, after being cleaned they were stained with haematoxylin and mounted in glycerine jelly by customary methods.

The histological study includes the following calculations:

a) stomata and epidermis per sq. mm. for both upper and lower surfaces, with the help of a lanometer.

b) leaf thickness, ratio between palisade and spongy parenchyma, cell size, and the number of layers.

c) proportion of cortex, phloem, xylem, and pith to each other and to the whole tissue structure of both stem and root.

We have calculated the percentage on the cross-sections on the basis of determining the area of the single tissue regions.

The mathematical and statistical analysis of the data was obtained by using the methods of significance and correlation. (SVÁB, 1973).

Results and Discussion

Alternation of cycles of light and darkness has a marked influence on the accumulation of dry weight and the tissue structure of the leaves, stem, and roots. In the evaluation of our results we have considered the following data:

Total dry-matter

As compared with control 16—8 hours of light and darkness it was found that the plants of 2-weeks grown under the treatment of 8—4 hours show a slight increase for dry matter production of about 8—10%, while those grown under treatment of 1—0.5 hour decreased it and the decrease was about 8—10%. Plants of 3-weeks grown under the rhythm of 8—4 hours exhibit no difference in comparison with the control.

At weeks 3, 4, and 5 the dry weight per plant in 1—0.5 rhythm was about 30% lower than in the control plants, while the one of 8—4 rhythm causes an increase only to 4 and 5 week plants, and the increasing was about 10% as compared to the control plants. Fig. 1.

Dry weight percentages of the organs

Plants of 2, 3, and 4 weeks grown under the three treatments show no difference in dry weight percentages for leaves, stem, and roots, but in case of 5th week plants the percentage ratio of leaves at the rhythm of 1—0.5 hour was about 47% as compared with 53% of the control, although the percentage ratio of the stem grown at 1—0.5 hour and 8—4 hour rhythm was about 25%, whereas the control presented 19%. The roots grown at 1—0.5 hour show a higher percentage about 28% than that of the control which was 23%.

Epidermis

In the three treatments 16—8, 1—0.5, and 8—4 hours no difference was found in the epidermal cells of upper leaf suface of plants at the age of 2, 3, and 4 weeks, while those of 5 weeks old grown at 8—4 hours show only a slight decrease of about 10% as compared with control 16—8 hours.

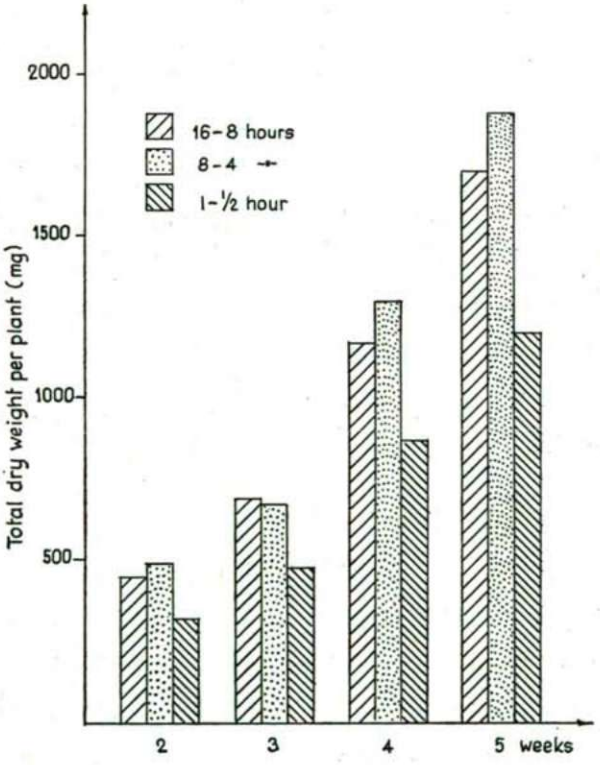

Fig. 2

In case of lower epidermal cells, it was found that plants of 2 weeks old grown under the three treatments did not show any significant difference. At week 3 the epidermal cells of 8—4 rhythm plants show a decrease of about 10% as compared with the control plants, while those of 1—0.5 rhythm show a very slight increase. At week 4 rhythms of 1—0.5 and 8—4 hours causes a decrease in the epidermal cells of about 10% as compared with the control.

Stomata

As compared with the control 16—8 hours of light and darkness it was found that plants of 2 weeks old grown under the treatment of 8—4 show an increase in stomata number of the upper leaf surface of about 20%, while those of 1—0,5 hour rhythm show no difference. On the other hand, plants of 5 weeks old grown under the three treatments do not show any difference in stomata number of the upper leaf surface.

For the lower part of leaf surface, it was found for plants of 2 weeks old grown under the three treatments that the lower stomata numbers are equal. Plants of 4 weeks old grown at the rhythm of 1—0.5 and 8—4 hours exhibit a slight decrease as compared to the control 16—8.

Leaf thickness

As compared to the control 16—8 hours, plants of 3, 4, and 5 weeks grown under the rhythm of 1—0.5 hour show a marked decrease in primordia leaf thickness, while those of 8—4 hours exhibit only a slight increase.

Stem

During our histological investigation on the stem, we have taken into consideration the structure and the rate of participation of the following regions:

Cortex, phloem, xylem, and pith. It was found that plants grown under the rhythm of 1—0.5 hour show a slight decrease in the percentage ratio of cortex, xylem, and phloem, while those of 8—4 rhythm show no difference as compared to the control 16—8 hours of light and darkness.

Root

According to the results we found that the percentage ratio of the stele of plants grown at 16—8 rhythm is 15 percent, at 8—4 rhythm it is 12 percent, and at 1—0.5 rhythm it is 10 percent.

References

HORVÁTH, I. (1965) A fény színképi összetételének növényökológiai szerepe. — Acad. Doct. Diss. Gödöllő.

HORVÁTH, I. (1972) Phytotron in Botanical Garden of Attila József University. — Acta Biol. Szeged, *18*, 1—4.

HORVÁTH, I. (1976) Effect of light rhytmicity on the utilization of photosynthetic energy. — Acta Biochim. et Biophys. *11*, 157.

HORVÁTH, I., MIHALIK, E. and TAKÁCS, E. (1977) The effect of rhytmicity of illumination upon the accumulation of dry substance. — Bot. Közlem. *64*, 2—8.

Plate I

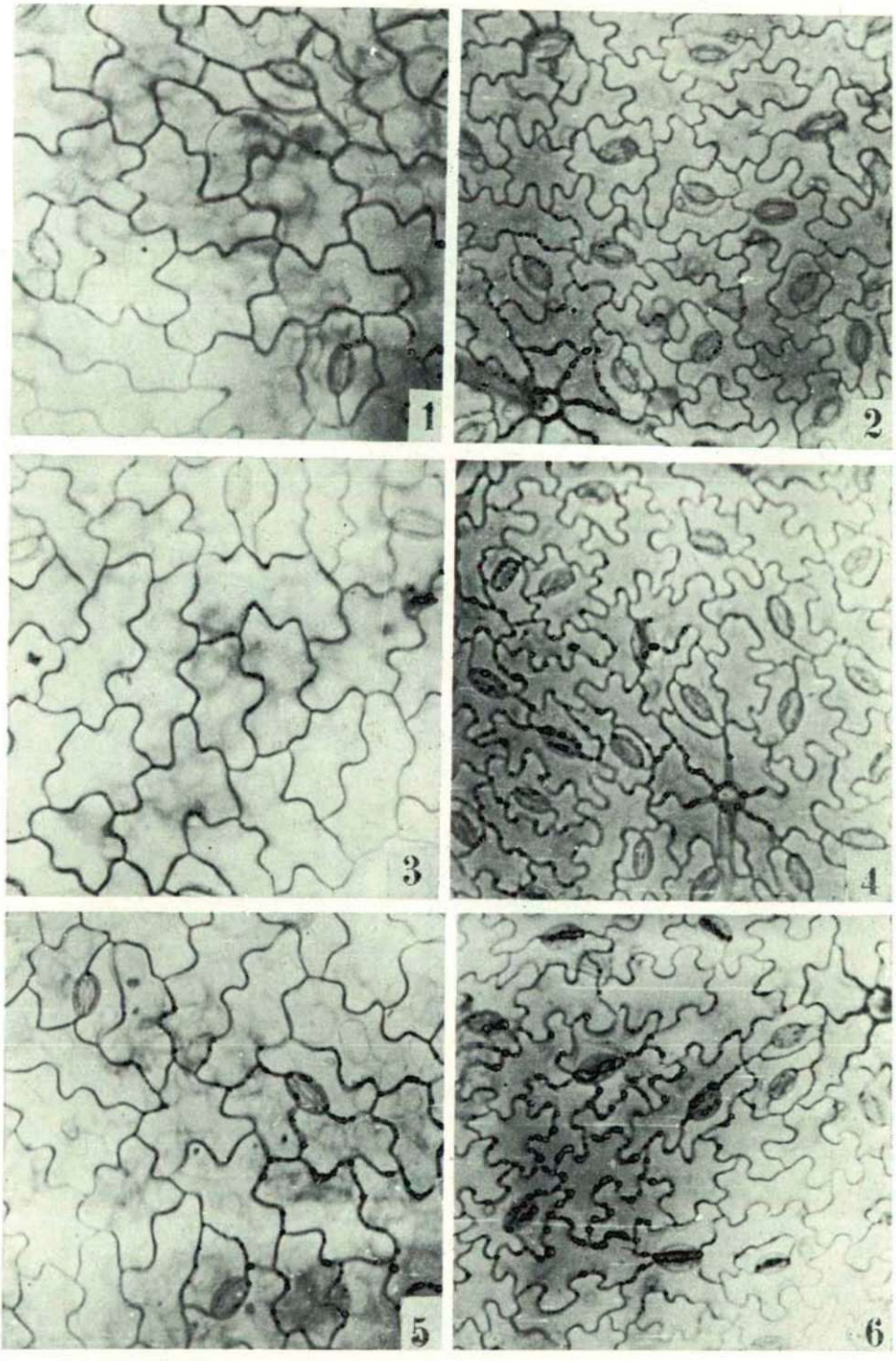

Fig. 1—6. Epidermis of upper and lower leaf surface of bean plants (*Phaseolus vulgaris* L.) — intensity of illumination 35 Watt/m². 1 and 2 upper and lower leaf surfaces grown under 16—8 hours of light and darkness.
3 and 4 upper and lower leaf surfaces grown at 8—4 hours. 5 and 6 upper and lower leaf surfaces grown under rhythm of 1—0.5 hour. (X 200)

Plate II

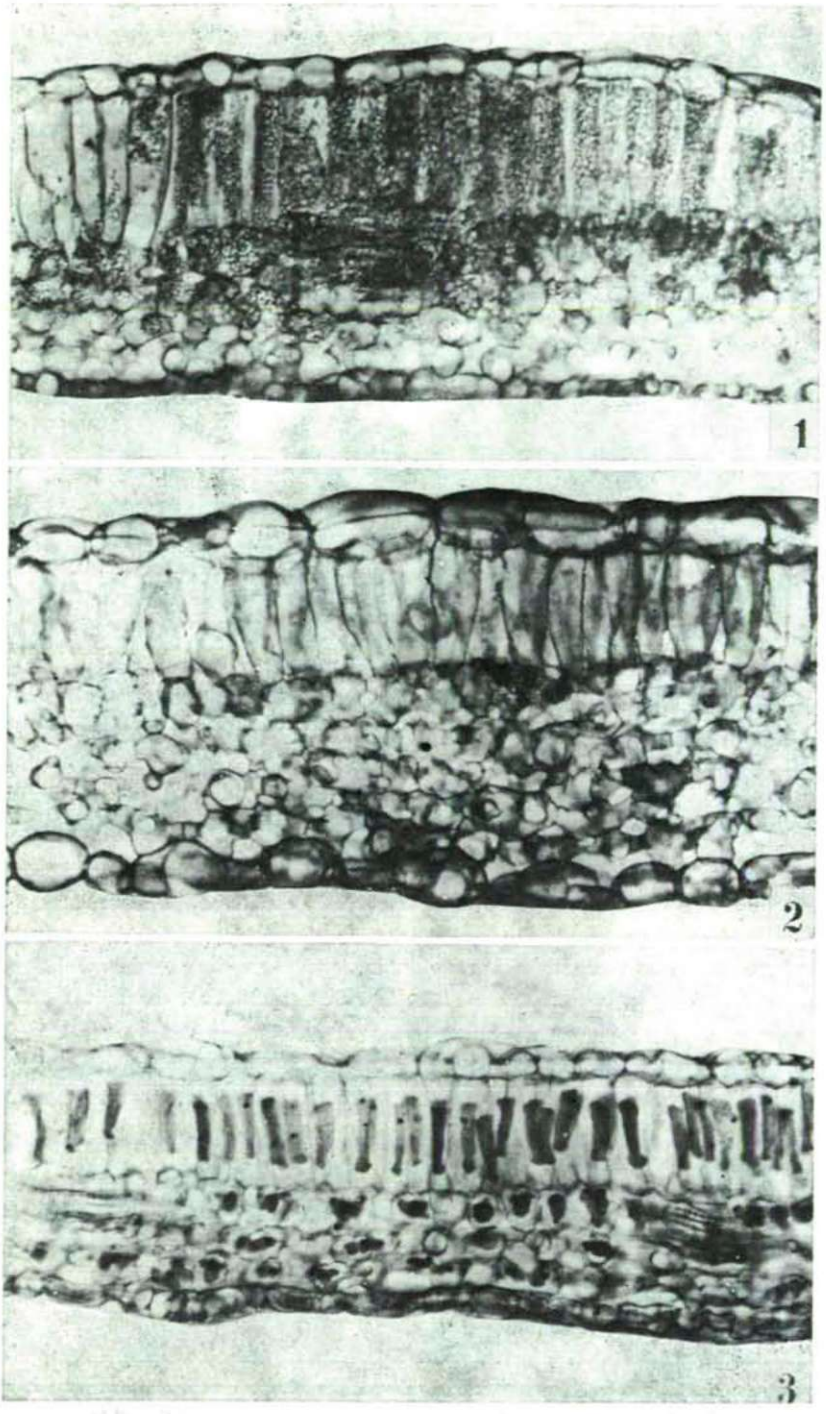

Fig. 1—3. Cross-sectional views of primordia leaves of bean plants (Phaseolus vulgaris L.) — intensity of illumination 35 Watt/m². 1/ 16—8 hours, 2/ 8—4 hours, 3/ 1—0.5 hour of light and darkness. (X 200)

Plate III

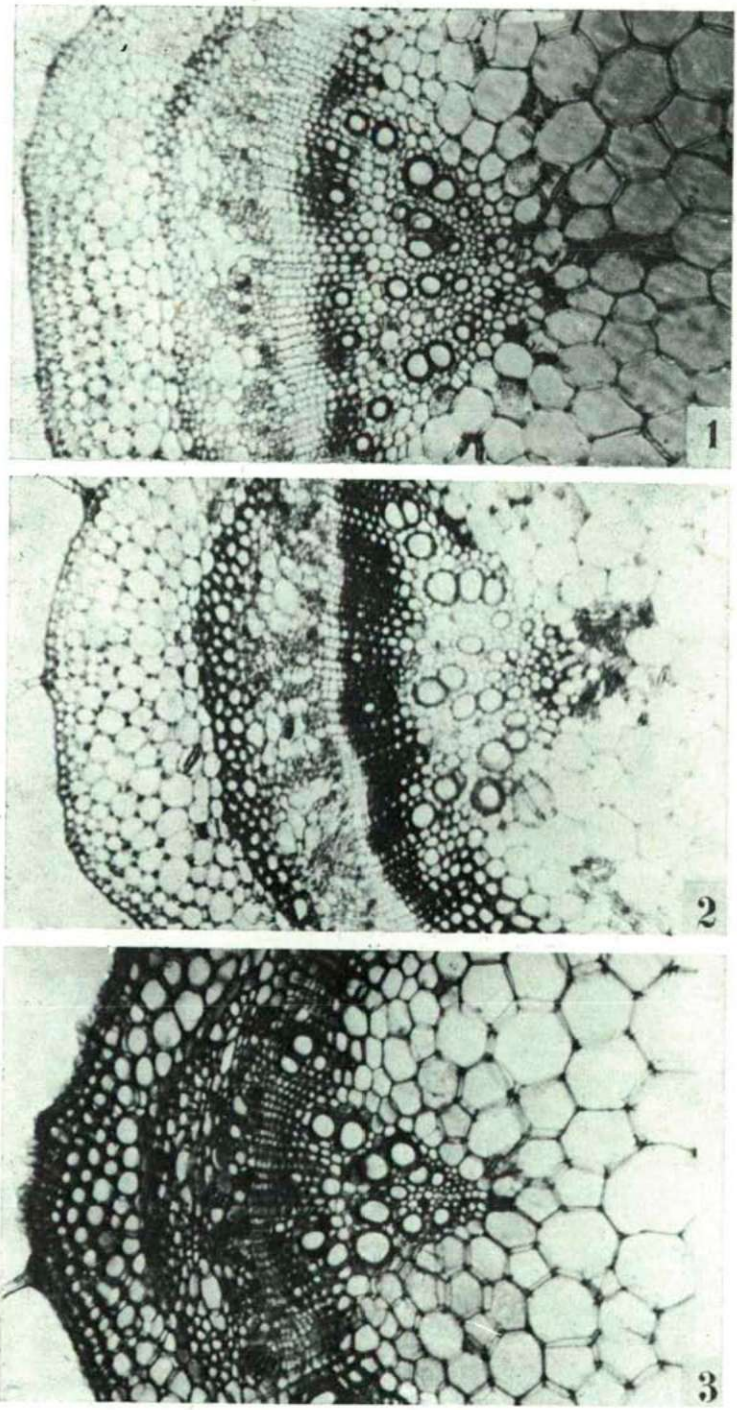

Fig. 1—3. Cross-sectional views of stem of bean plants *(Phaseolus vulgaris* L.*)* — intensity of illumination 35 Watt/m². 1/ 16—8 hours, 2/ 8—4 hours, 3/ 1—0.5 hour. (X 80)

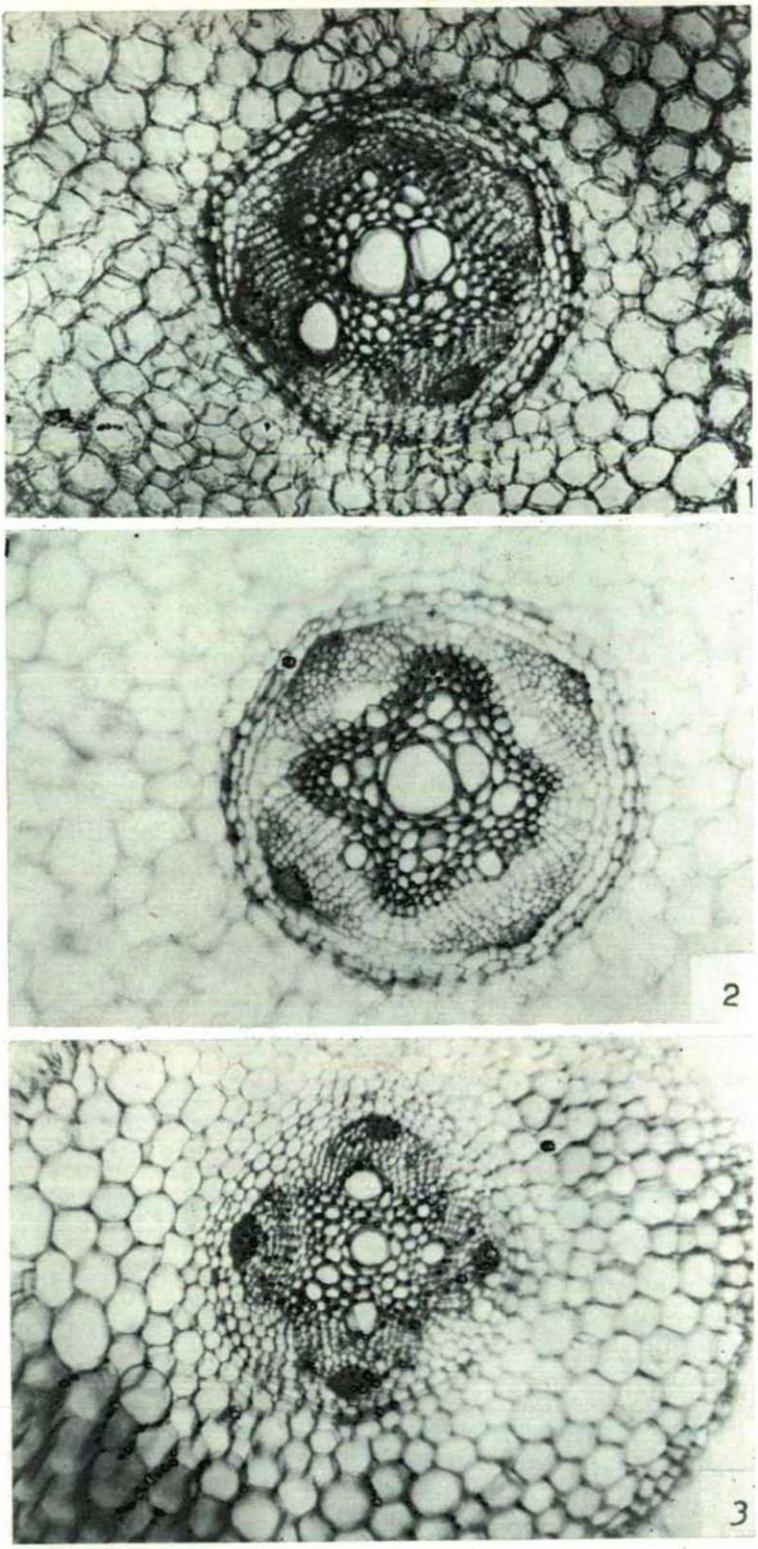

Fig. 1—3. Cross-sectional views of root of bean plants *(Phaseolus vulgaris* L.*)* — intensity of illumination 35 Watt/m². 1/ 16—8 hours, 2/ 8—4 hours, 3/ 1—0.5 hour. (X 100)

PORTSMOUTH, G. B. (1937) The effect of alternate periods of light and darkness of short duration on the growth of the cucumber. — Ann. Bot. *1*, 175—189.
RAJAN, A. K., BETTERIDGE, B. and BLACKMAN, G. E. (1971) Changes of light and darkness of widely different duration. — Ann. Bot. *35*, 597—604.
SVÁB, J. (1973) Biometriai módszerek a kutatásban. Mezőgazdasági Kiadó. Budapest.

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