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Root-Shoot Ratio in Irrigated Plants

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Abstract: Relationship between roots and shoots of *Pimpinella saxifraga* L., *Petroselinum hortense* HOFFM., *Lactuca sativa* L., and *Beta vulgaris* subsp. *esculenta* (SALISBURY) GÜRKE var. *altissima* ROESSIG was studied in irrigated and non-irrigated plants. It was found that the irrigation water did not influence distinctly the root-shoot ratio of the experimental plants. From the statical point of view, this relationship could be expressed by the following quantitative ratios for irrigated and non-irrigated plants: 3 : 1 for *Pimpinella saxifraga* L., 2 : 1 for *Petroselinum hortense* HOFFM., 9 : 1 for *Lactuca sativa* L., and 1 : 1 for beetroot. From the dynamic point of view it is possible to state that this ratio changes in the course of individual development. With plants cultivated for their aerial parts, it increased with age, while with plants cultivated for their roots, it decreased with age. The irrigation water produced much greater morphological changes (the shape and the surface area) in the root and shoot system of experimental plants.

In our earlier work we found that the applied irrigation produced morphological changes (shape and surface area) in roots and shoot parts of experimental plants (PENKA 1953, 1958a, b, 1962, 1963 etc.). Therefore, in this paper we are trying to solve experimentally the problem of whether irrigation water is a factor which changes the weight ratio, and hence also the relationship, correlation between roots and shoots of the plants.

Material and Methods

For our experiments the following plants were used: *Pimpinella saxifraga* L., *Petroselinum hortense* HOFFM. Sowing of these species of plants of the Daucaceae family was carried out on April 26, 1958, on a field divided to parcels 10 m long and 1.5 m broad, in rows 20 cm apart. The soil was ploughed already the preceding autumn and fertilized with stable manure. The antecedent culture was clover. Each piece of land was divided into two halves, one of which was regularly irrigated, while on the other the plants grew under natural

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conditions. The monthly dose of irrigation was approximately 60 mm of precipitation water. Irrigation was carried out between 6 and 7 p.m.

In the course of vegetation, fresh weight, dry matter, water content, and the length of aerial parts as well as of roots were determined.

The samples of *Daucaceae* plants were collected from the field for analysis on the following days: 23. VI., 3. VII., 18. VII., 1. VIII., 19. VIII., 2. IX. and 20. IX. The samples were taken at midday (between noon and one p.m.), because the plants were also analysed for their content of essential oils (according to Czechoslovak Pharmacopoeia 1954). Certain meteorological data were also observed during the cultivation. Part of our results will be discussed and published elsewhere.

I should like to express my gratitude to the Mrs. M. Štursová, M. Šebová, and A. Valeská for their technical assistance.

Results

Figures 1—4 show the ratios for fresh weight and dry weight of roots and shoot parts of the same experimental plant. The horizontal line (full line for irrigated, dotted line for non-irrigated plants) represents the average of these

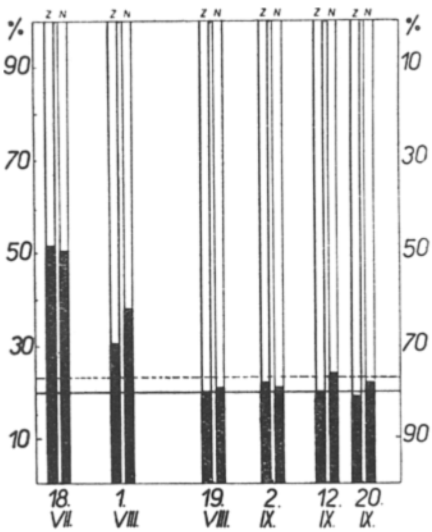

Fig. 1.

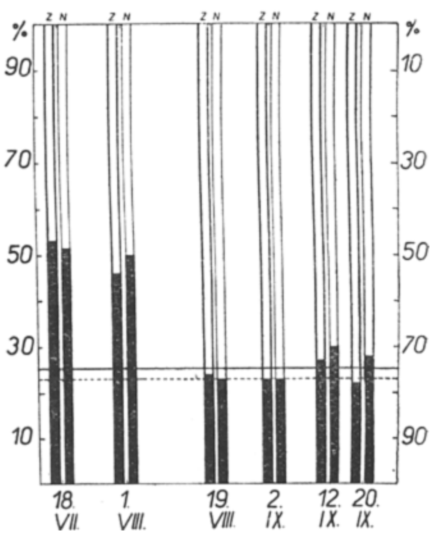

Fig. 2.

Fig. 1: The ratio of fresh weights of shoot parts and of roots in experimental plants of *Pimpinella saxifraga* L. (1958). On the y axis — the total fresh weight represented by a column equal to 100%; the portion of the column completely blackened represents the percentage of the fresh weight of roots, while the remaining (white) portion represents the percentage of the fresh weight of aerial parts. In the case of irrigated plants the columns are drawn in thick line (Z), for non-irrigated plants the columns are drawn in a thin line (N). Average values for irrigated plants are represented by a full line, for non-irrigated plants, by a dotted line. On the x axis — time in days.

Fig. 2: The ratio of dry matter, of shoot parts and of roots in experimental plants of *Pimpinella saxifraga* L. (1958). For detailed description see legend to Fig. 1.

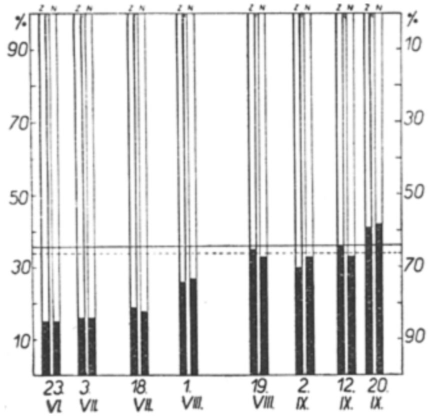

Fig. 3.

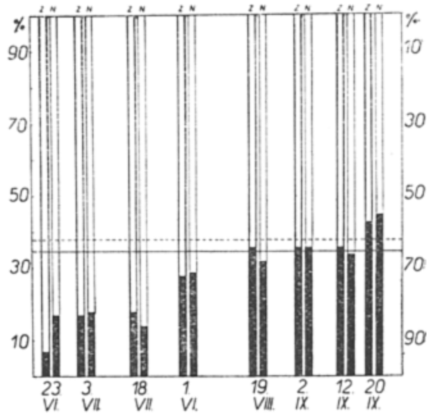

Fig. 4.

Fig. 3: The ratio of fresh weights of shoot parts and of roots in experimental plants of *Petroselinum hortense* HOFFM. (1958). For detailed description see legend to Fig. 1.

Fig. 4: The ratio of dry matter, of shoot parts and of roots of experimental plants of *Petroselinum hortense* HOFFM. (1958). For detailed description see legend to Fig. 1.

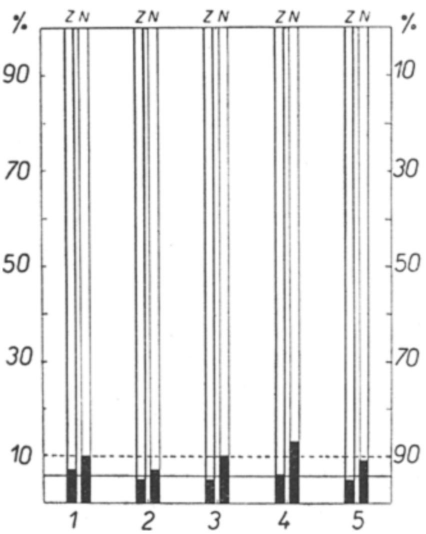

Fig. 5.

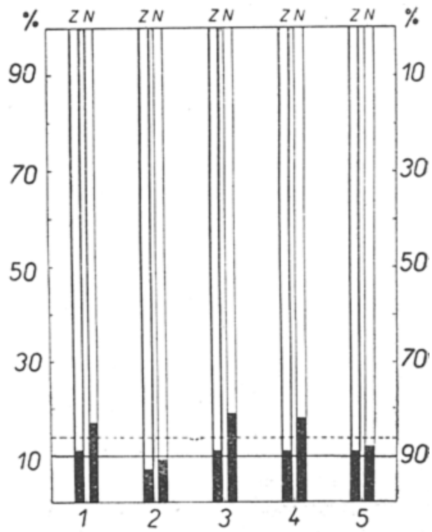

Fig. 6.

Fig. 5: The ratio of fresh weight of shoot parts and of roots of experimental plants of *Lactuca sativa* L. (1963). For detailed description see legend to Fig. 1.

Fig. 6: The ratio of dry matter, of shoot parts and of roots of experimental plants of *Lactuca sativa* L. (1963). For detailed description see legend to Fig. 1.

values, calculated for the whole vegetation period. The results obtained with *Lactuca sativa* L. cultivated in 1963 (see Figs 5 and 6), and those obtained by BAŇOCH and SLEPIČKA (1963) with beetroot (*Beta vulgaris* subsp. *esculenta* (SALISBURY) GÜRKE var. *altissima* ROESSIG), cultivated with irrigation and without irrigation (see Fig. 7), were worked up in a similar manner. In order to complete and illustrate our results we give in Figs 8 and 9 the ratio for essential oil content of experimental plants of the Daucaceae family, represented in the same manner.

Discussion

Views concerning the root system and shoot parts of plants can differ from theoretical as well as from practical points of view. From the practical point of view the mass of these two systems is usually reduced (lessened) by those parts which are uneasily accessible (hairs of roots, endings of main and side roots, fallen leaves etc.). The main purpose for which the plants are cultivated (whether for aerial or for underground parts) influences the choice of plants and the method of their cultivation, and, therefore, also their shape and size, but also the root-shoot ratio. Numerous authors pay attention to the relationship of these two systems in plants (LOEB 1924; KRENKE 1950; CHALYAKHIAN 1955, 1958; DOSTÁL 1959; KURSANOV 1960; BROWER 1962a, b; DOBBEN 1962, and others).

It was found that the most important and limiting factors able to change distinctly the root-shoot ratio are glucides, minerals, and water (KURSANOV 1960; BROUWER 1962a, b, and others). Any intervention changing the amount of glucides in the shoot parts of the plants stimulates simultaneously the growth of roots. On the other hand, any intervention increasing the intake of minerals and water enhances more the growth of the shoot parts than of the roots. The functional equilibrium between the aerial parts and the roots, between the intake and the distribution of glucides, minerals and water can be explained in this manner. This functional equilibrium changes in every plant in the course of its individual development. DOBBEN (1962) states, for example, that during the germination period of cereals the root-shoot ratio remains rather low. In subsequent stages of development this value increases and reaches its maximum during ripeness.

When studying morphological changes in plants used in this work we found that the shoot parts of the irrigated plants were strongly developed and abundantly branched, while the roots consisted of a strong main root and a restricted number of side branches (roots). In contrast to this, the aerial parts of non-irrigated plants were smaller and poorly branched, while the roots were also smaller but abundantly branched.

In view of these morphological changes it is presumed that it is the irrigation water which distinctly changes the root-shoot ratio of experimental plants. However, when the values for weights of fresh and dried experimental plants were compared (see Figs 1 to 7) it was found that the resulting root-shoot ratio for irrigated and non-irrigated plants was substantially the same. The following values were found: 3 : 1 for *Pimpinella saxifraga* L., 2 : 1 for *Petro-*

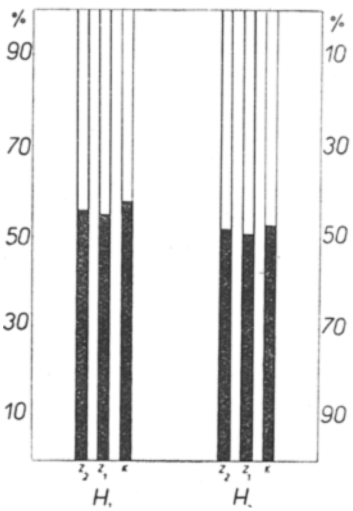

Fig. 7.

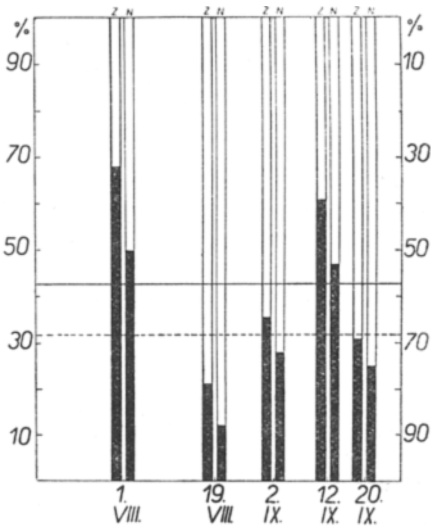

Fig. 8.

Fig. 7: The ratio of weights (crops) of shoot parts and of roots of experimental plants *Beta vulgaris* subsp. *esculenta* (SALISBURY) GÜRKE var. *altissima* ROESSIG. For detailed description see legend to Fig. 1. — Z_2 — irrigation was dependent on soil humidity, which was controlled and carried out with smaller doses of water, but given more often; K — with natural development of soil humidity; H_1 — low mineral and organic fertilizing. As the basis for the calculation of ratio of leaves and roots expressed in a relative way, the absolute values from the paper by BAŇOCH and SLEPIČKA (1963) were used.

Fig. 8: The ratio of essential oil content of shoot parts and of roots of experimental plants of *Pimpinella saxifraga* L. (1958). For detailed description see legend to Fig. 1.

selinum hortense HOFFM. (in the first year), 9 : 1 for *Lactuca sativa* L. (in the first year), and 1 : 1 for beetroot (in the first year). If we evaluate the obtained results from the dynamic point of view, it becomes obvious that the root-shoot ratio changes in the course of the individual development of the plants. In the case of *Pimpinella saxifraga* L., the value of this ratio increased with age (see Fig. 1 and Fig. 2), while with *Petroselinum hortense* HOFFM. it decreased (Figs 3 and 4). *Lactuca sativa* L. (see Figs 5 and 6) and beetroot (Fig. 7) behaved

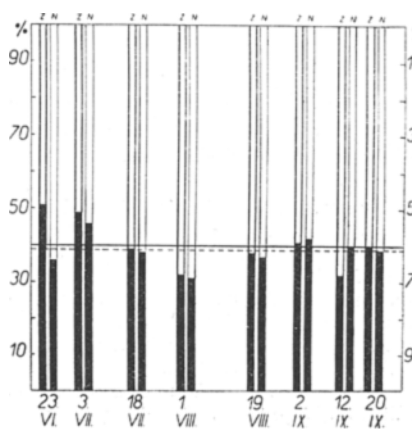

Fig. 9: The ratio of essential oil content of shoots parts and of roots of experimental plant of *Petroselinum hortense* HOFFM. (1958). For detailed description see legend to Fig. 1.

in a similar manner. This was caused by the fact that in plants cultivated for their shoot parts water accumulated more intensely in shoots, while in plants cultivated for their roots, solid components (non-volatile matter) were accumulated at a greater rate. It is interesting that the accumulation of essential oils was also greater in roots than in shoot parts of the experimental plants (see Figs 8 and 9).

Hence, irrigation distinctly influenced the root-shoot ratio of experimental plants. However, the changes in morphology (the shape and the area of the surface) and the growth intensity of roots and shoot parts of these plants were much more conspicuous.

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Byl sledován poměr mezi lodyžním a kořenovým systémem zavlažovaných a nezavlažovaných rostlin *Pimpinella saxifraga* L., *Petroselinum hortense* HOFFM., *Lactuca sativa* L. a *Beta vulgaris* subsp. *esculenta* (SALISBURY) GÜRKE var. *altissima* ROESSIG. Bylo zjištěno, že závlaha zřetelně neovlivnila poměr mezi lodyžním a kořenovým systémem pokusných rostlin. Z hlediska statického bylo možno tento poměr vyjádřit u zavlažovaných i nezavlažovaných rostlin *Pimpinella saxifraga* L. vztahem 3 : 1, *Petroselinum hortense* HOFFM. — 2 : 1, *Lactuca sativa* — 9 : 1 a u rostlin cukrovky — 1 : 1. Z hlediska dynamického bylo možno říci, že se tento poměr v průběhu individuálního vývoje mění. U rostlin pěstovaných pro nadzemní část se stářím zvyšoval a u rostlin

pěstovaných pro kořenovou část se stářím snižoval. Daleko výrazněji pozměnila závlahová voda morfologii (tvar a velikost povrchu) lodyžního a kořenového systému pokusných rostlin.

М. Пенка, Кафедра ботаники леса и фитоценологии лесохозяйственного факультета Высшей сельскохозяйственной школы, Брно: **Отношение стеблевой и корневой системы у орошаемых растений.** — Biol. Plant. **7** : 129—135, 1965.

Изучалось отношение корневой и стеблевой системы орошаемых и неорошаемых растений *Pimpinella saxifraga* L., *Petroselinum hortense* Hoffm., *Lactuca sativa* L. и *Beta vulgaris* subsp. *esculenta* (Salisbury) Gürke var. *altissima* Roessig. Установлено, что орошение не оказывает заметного влияния на отношение стеблевой и корневой системы. С точки зрения статистики возможно это отношение выразить у орошаемых и неорошаемых растений *Pimpinella saxifraga* L. отношением 3 : 1, *Petroselinum hortense* Hoffm. 2 : 1, *Lactuca sativa* 9 : 1 и у растений сахарной свеклы 1 : 1. С динамической точки зрения возможно утверждать, что данное отношение в течение индивидуального развития меняется. У растений выращиваемых ради надземной части это отношение с возрастом повышалось и у растений выращиваемых ради корневой части с возрастом понижалось. Гораздо значительнее изменило орошение морфологию (форму и величину поверхности) стеблевой и корневой системы подопытных растений.