QUALITATIVELY ANATOMIC CHARACTERISTICS OF VEGETATIVE ORGANS OF JUVENILE HOP PLANT (*HUMULUS LUPULUS* L.), THE FAMILY *CANNABACEAE*

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The roots have the primary structure (rhizodermis with root hairs, primary bark, and actinostele with radial, mostly tetral vascular bundle) at a distance 15–20 mm from the growing point. The lateral root was established exogenously. The roots pass soon to the secondary structure by activities of phellogen and cambium. Their tissues manifested minimal to zero lignification of cell walls and high presence of starch (amyloplast). The stem has a primary structure, too (epidermis, primary bark, collateral vascular bundles, pith), only on a short section behind the growing point. Cambium is applied functionally at a distance 10 mm from the growing point and internal structures pass into the secondary structure. The secondary xylem of arising growth cylinder has a character of homoxylous porously scattered deuteroxylem. Phellogen was not recorded. Excretory (latex) channels have been already established in undifferentiated zone and are present in all internodes. Lignification of cell walls of mechanical tissues was very low, vascular walls of deuteroxylem components are more lignified. Though the hop is considered the herb, anatomically the stem has a character of woody species. The internal structure of petiole (the system of cover, conductive and basal tissues) reminds the stem structure anatomically. The secretory channels placed among phloem sections penetrate from the stem through the leafstalk into the main vein of the leaf blade. The blade is significantly thin among the veins and has a typical bifacial structure. Stomata and huge trichomes are present only in abaxial epidermis. Mostly the cell walls are not lignified. The resistance is provided by xylem segments of vascular bundle and subepidermal layer of tissues with mechanical function (collenchyma and sclerenchyma) in the leafstalk and thick veins. The knowledge found has a meaning for applied agricultural research and hop-growing practice.

Humulus lupulus L.; juvenile plant; root; stem; leaf; anatomy

INTRODUCTION

Two hop species are cultivated in the territory of the Czech Republic. As mentioned by Dostál (1989) one of them is a Japanese hop variety *Humulus scandens* (Lour) Merill, syn. *H. japonicus* (as referred to by Novák, 1961) originating from Japan and another one hop species (also rotational) *Humulus lupulus* L. originally growing in the Czech Republic.

Morphologically the hop is a dioecious liana (dextrorotatory plant) distinguished by herbaceous vines. It has been cultured in Bohemia since the Middle Ages for containing substances of female catkins used for beer production. This ancient cultural plant was in the past and still is an object of long-term attention of breeders and growers.

The data on anatomical structure of hop are minimal in the Czech literature, microphotographic documentation is fully missing. Metcalfe and Chalk (1957) present a brief characterisation; they are devoted only to the above-ground vegetative organs and without microphotographic documentation. The contribution dealing with anatomy of above-ground organs of the mature hop plant is the only available material (Jurčák, 1994) that is oriented to the sphere of didactics of biology, to be concrete into the education of practical exercise from botany.

For hop-growing practice hop is propagated by cuttings (stem cuttings). This study has been aimed at presenting the basic qualitative and anatomic characteristics of internal structure of organs (root, stem, leaf) of juvenile hop plants cultivated from stem cuttings. This knowledge can be contributive for hop-growing practice particularly in vegetative propagation of hop plants from stem cuttings.

MATERIAL AND METHODS

The studied plant material originated from cut juvenile plants of regenerated Osvald clone No. 72 (M-VT) developed from the stage of three stem internodes (samples taken on 5 October 2005). These plants were obtained from cutting of green shoots on 30 July 2005. Cuttings about 25 mm long, with a single pair of leaves (1 node) were rooted in multiplastic bags (planting tubes of the volume of single cell 19 cm^3) filled with propagation substrate (peat : perlite, 5 : 1). The rooting itself was

done in tunnels covered by propagation foil, under great shading (at about 65% shading). After rooting and hardening (after 19 days) cuttings were replanted into plastic bags of the volume approximately 1000 cm^3 of growing substrate (mixture of fermented bark, peat and mineral fertilizers). The bags were perforated in the lower part for outflow of abundant rain and irrigation water and placed in the field in flat position, into the bed 1 m in width. Substrate nursery textile was spread under the bags permeable for water and preventing the growth of weeds and excessive over-growing of roots of hop plantings.

Procedures as presented by Němec et al. (1962) were used for microscopic observation. The material was taken from soil substrate, rinsed with tap water, divided into organs and fixed in FAA. After 48-hour fixation it was rinsed in water and transported into glycerol ethanol (1 : 1). Roots were studied anatomically, of which the hugest developed (main) root of the length 220 mm was documented by microphotographs, followed by all stem internodes, leafstalks of leaves and leaf blade. Cuts of 15–20 m were prepared in the manual microtome. Some cuts were cleared by chloral hydrate. Transition preparations were coloured by safranine, tested by floroglucinol and diluted by Lugol (iodine-iodine-potassium). Photomicroscope Olympus BX 40 was used also for photodocumentation.

RESULTS AND DISCUSSION

The root

Adventitious roots are forming soon in the same way from callus created basally on the cutting surface of internode, so the root system reminding homorhizia is resulting. Some of the roots are developing faster, out of which several roots (sometimes only one) are growing more distinctly by prolonged growth, stronger thinning and changing into the main root sooner or later. Roots are branching; the root system receives the character of allorhizia.

Roots in the primary structure are behind the root tip, only in relatively short section (to the distance ± 10–20 mm). They are fine, threadlike and their rhizodermis bears root hairs in the zone of the rhizoid hair. Rhizoderm cells are thin-walled, parenchyma primary bark is only slightly developed and central cylinder contains radial (tetrarch) vascular bundle. Soon, at the distance less than 20 mm from the root tip, a distinct transition of the root to the secondary structure could be observed (Fig. 1). Cambium is circular, the first elements of the secondary xylem (Fig. 2) are forming and the fundamentals of the pith rays are creating as well. The activity of phellogen that creates the layers of phellem (Fig. 3). The base of the lateral roots, which was forming from the root phellogen, was recorded, i.e. it was forming exogenously.

Anatomically the root is yet in the secondary structure at the distance about 20 mm from the root collar (Fig. 3). Primary xylem in the central cylinder has been preserved only in the secondary zone, the secondary xylem around it prevails (Fig. 4). Wood conducting elements of the secondary xylem are accompanied by parenchyma and sclerenchyma cells forming columns of mechanically hardening central cylinder. The secondary xylem is created by multilayer cambium that centrifugally produced also the secondary phloem. From the primary xylem to the residues of primary bark parenchyma pith rays are running. In the primary bark too (or in the primary and secondary phloem, respectively) islets of sclerenchyma cells were evident. Sclerenchyma cells form the ligaments with mechanical function, so the roots are tough during handling. Phellogen is produced in peripheral zone (2–3 layers of cells) that produced secondary cover tissue phellem. It is formed by dead cells that are peeling off in places with more than three layers.

Testing for lignin (colouring by safranine, reaction with floroglucinol) showed that cell walls are not lignified or only slightly (vascular walls, walls of sclerenchyma cells). It is connected evidently with the fact that lignification processes could not pass in a juvenile plant. On the contrary, the reaction with iodine-iodine-potassium to the starch showed the presence of numerous amyloplasts in root structures (Fig. 7). They were present in parenchyma cells of the central cylinder (secondary xylem), in the primary and secondary phloem, pith rays, in the primary bark (Fig. 8) and phellogen as well. They were missing in lumen of sclerenchyma cells (Fig. 9) and in cambium cells. This fact can be explained that a juvenile plant was taken for investigation as late as in the time of finishing growing season, i.e. in the time when starch production and deposition of reserve are dominant.

The stem

The stem was hexagonal in cross-section in all tested internodes. At the distance 5 mm (± 1 mm) from the growing point its internal structures were in undifferentiated state (Fig. 6). Each edge bore usually 2–3 not branched or branched great trichomes with a covering and holding function. Single-layer epidermis with small glandular trichomes was found on the surface of stem. The primary bark was parenchymal. In the zones outside the edge, i.e. opposite to the surfaces, 1–2-layer section

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Abbreviations for Figs 1–17:

BS = colored by safranine
CHh = cleared by chloral dehydrate
FAA = fixed by formaldehyde-acetum-ethanol fixations
GE = deposited in glycerol ethanol
Lu = tested by Lugol solution (iodo-iodo-potassium)
= = 0.001 mm

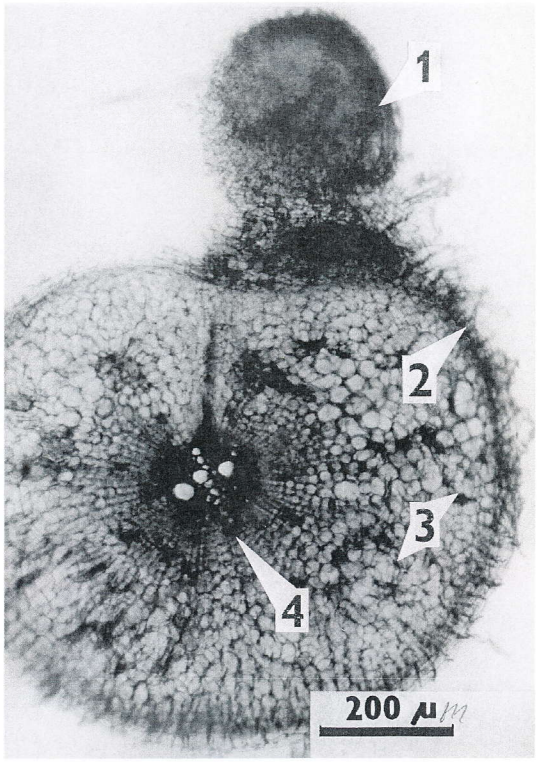

Fig. 1. *Humulus lupulus.* Root 20 (± 2 mm) behind the root tip (FAA, GE, BS, CHh). General view
1 – lateral root, 2 – secondary cover tissue (phloem), 3 – primary bark, 4 – central cylinder

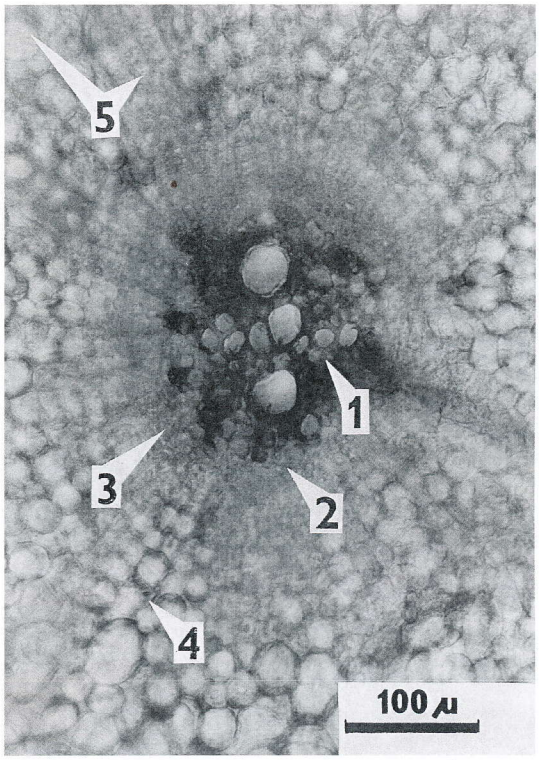

Fig. 2. *Humulus lupulus.* Root 20 (± 2 mm) behind the root tip (FAA, GE, BS, CHh). Central cylinder
1 – primary xylem, 2 – cambium, 3 – primary phloem, 4 – base of pith ray, 5 – primary bark

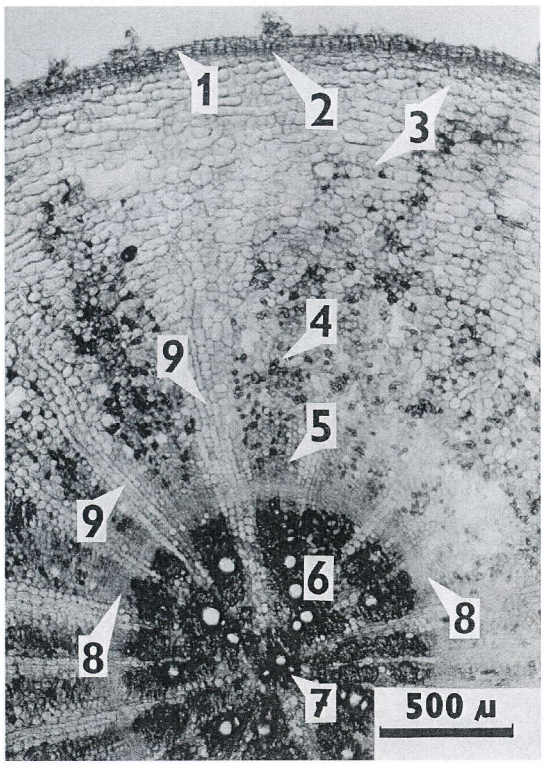

Fig. 3. *Humulus lupulus.* Root 20 (± 2 mm) under the root neck (FAA, GE, BS, CHh). General view
1 – phelem, 2 – phellogen, 3 – primary bark, 4 – primary phloem, 5 – secondary phloem, 6 – secondary xylem, 7 – primary xylem, 8 – cambium, 9 – pith rays

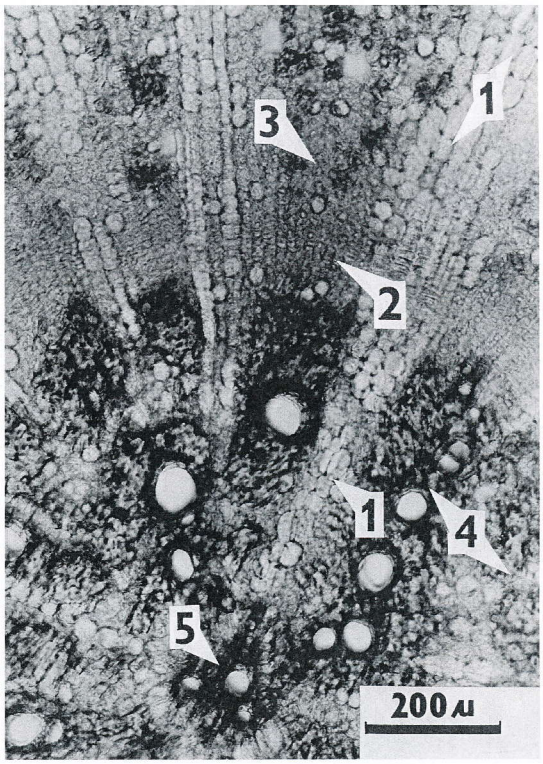

Fig. 4. *Humulus lupulus.* Root 20 (± 2 mm) under the root neck (FAA, GE, BS, CHh). Central cylinder
1 – pith ray, 2 – cambium, 3 – secondary phloem, 4 – secondary xylem, 5 – primary xylem

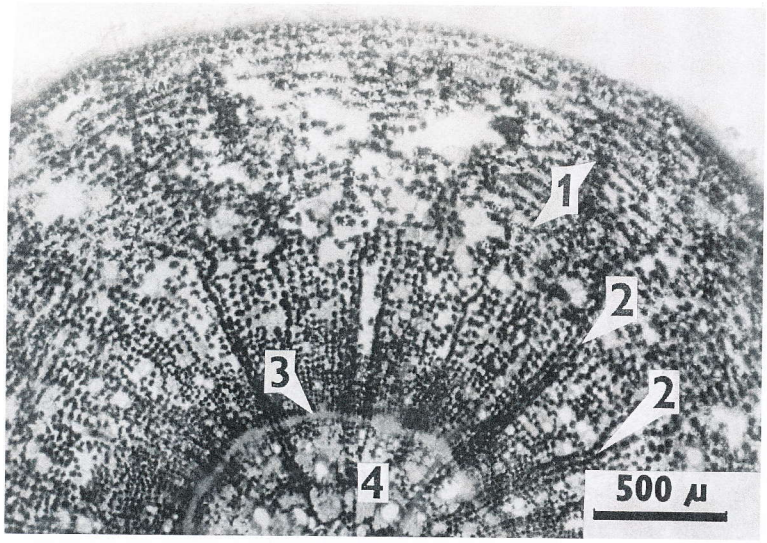

Fig. 5. *Humulus lupulus.* Root 20 (± 2 mm) under the root neck (FAA, GE, BS, Lu). General view
1 – primary bark, 2 – pith rays, 3 – cambium, 4 – secondary xylem

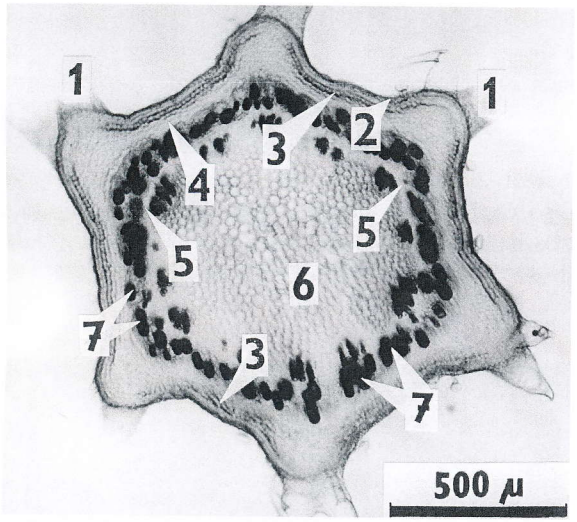

Fig. 6. *Humulus lupulus.* 1st stem internode 5 (± 1 mm) under the growing point (FAA, GE, CHh). General view
1 – edges of stem, 2 – epidermis, 3 – primary bark (chlorenchyma), 4 – primary bark (parenchyma), 5 – procambium zone, 6 – pith (parenchyma), 7 – latex channels

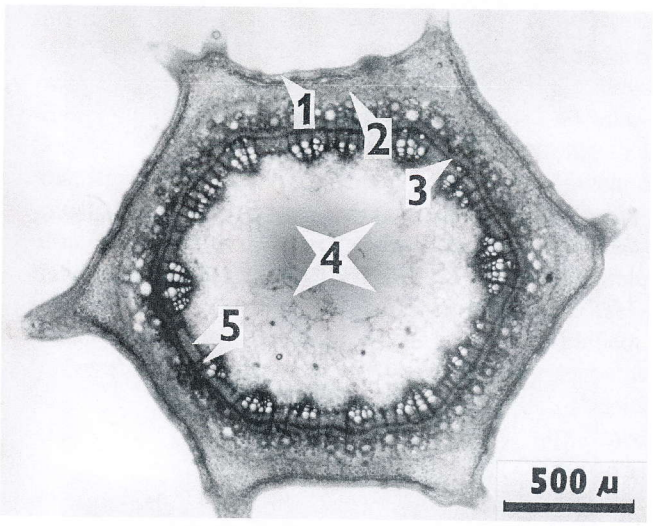

Fig. 7. *Humulus lupulus.* 1st stem internode 10 (± 2 mm) under the growing point (FAA, GE, BS). General view
1 – epidermis, 2 – primary bark, 3 – cambium, 4 – pith, 5 – secondary xylem (arising annual ring)

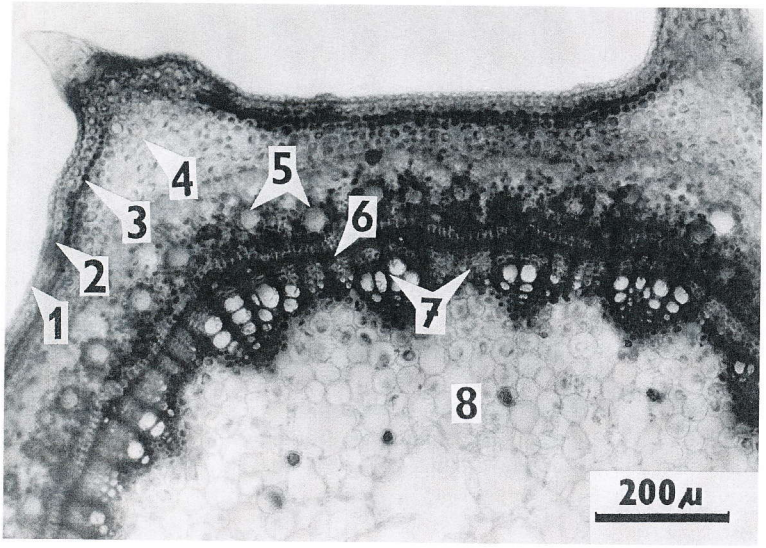

Fig. 8. *Humulus lupulus.* 1st stem internode 10 (± 2 mm) under the growing point (FAA, GE, BS). Primary bark
1 – epidermis, 2 – hypodermis, 3 – primary bark (layer of chlorenchyma), 4 – primary bark (collenchyma), 5 – secretory (latex) channels, 6 – cambium, 7 – deuteroxylem (arising annual ring)

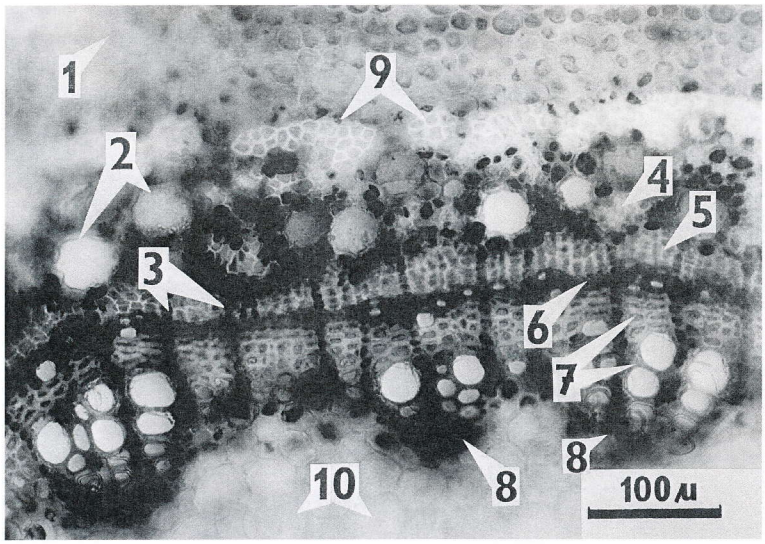

Fig. 9. *Humulus lupulus*. 1st stem internode 10 (± 2 mm) under the growing point (FAA, GE, BS). Arising annual ring
1 – primary bark, 2 – secretory channels, 3 – pith rays, 4 – primary phloem, 5 – secondary phloem, 6 – cambium, 7 – secondary xylem, 8 – primary xylem, 9 – sclerenchyma, 10 – pith

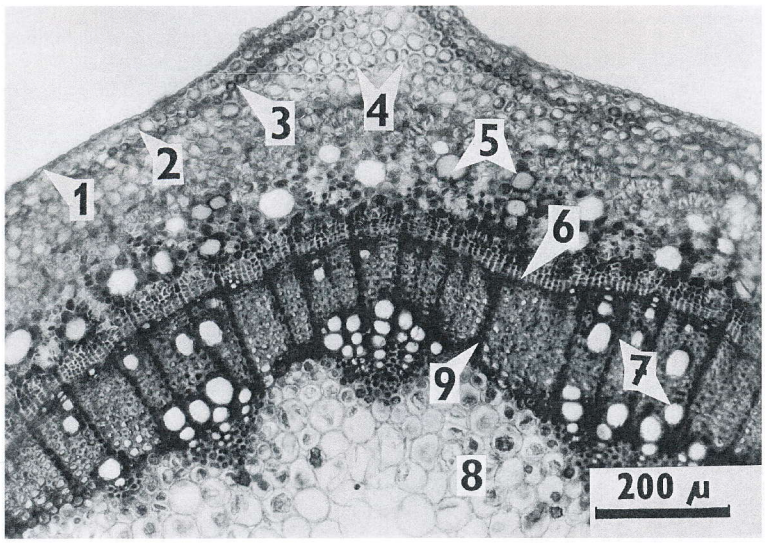

Fig. 10. *Humulus lupulus*. 3rd stem internode through the centre (FAA, GE, BS). Primary bark
1 – epidermis, 2 – hypodermis, 3 – primary bark (chlorenchyma), 4 – primary bark (colenchyma), 5 – secretory (latex) channels, 6 – cambium, 7 – secondary xylem (annual ring), 8 – pith (parenchyma), 9 – pith ray

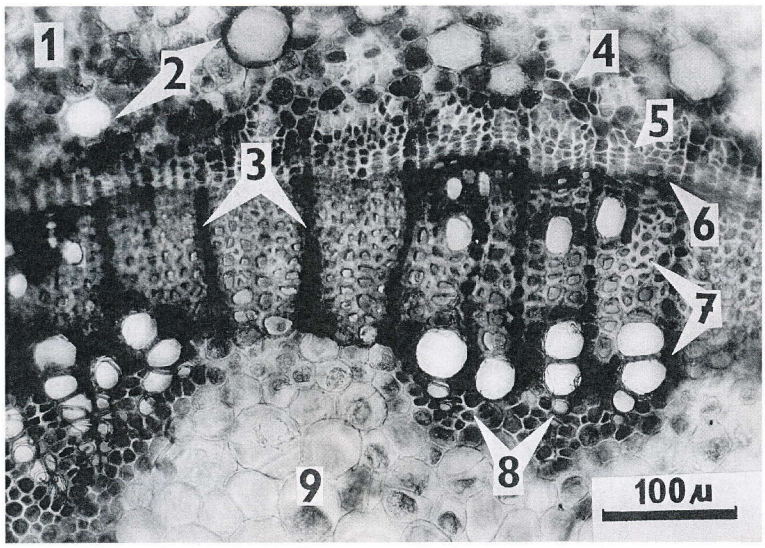

Fig. 11. *Humulus lupulus*. 3rd stem internode through the centre (FAA, GE, BS). Deuteroxylem
1 – primary bark, 2 – secretory channels, 3 – pith rays, 4 – primary phloem, 5 – secondary phloem, 6 – cambium, 7 – secondary xylem, 8 – primary xylem, 9 – pith ray

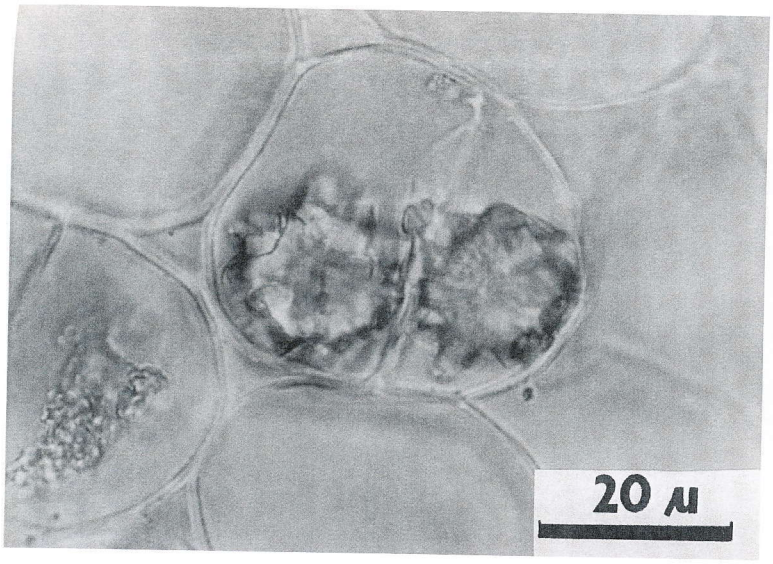

Fig. 12. *Humulus lupulus*. 3rd stem internode through the centre (FAA, GE, BS). Pith cell with 2 plates

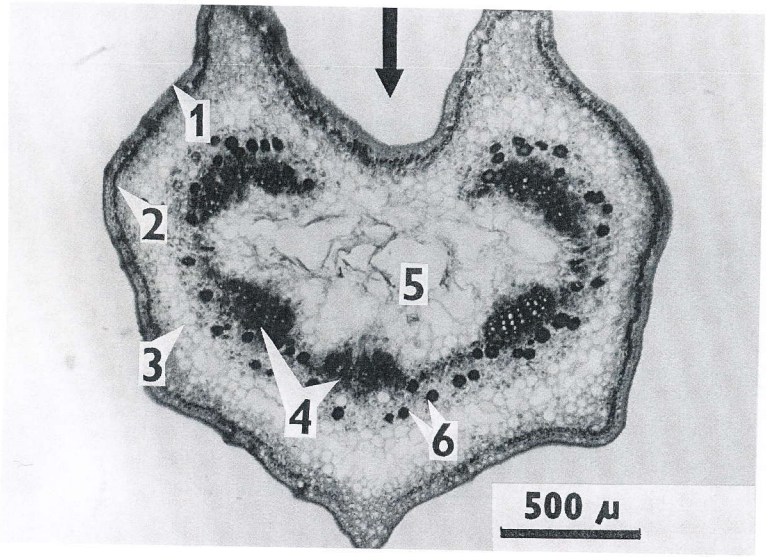

Fig. 13. *Humulus lupulus*. Leafstalk of leaf through the centre (FAA, GE, BS). General view
1 – epidermis, 2 – chlorenchyma of primary bark (of mesophyll*), 3 – parenchyma of primary bark (mesophyll*), 4 – vascular bundles, 5 – pith (of mesophyll*); arrow – adaxial area
Note: *The term mesophyll denotes the system of basic tissues in the leaf.

of parenchyma with numerous chloroplasts (chlorenchyma) was found always under the epidermis, and so the stem participates in the plant photosynthesis. Procambium between the primary bark and parenchyma pith started only to produce elements differentiating into the primary phloem and xylem. However, the presence of great intercellulars filled with a brown solution in this zone was very conspicuous that can be considered as secretory channels, and that are denoted as latex channels (Metcalfe, Chalk, 1957).

At the relatively small distance from the growing point (approximately 10 mm) and from the previous cut (at the distance about 5 mm) the internal structures of the stem internode were distinctly differentiated and demonstrated the traits of transition to the secondary structure (Fig. 7) in the central cylinder. Single-layer hypodermis created by collenchyma to sclerenchyma was developed under single-layer epidermis (Fig. 8). The layer of chlorenchyma was present on surfaces under it that was missing opposite to edges. On the contrary, hypodermis passed to several layers on edges. These layers were a follow-up to the layers of the primary bark spread under the chlorenchyma. Secretory channels are formed in internal layers of the primary bark, between the sections of the primary phloem. There are isles of sclerenchyma inside from them. So the tissues of mechanical functions (collenchyma, sclerenchyma) are present in the zone between epidermis and central cylinder (in the primary bark), providing flexibility and hardiness of the stem as well. The system of conducting tissues is in the primary structure formed by open collateral vascular bundles, in whose primary xylem protoxylem and metaxylem can be distinguished. However, cambium was functionally applied in the central cylinder (Fig. 9). Elements of secondary phloem are producing centrifugally. The secondary xylem forming the base of annual ring is creating inward. Numerous amyloplasts were present in parenchyma cells being adjoining to the secretory channels and in cells of pith rays. Mechanical tension arising above all by production of the secondary xylem of activities of cambium, i.e. secondary thickening of the stem, causes pulling out of parenchyma cells of the central part of the pith where

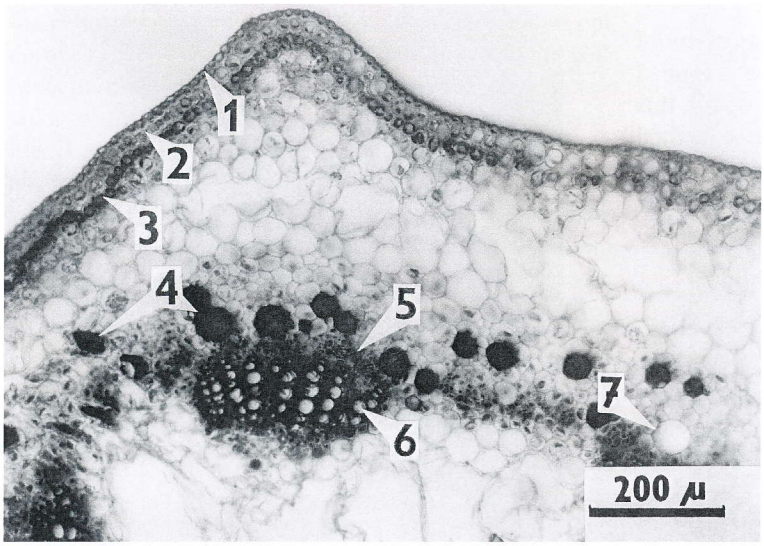

Fig. 14. *Humulus lupulus*. Leafstalk of leaf through the centre (FAA, GE, BS). External layers of primary bark (or mesophyll, respectively)
1 – epidermis, 2 – hypodermis, 3 – chlorenchyma, 4 – filled excretory (latex) channels, 5 – phloem, 6 – xylem, 7 – empty excretory channel

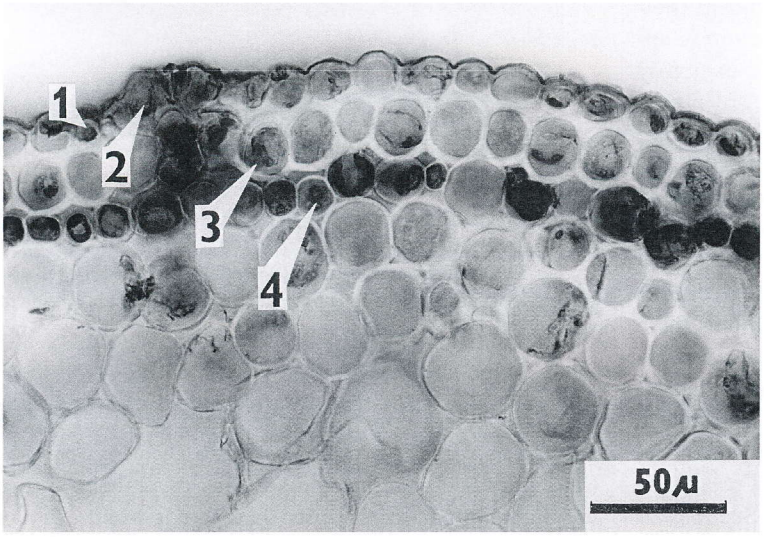

Fig. 15. *Humulus lupulus*. Leafstalk of leaf through the centre (FAA, GE, BS). Detail of surface layers
1 – epidermis, 2 – stoma, 3 – hypodermis, 4 – chlorenchyma

rhexigenous intercellulars are forming and rhexigenous cavern arises by merging in further (older) internodes.

The process of transition to the secondary structure is deepening in the second internode behind the growing point. Cambium only is participating in it. Phellogen is not applied even in the second and the third internodes; the stem is covered by the primary covering tissues (epidermis with stomata and trichomes).

The structure of epidermis, hypodermis and primary bark in the third internode ± is identical with the structure in the second internode and differentiated zone of the first internode (compare Figs 8 and 10). The continuing differentiation is manifested by hardening of the cell walls of mechanical tissues; sclerenchyma and collenchyma are developed more distinctly. The activity of cambium is applied more significantly, continuing above all by formation of the secondary xylem and thus also by an annual ring (Figs 10 and 11). The secondary xylem produced by fascicular cambium contains tracheas; the secondary xylem formed by interfascicular cambium contains only thick-walled wood cells and has a character of homoxyle deuteroxylem in these parts. In total, xylem of an annual ring can be characterised as a heteroxyle porously scattered deuteroxylem. Crystal plates of calcium oxalate are numerous in parenchyma cells of the pith (Fig. 12).

Botanically the hop is a herbaceous plant with respect to the morphology of stem (the stem is meant as a stalk); anatomically it exhibits the structure of wood species.

It follows from authors' knowledge that is in accordance with the finding of Š t r a n c et al. (2005) that cuttings in ontogeny stage of the second and third internode are rooting very well. Cuttings from older segments of the stem are rooting worse. During the development of the cutting the healing callus (callus) is forming on the cutting surface by dedifferentiation of tissues and vegetative organs by regeneration are forming into new plants (the first roots). This fact can be explained in the following way: (1) Though mechanical tissues are established and developed in the mentioned zones of the stem, their stage of lignification of their cell walls is still relatively very low and therefore the dedifferentiation of cells is

done easier. (2) On the contrary, a significant activity of the secondary meristem of cambium that can be applied above all in the production of callus cells (however, this issue needs further research with applying of the method of comparing anatomy) could be observed.

The leaf

The leafstalk is heptagonal in cross-section, 2 edges are adaxially (to the upper leaf area) oriented and they form more distinct projections (Fig. 13). Anatomically internal structures of the leafstalk are very similar to the stem in the primary structure. Surface layers form epidermis with stomata and under it collenchyma to sclerenchyma hypodermis (Fig. 15). Further layer of cells contains numerous chloroplasts (chlorenchyma) compared with the stem, opposite to stem this layer is continuous and interrupted only under the abaxial (bottom) edge. The similarity with the stem structure is apparent also in production of the primary bark, excretory channels, collateral vascular bundles (these are closed opposite to the stem, as they miss a fascicular cambium) and the pith (Fig. 14). With respect to the fact that the leafstalk is a part of the leaf, it would be more suitable to denote the primary bark as a mesophyll (the system of the basic leaf tissue).

The leaf blade has a different structure in thicker veins (particularly in the main vein) and among them (compare Figs 16 and 18). Undifferentiated mesophyll is under epidermis in the position of the thickest (central) vein. Collenchyma to sclerenchyma that is particularly distinctly developed form its outer layers under the adaxial surface. Chloroplasts were almost not present in the cells of mesophyll of this part of blade. Sections of the blade around thick veins fill the mechanical and conducting function (vascular bundles), not synthetic one. Closed collateral vascular bundles pass over from leafstalk into the blades' veins that are accumulated and they form a U-shaped unit in the cross-section (Fig. 17).

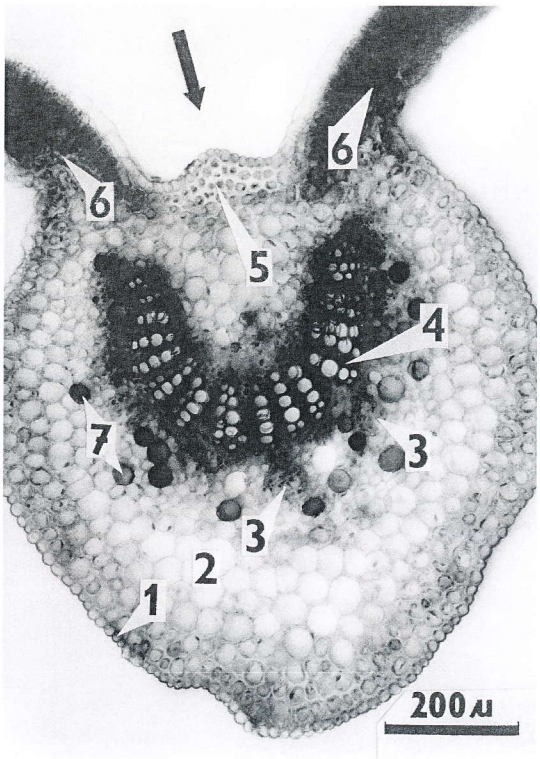

Fig. 16. *Humulus lupulus.* Leaf blade in the central vein (FAA, GE, BS). General view
1 – epidermis of abaxial area, 2 – undefferentiated mezophyll, 3 – phloem, 4 – xylem, 5 – sclerenchyma, 6 – sections of blade outside the vein

They are xylem-oriented to the upper (adaxial) and by phloem to the lower (abaxial) blade surface. Secretory (latex) channels among the sections of phloem, like in the stem and leafstalk, also here are present. Crystal plates of calcium oxalate are in some parenchymal cells adjoining to xylem.

The leaf blade has a distinctly bifacial structure among the veins (Fig. 18). Upper (adaxial) epidermis is composed of significantly greater cells compared with

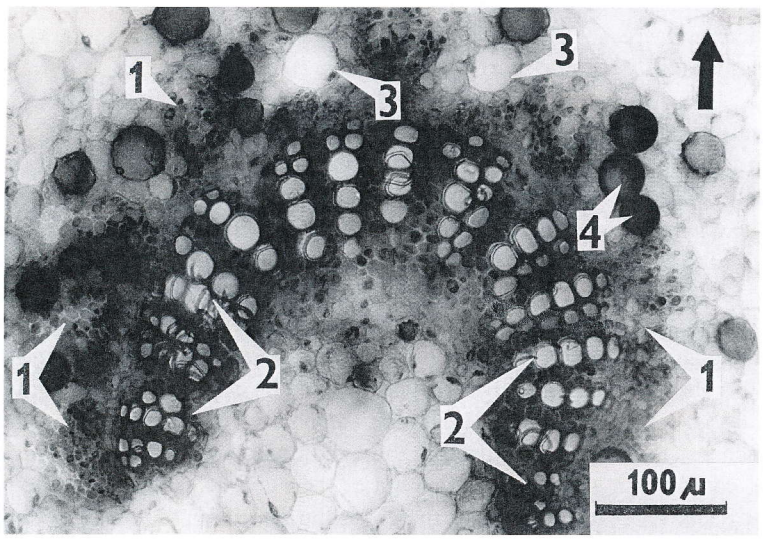

Fig. 17. *Humulus lupulus.* Leaf blade in the central vein (FAA, GE, BS). Detail of vascular bundles
1 – phloem sections, 2 – xylem sections, 3 – filled excretory channels, 4 – filled excretory channels (arrow oriented to abaxial area)

the cells of lower epidermis (abaxial). The walls of epidermal cells of both epidermises were thin and the cells (except clinching cells of stomata) did not contain chloroplasts. Stomata are placed only in abaxial epidermis. Lateral and clutching stomata cells are projected above the level of the other epidermal cells (Fig. 19), what is an eco-anatomical trait supporting stomata transpiration. Parts of the lower epidermis are great covering single-cell trichoma, whose cell walls are significantly thicker. Lignification of cell walls of epidermis is minimal. Mezophyll between both epidermises is distinguished to palisade and fungal parenchyma. Palisade cells compose mostly a single layer (2 to 3 layers in some parts) and they closely adhere to. Intercellulars penetrate from place to place among them communicating with intercellular fungal parenchyma and respiratory caverns under crunching cells. Fungal parenchyma is composed of isodiametric cells (globular) or slightly elongated (ellipsoid).

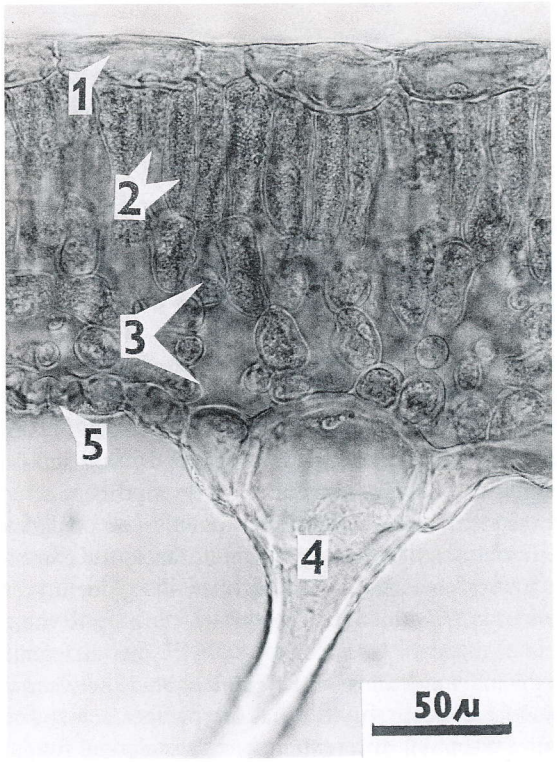

Fig. 18. *Humulus lupulus.* Leaf blade outside the vein (FAA, GE, CHh). Section with trichome
1 – epidermis with adaxial areas, 2 – palisade parenchyma, 3 – fungal parenchyma, 4 – trichome, 5 – epidermis of abaxial area

CONCLUSION

Methods of qualitative anatomy (fast methods) were used to study the internal structure of the root, stem and leaves of hop. The material taken at the end of the growing season originated from juvenile plants cultivated vegetatively from stem cuttings.

The roots have a primary structure at a distance up to 15–20 mm from the growing point (rhizodermis with root hairs, primary bark, actinostele with radial, mostly tetrarch vascular bundle). At a given distance soon by the activities of phellogen and cambium they pass into the secondary structure. The root tissues showed a minimum to zero lignification of cell walls and a high presence of starch (many amyloplasts). The lateral roots are usually established endogenously (in pericycle), in hop they were developing from phellogen exogenously.

The stem has a primary structure (epidermis, primary bark, collateral vascular bundles, and the pith) only in a short section behind the growing point. Yet at a distance 10 mm from the growing point cambium has been applied functionally and internal structure pass into the secondary structure. The secondary xylem of an arising annual ring has a character of homoxyl porously scattered deuteroxylem. Phellogen in a juvenile plant in 1st to 2nd internode was not recorded. Excretory (latex) channels are establishing soon, as early as in undifferentiated zone and are present in all internodes. Lignification of cell walls of mechanical tissues (collenchyma and sclerenchyma) was very low, cell walls of deuteroxylem components are more lignified. Phellogen has not been

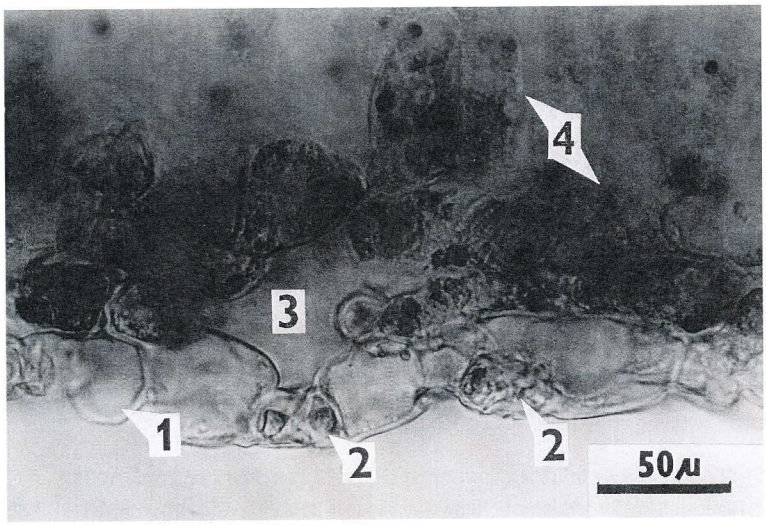

Fig. 19. *Humulus lupulus.* Leaf blade outside the vein of the centre (FAA, GE, CHh). Detail of epidermis of abaxial (lower) area with stoma
1 – epidermal cell, 2 – clenching cells of two stomata, 3 – respiratory cavern, 4 – fungal parenchyma

found. Though the hop is considered a herb, the stem shows a character of a wood species anatomically.

As regards to the growing aspect (vegetative propagation of hop by stem cuttings), a low lignification of cell walls of mechanical tissues and active cambium in the zone of the 2nd to the 3rd internodes can be an answer to the question why the cuttings in the stage of the 2nd to the 3rd internodes can root the easiest. However, only a comparative anatomical study can bring a definite explanation.

The leaf has a similar internal structure in a leafstalk and main vein that is different from the structure of the blade among the thinner veins. Internal structures of the leafstalk (the system of covering, conducting and fundamental tissues) remind anatomically a primary structure of the stem. Collateral vascular bundles are considerably different; they are closed (without fascicular cambium). Secretory channels placed between the phloem sections penetrate from the stem by the leafstalk up to the main vein of the leaf blade. The mesophyll is not differentiated in the main and thick veins. The leaf blade between veins is conspicuously thin and has a typical bifacial structure with mesophyll differentiated to palisade and fungal parenchyma. The cells of the both epidermises are thin-walled, stomata and huge single-cell trichoma with thick single-cell walls are in abaxial epidermis only. Mostly, the cell walls are not lignified. The resistance of leaf is provided by xylem components of vascular bundles and subepidermal layer of tissues with mechanical function (collenchyma and sclerenchyma) in the leafstalk and thick veins of the blade.

The knowledge found on anatomical structure of vegetative organs of a juvenile hop plant or container-growing (container planting) young hop plants can be important for applied agricultural research and subsequently for hop-growing practice in these aspects:

1) The knowledge of internal structures of the root system allows judging the dynamics and intensity of its formation and its metabolic and growth activities (regeneration, velocity and direction of the root growth, supply of water and nutrients etc.). Then the deeper knowledge are a prerequisite for preparation and testing of new more rational ways of cultivation not only of hop plants (pot-growing plants) but also for the treatment of hop plants after their planting into the hop-field, i.e. for cultural practice of hop-fields (particularly, it is the case of the treatment of underground hop plants, the so-called cones, cutting and technological procedures of soil treatment in hop-fields).

2) Anatomical knowledge on the stem may be an important prerequisite for determination of qualitative parameters of herbal "green" hop cuttings and to make more accurate way and the time of their sampling. Sequentially, procedures of more suitable and more efficient rooting of cuttings and treatment of mother hop plants can be elaborated.

3) Based on the knowledge on anatomical structure of leaves (in particular, leaf blade) the degree of resistance of hop plants to activity of biotic and abiotic stressors can be judged to a certain extent, what is also very significant for further specification of cultural practices and hop protection.

In conclusion, it should be said that in the interest of further improvement and to increase further efficiency of cultural methods of not only hop plantings as well as in young and fully productive hop stands it is very purposeful to continue in anatomical (particularly, in quantitatively anatomical) studies of a hop plant. It seems to be very useful to make accurate its anatomic characteristics not only in different stages of its development, but also in a succession on dynamics of ecological conditions and cultural measures.

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Received for publication on November 30, 2005
Accepted for publication on April 19, 2006

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Kvalitativně anatomická charakteristika vegetativních orgánů juvenilní rostliny chmele obecného (*Humulus lupulus* L.), č. *Cannabaceae.*

Scientia Agric. Bohem., *38*, 2007: 13–23.

Kořeny mají ve vzdálenosti do 15–20 mm od vzrostného vrcholu primární stavbu (rhizodermis s rhizinami, primární kůra, aktinostélé s radiálním, většinou tetrarchním svazkem cévním). Postranní kořen se zakládal exogenně. Záhy činností felogenu a kambia přecházejí kořeny na sekundární stavbu. Jejich pletiva vykazovala minimální až nulovou lignifikaci stěn buněčných a vysokou přítomnost škrobu (amyloplastů). Též stonek má primární stavbu (epidermis, primární kůra, kolaterální svazky cévní, dřeň) jen v krátkém úseku za vzrostným vrcholem. Ve vzdálenosti 10 mm od vzrostného vrcholu se funkčně uplatňuje kambium a vnitřní struktury přecházejí na sekundární stavbu. Sekundární xylém vznikajícího letokruhu má charakter homoxylního pórovitě roztrouseného deuteroxylému. Felogen zaznamenán nebyl. Exkreční (latexové) kanálky se zakládají již v nediferencované zóně a nacházejí se ve všech internodiích. Lignifikace stěn buněčných mechanických pletiv byla velmi nízká, více lignifikovány byly buněčné stěny složek deuteroxylému. Ačkoliv je chmel považován za bylinu, anatomicky vykazuje stonek charakter dřeviny.Vnitřní struktury řapíku (systém pletiv krycích, vodivých a základních) připomínají anatomicky primární stavbu stonku. Sekreční kanálky umístěné mezi lýkovými úseky pronikají ze stonku řapíkem až do hlavní žilky listové čepele. Mezi žilkami je čepel výrazně tenká a má typickou bifaciální stavbu. Průduchy a mohutné trichomy jsou jen v abaxiální epidermis. Stěny buněčné většinou nejsou lignifikovány. Odolnost zajišťují xylémové části svazků cévních a subepidermální vrstvy pletiv s mechanickou funkcí (kolenchym a sklerenchym) v řapíku a v silných žilkách. Zjištěné poznatky mají význam pro aplikovaný zemědělský výzkum a chmelařskou praxi.

Humulus lupulus L., juvenilní rostlina, kořen, stonek, list, anatomie.

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