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ESTABLISHMENT OF QUALITY INDICATORS OF PROMISING PLANT RAW MATERIALS - UNDERGROUND ORGANS OF RUMEX CONFERTUS WILLD

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The aim *is to study the morphological and anatomical structure of the underground organs of R. confertus and to establish the type of medicinal plant raw materials, to determine a number of its indicators of quality and quantitative content of some groups of biologically active substances using modern methods of analysis.*

Materials and methods. *It was used air-dry and freshly collected raw materials and a microscope Delta optic BioLight 300 (Poland) to study the macro- and microscopic characteristics of the plant raw materials. Determination of amount of hydroxycinnamic acids and total polyphenols was determined spectrophotometrically according to monograph «Nettle leaf» and the method 2.8.14 of the State Pharmacopoeia of Ukraine 2.0 (on a spectrophotometer Optizen POP (Korea)). The study of the component composition of hydroxycinnamic acids was performed by HPLC.*

Results. *As a result of research of plant raw materials it was established that the underground organs of Rumex confertus are the roots of annual plants and the rhizomes and roots of two or three annual plants. Diagnostic features: morphological (for the root and rhizome – the nature of the surface and fracture) and anatomical (for the rhizome – aerenchyma in the cortex, the presence and location of scleroids and sclerenchyma in the plant raw materials of two or three annual plants, the presence in the cells of the cortex and pith parenchyma simple starch grains, druses and cells with yellow content in freshly harvested plant raw materials; for the root – the colour of peridermal cells, the degree of development of pith rays, the remainder of the primary xylem; a distinctive feature of the annual root from two or three annuals is the absence of scleroids). It was determined the borderline boundaries of indicators in the series of plant raw materials: loss on drying (not more than 13.5 %), total ash (not more than 11 %), extractable matter (not less than 33 %) and the quantitative content of amount of hydroxycinnamic acids (not less than 1.3 %) and total polyphenols (not less than 3.5 %). It was identified chlorogenic and neochlorogenic acids.*

Conclusions. *It was determined the type of underground organs of Rumex confertus: annuals had only roots (tap root systems), from the second to the third year of life the plants have both rhizomes and tap root system. It was established their morphological and anatomical diagnostic features and determined numerical indicators and the quantitative content of the amount of hydroxycinnamic acids and total polyphenols with using modern methods of analysis and chlorogenic and neochlorogenic acids were identified. The obtained data will be used in further research, including the development of the draft monograph of the State Pharmacopoeia of Ukraine 2.0 or the draft methods of quality control of medicinal plant raw materials Rumex confertus and the creation of herbal medicines*

Keywords: *root, rhizome, Rumex confertus, diagnostic features, morphological and anatomical structure, numerical indicators*

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1. Introduction

The genus Rumex of the family Polygonaceae has more than 200 species in the world [1, 2]. There are 24 species in Ukraine [3, 4], among which the most common is *Rumex confertus* Willd. It is a perennial herbaceous plant that grows along roads, on the edge of forests, near rivers. In America and Poland, the plant is considered an invasive weed that is constantly controlled [5, 6].

It is carried out scientific research about influence of environmental factors on the growth and development of *R. confertus* and other species. It was determined that the seeds germinate well in moist soils with high nitrate content and are able to enter a state of dormancy under adverse conditions [2]. However, despite the high similarity, the seedlings of the plant very often die in the initial phase of growth, and very rarely can be seen in one area different stages of development plant [6].

According to the literature, the question remains what the underground organs of plants of the genus Rumex are and what is a medicinal plant raw material. The last 10–15 years nobody does not carry out any research in this field. Authors Kuzmin V. and Gontar E. studied the morphological features of the root system of *R. alpinus*, *R. confertus, R. crispus, R. domesticus* Hartm., *R. patientia L.*, *R. pseudonatronatus* Borb., *R. rechingerianus* Losinsk., *R. tianschanicus* Losinsk., *R. aquaticus L.*, *R. hydrolapathum* Huds. in the 1970-s and concluded that the underground part of these plants is represented by rhizome, hypocotyl (one part of which has a stem structure with additional roots, and the other – the structure of the main root with lateral roots) and the main root system, but they conclude that the underground organs of the plant are the roots [7]. Later, in 2000-s it has also been determined that rhizomes with additional roots appear at about 3 years of the age in the generative phase of the plant, and before that the plants have only a top root system (that is the underground organs of the plant are both rhizomes and roots) [6].

It is known a number of works, which are devoted to the study of the anatomical structure of the rhizomes and roots of *R. dentatus* L., *R. pulcher* L., *R. thyrsiflorus* Fingerh. [8], *R. patientia L.* [1] and only roots of *R. confertus* [4], *R. crispus* L. [9], *R. nepalensis* Spreng. [10], *R. patientia L.* [1]. According to Ulcay S. *R. crispus* has underground organs of rhizomes and roots [1], while Kryuchkova T. studied the anatomical structure only of the root of this plant [9].

R. confertus is quite popular in scientific and folk medicine. According to the monograph “Sorrel horse root”, which is available in the State Pharmacopoeia of the Russian Federation (SPhRF) XIV edition the medicinal plant raw materials of *R. confertus* are roots, which may contain up to 5 % of rhizomes as an impurity. Also, the roots are medicinal plant raw materials that are part of the plant collection Zdrenko, which has antitumor activity [11, 12].

Underground organs (it is not specified which ones) of *R. confertus* accumulate 5–8 % of tannins, 1–2 % of anthracene derivatives and 0.5–3 % of organic acids (determined according to the methods of the SPh of the USSR XI edition), 12–16 % of total polyphenols (determined by photo colorimetric method, in terms of caffeic acid), 5–10 % anthocyanins (determined by spectrophotometric method), 1–3 % of carbohydrates (determined by gravimetric method) [13].

Roots of *R. hydrolapathum, R. scutatus, R. altissimus, R. crispus, R. stenophyllus, R. arifolius, R. patientia, R. confertus, R. sanguineus, R. brownii, R. pulcher, R. acetosa, R. conglomeratus, R. acetosella, R. nepalensis, R. maritimus, R. alpinus, R. palustris, R. obtusifolius, R. aquaticus and R. crispus* contain anthracene derivatives (emodin, chrysophanol and physcion in free, O- and/or C-glycosidic forms), flavonoids, polyphenols, oxalic acid [13, 14]. It is well studied the component composition of flavonoids in the roots of *R. hastatus* D. Don. [15] and *R. nervosus* [16].

Folk medicine of different countries uses the roots of plants of the genus Rumex: *R. abyssinicus* (East Africa), *R. acetosa* (Britain and Ireland), *R. alpinus* (Hungary), *R. bequaertii* (East Africa Cameroon), *R. chinensis* (Vietnam), *R. confertus* (Ukraine, Russian, Belarus) *R. crispus* (Hungary, Britain and Ireland Turkey), *R. dentatus* (China), *R. maritimus* (India), *R. obtusifolius* (North America Britain and Ireland), *R. patientia* (Hungary Afghanistan, North India North America) and *R. usambarensis* (East Africa) for the treatment of various diseases of the gastrointestinal tract [14].

Ethanol extracts were obtained from the root, leaves and seeds of *R. acetosa*, *R. acetosella*, *R. confertus*, *R. crispus*, *R. hydrolapathum* and *R. obtusifolius* and their anti-cancer effect was established by using trypan blue test and annexin – V FITC and propidium iodide assay [17]. Extracts that showed antimicrobial activity against Candida glabrata and Staphylococcus aureus and antioxidant activity were obtained from herb of *R. confertus* with using various solvents, including dichloromethane and ethanol [18]. The quantitative content of catechins, proanthocyanidins was determined in the underground organs of *R. crispus* and *R. obtusifolius* and their antioxidant activity was established [19].

The ambiguity regarding the clear definition of which underground organs of *R. confertus* has and which are the plant raw materials (which leads to the use of different terminology in the interpretation of plant raw materials), the diversity of information on the quantitative content of active substances of plant raw materials (roots, underground organs) confirms the fact that establishing the type of underground organs as medicinal plant raw materials and determining a number of their quality and quantitative content of some groups of biologically active substances using modern methods of analysis is relevant.

The aim is to study the morphological and anatomical structure of the underground organs of *R. confertus* and to establish the type of medicinal plant raw materials, to determine a number of its indicators of quality and quantitative content of some groups of biologically active substances using modern methods of analysis.

2. Research planning (methodology)

The design of the experiment included several steps (Fig. 1).

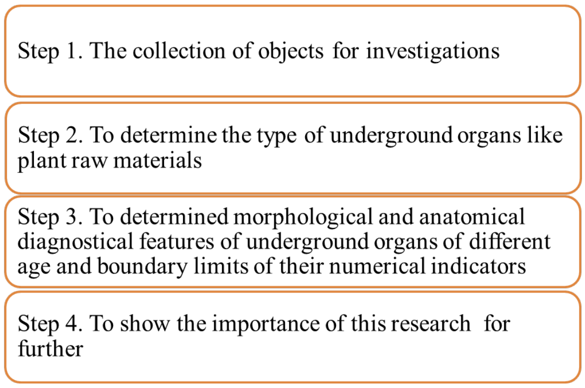


Fig. 1. Stage of determination of quality indicators of perspective plant raw materials – underground organs of *R. confertus*

3. Materials and methods

Several samples of underground organs of R. confertus were harvested in 2019 in different regions of Ukraine (Table 1). It was used organs of different plants: the first year with root rosette and two-, three-year-old with shoot, for morphological and anatomical study and determined numerical values.

The study was carried out based on the National University of Pharmacy.

The harvested plant raw material was dried in a fruit and vegetable dryer (Scarlett SC-FD421004, China), at a temperature of 45–50 °C. Fresh and dry fragments of underground organs (up to 10 cm long) were used to determine the type of organs and study the anatomical structure. Plant raw materials were powdered on the grinder LZM-1 (Ukraine) according to methods for establishment numerical indicators and determine of amount of hydroxycinnamic acids and total polyphenols.

Table 1

Date and regions of harvested of plant raw material of *R. confertus*

Date	Region of harvested	Coordinates
Underground organs for morphological and anatomical study		
27.04.2019	Vinnytsia	48.195471, 28.676139
20.09.2019	Vinnytsia	48.197473, 28.668886
Underground organs for determination of numerical values		
22.10.2019	Vinnytsia	48.195471, 28.676139
10.11.2019	Ternopil	49.064353, 26.157846
26.10.2019	Kharkiv	49.964760, 36.767050
02.11.2019	Poltava	49.788147, 34.611761
01.11.2019	Kyiv	49.990488, 29.973195

The fresh and dry raw materials were used to study the morphological features, which were examined under a magnifying glass and microscope Delta optical BioLight 300 (Poland) at a magnification of 4 times to describe the fracture. The anatomical structure was studied from freshly harvested, fixed and dried plant raw materials. Surface preparations and cross-sections were prepared according to generally accepted methods [20]. The microscopes Delta optical BioLight 300 with camera 2 Mpx (Poland) were used for magnification at 100 and 400 times.

Quantitative determination of amount of hydroxycinnamic acids and total polyphenols was performed by spectrophotometric method on a spectrophotometer Optizen POP (Korea) according to monograph "Nettle leaf" [21] and 2.8.14. "Determination of tannins in herbal drugs" [22]. Loss on drying, total ash and extractable matter were determined according to monographs 2.2.32 "Loss on drying" [23], 2.4.16 "Total ash" [22] and 2.8.16 "Dry residue of extracts" [22].

The study of the component composition of hydroxycinnamic acids was performed by HPLC. The WATERS ALLIANCE 2695 HPLC chromatograph («Waters Corporation», USA) was used for this purpose.

The analysis was performed by reverse phase chromatography using a 250×4.6 mm ACE C18 chromatographic column with a silica gel sorbent with a grain diameter of 5 μm, which was modified with octadecyl groups.

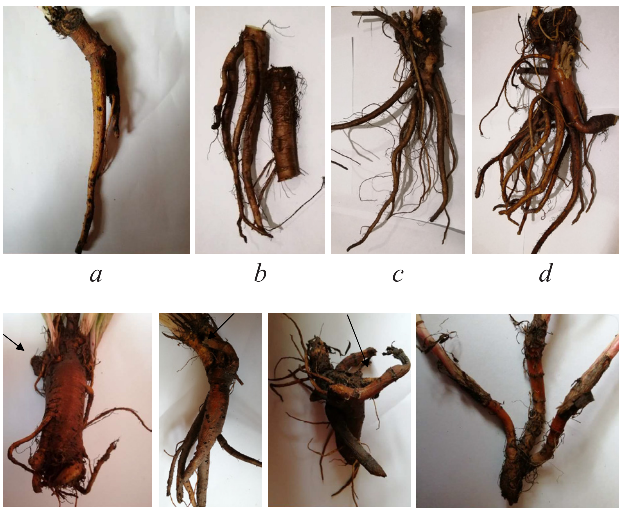
Acids as the mobile phase used: solvent A – 0.1 % solution of trifluoroacetic acid in water and solvent B – acetonitrile. Maximum feed rate of the mobile phase 1 ml/min, column thermostat temperature 25 °C; sample volume 10 μl, chromatography time – 81 min. Scan time 0.6 sec, detection range – 320, 330 nm.

Test solution:

0.2 g (exact portion) of the plant raw material was placed in a 50 ml flask, extracted with 10 ml of 70 % methanol solution for 20 minutes in an ultrasonic bath WUC-A06H (Korea). Filtered, quantitatively transferred to a 10 ml flask, and made up to the mark with solvent (70 % methanol solution). Before chromatography, it was filtered through a disposable filter with a pore diameter of 0.45 μm.

4. Results

The first stage of work was to establish the type of underground organs of *R. confertus*. Identification organs was carried out on 10 samples of first and 10 samples of second-third years old from each place of harvested with using macro- and microscopic methods of analysis [20]. As a result, it was found that the plants of the first year in the phase of formation of the root rosette have underground organs roots of the secondary structure that form the tap root system (Fig. 2, *a*, *b*). There was a relationship between the development of the aboveground part and the underground. Thus, in plants with a "poor" root rosette, the root is spindle-shaped and not branched (Fig. 2, *a*), in plants with a well-developed root rosette the root is spindle-shaped, branched (Fig. 2, *b*, *c*). In two-, three-year-old plants in the phase of shoot formation, the underground organs are massive, there is a thickening and shortening and strong branching of the main root (Fig. 2, *d*, *e*), from the hypocotyl of which are formed horizontally placed rhizomes (Fig. 2, *f*–*i*). In this case, an erect leafy shoot with an alternating arrangement of leaves represents the aboveground part and there may be several new plants with aboveground parts in the phase of formation of the root rosette, formed from the rhizome of the main plant. As the "aging" rhizomes grow and become too massive, so in the harvested plat raw materials it is difficult to separate the roots from the rhizomes.



a *b* *c* *d* *e* *f* *g* *h*

Fig. 2. Underground organs of *R. confertus*: *a* – the root of the first year; *b* – the root of the first year with a lateral root; *c* – the root of the first year with strong branching; *d*, *e* – the root of the second-third year: strongly branched and thickened main root, at the base of which rhizomes were formed; *f* – strongly thickened main root of the second year with the rudiments of rhizomes; *g*, *h* – the root of the second or third year with rhizomes

Macroscopic features of plant raw materials: fragments of rhizomes and roots of different lengths (up to 5–6 cm) and diameter (up to 1 cm), roots – spindle-shaped or cylindrical with longitudinal deep wrinkles and nodules (traces of lateral roots), (Fig. 3, *a*), under a magnifying glass in cross section have the form of small growths in the recess of the root surface (Fig. 3, *b*); rhizomes – spindle-shaped (annual), thickened, flattened, irregularly shaped (perennial) with shallow transverse or longitudinal wrinkles and nodules (traces of additional roots) (Fig. 3, *b*, *c*). The surface of the roots and rhizomes is brown or grey-brown. The nature of the fracture at the root (Fig. 3, *d*) and rhizome (Fig. 3, *e*) is the same – fibrous, yellow (in young organs) or yellow-brown (in perennial organs).

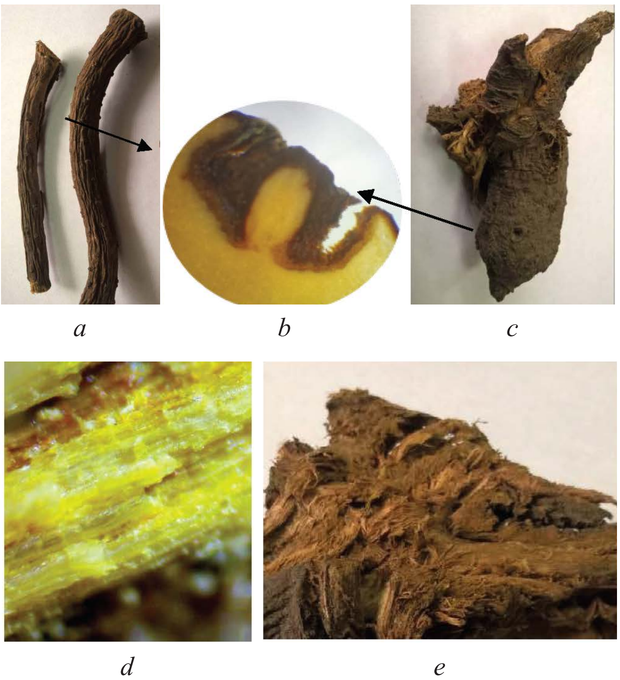


Fig. 3 Morphological features underground organs of *R. confertus*: *a* – a form and surface of the root; *b* – the place of growing lateral (additional) root on the cross section under magnifying glass; *c* – a form and surface of the rhizome; *d* – a fracture of the root; *e* – a fracture of the rhizom

In the cross section, the rhizome of *R. confertus* is round or oval, with a secondary beamless structure (Fig. 4, *a*).

Covering tissue is periderm, which is formed by quadrangular, rarely pentagonal parenchymal cells with uniformly thickened brown cell walls, the cell cavity is colorless (Fig. 4, *b*, *c*). Under the periderm is a well-developed cortex parenchyma, which is represented by an aerenchyma with thin cell walls, large and medium-sized oval or rounded intercellular spaces (in one-two-year-old rhizomes) (Fig. 4, *c*) and densely spaced parenchymal cells with unevenly thickened cellulosic cell walls. three annual rhizomes) (Fig. 4, *d*). There are scleroids in the cortex parenchyma under the periderm of two or three annual rhizomes (Fig. 3, *d*), which are located parallel to the covering tissue and closer to the cambium there are small clusters (10–20) of sclerenchyma cells, which are arranged in a circle (Fig. 4, *e*). The cambium thin, single-double-layered, well defined. The secondary xylem is mainly represented by ladder vessels of different diameters (which are located singly or 2–4, less on 5 in groups), wood parenchyma and libriform (Fig. 4, *a*, *f*, *g*). Pith rays are broad, formed by parenchymal thin-walled round cells.

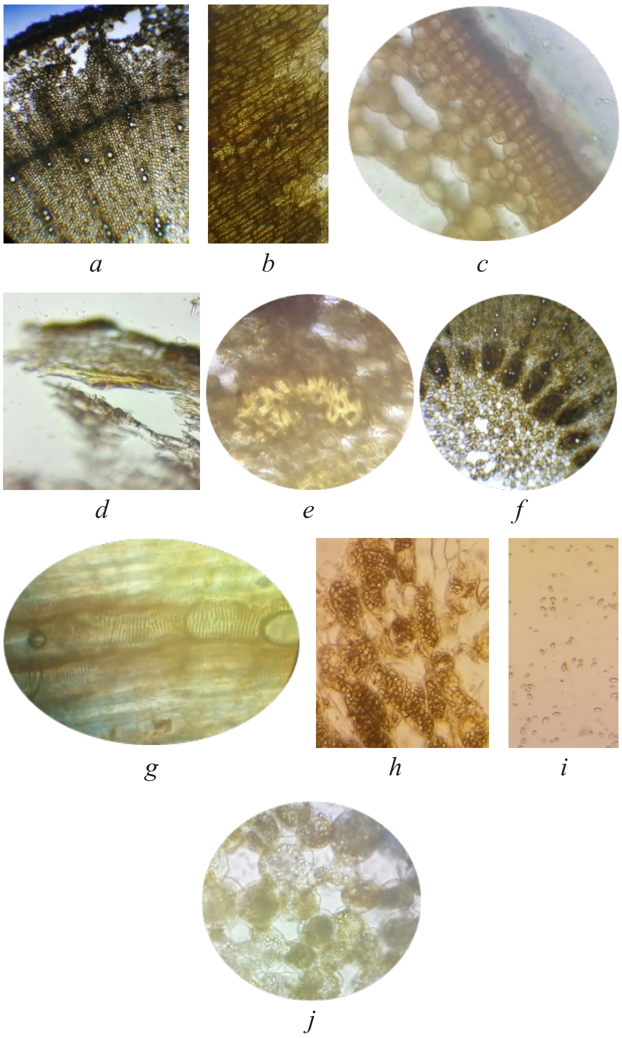


Fig. 4. Anatomical features of the rhizome of *R. confertus*: *a* – the structure; *b*, *c* – covering tissue; *d* – sclereida; *e* – mechanical tissue; *f* – pith; *g* – ladder vessel; *h*, *i* – simple starch grains; *j* – druse in the cell

The pith is well expressed, represented by a loose parenchyma which is formed by thin-walled rounded cells with stellate, rarely hexagonal or quadrangular intercellular spaces of different sizes (intercellular spaces in the pith are smaller than in the cortex) (Fig. 4, *f*).

There are simple starch grains of oval or egg-like form (Fig. 4, *h*, *i*) and small druses calcium oxalate (they can meet rarely or often which is dependent on the condition of growth of plant) (Fig. 4, *h*) in the cells of cortex, pith and wood (in the less amount) parenchyma of rhizomes. In the freshly harvested plant raw materials, some cells of the cortex and pith parenchyma are filled with yellow contents, which are not detected in the fixed and air-dry plant raw materials.

The main and lateral roots are a round shape on a cross-section and secondary beamless structure (Fig. 5, *a*).

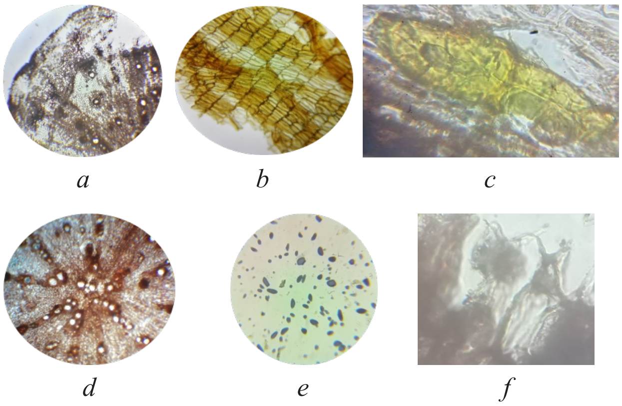


Fig. 5 Anatomical features of the root of *R. confertus*: *a* – the structure; *b* – covering tissue; *c* – sclereida; *d* – pith; *e* – simple starch grains; *f* – druse in the cell

Covering tissue – periderm. The root periderm differs from the rhizome periderm by the presence of cells with brown cavities and thicker colourless cell walls (Fig. 5, *b*). The cortex parenchyma is formed by parenchymal thin-walled cells (Fig. 5, *a*). There are small intercellular spaces in the cortex part of some roots, but generally, parenchymal cells are located densely. There are single scleroids in two or three annual roots (Fig. 5, *c*). Cambium is no different from cambium rhizome. A distinctive feature of the secondary xylem of the root is the location of the vessels: single or single-row radial rays and narrow pith rays (Fig. 5, *a*, *d*). In the center of the root, there are remnants of a tetraarchic radial bundle of the primary xylem (Fig. 5, *d*).

Like a rhizome, root accumulates simple starch grains (round or oval) (Fig. 5, *e*), druses (Fig. 5, *f*) and a yellow substance (freshly harvested plant raw materials).

The results of determination of loss on drying, total ash, extractable matter, amount of hydroxycinnamic acids and total polyphenols in different series of underground organs of *R. confertus* are given in Table 2.

According to the Table 2 loss on drying during of underground organs of *R. confertus* ranged from 11.7 % to 13.3 % but did not exceed 13.5 %. The content of total ash was the highest in the plant raw materials which were harvested in the Kharkiv region (10.38±0.49 %) and the lowest – 8.79±0.40 % in the plant raw materials which were harvested in the Kyiv region. Therefore, the total ash content should not exceed 10.5 %. The plant raw materials of the Kharkiv region also contained the highest amount of extractable matter (36.04±1.23 %), but the content of amount of hydroxycinnamic acids and total polyphenols was the lowest – respectively 1.30±0.05 % and 3.53±0.17 %.

The highest content of amount of hydroxycinnamic acids and total polyphenols was in the plant raw materials which was harvested in the Kyiv region and amounted to 1.59±0.08 % and 4.42±0.20 % respectively, which is on 20 % higher than in the plant raw materials of the Kharkiv region for polyphenols and on 18 % higher than in plant raw materials from the Kyiv region for hydroxycinnamic acids.

The content of extractable matter in the series of plant raw materials *R. confertus* was not less than 33 % and the content of amount of hydroxycinnamic acids in terms of chlorogenic acid – not less than 1.3 % and total polyphenols in terms of pyrogallol – not less than 3.5 %.

As we could see the results of determination of extractable matter, amount of hydroxycinnamic acids and total polyphenols in some series from different places of harvesting are very similar. We could connect this fact only with the conditions of growing and that plant raw materials were harvested at the same year. Apart from that, to determine the quantitative content of substances, we used underground organs without reference to the organ (whether root or rhizome) and the year of growing (first, second, third). The similar number of total ashes we could explain on the one hand the anatomical structure of underground organs, the most of them are dead and could not contain a lot of elements on the other – the cleaner of underground organs. All plant raw materials were prepared by us, and we very thoroughly cleaned it from the soil.

It was identified chlorogenic and neochlorogenic acids in the roots and rhizomes of *R. confertus* (place of harvested is Kyiv region) by using HPLC and determined their content in terms of dry raw materials: 0.012 % of chlorogenic and 0.004 % neochlorogenic acids (Fig. 6).

In our research of studying hydroxycinnamic acids by two methods we have got a big difference in result. We can explain this fact only that we used different methods. HPLC for identification of hydroxycinnamic acids separately and determination their content and spectrophotometry for determined quantitative content of amount of hydroxycinnamic acids in terms of chlorogenic acid.

Table 2

Determination of loss on drying, total ash, extractable matter, amount of hydroxycinnamic acids and total polyphenols in the underground organs of *R. confertus* (%, *n*=5, in terms of dry plant raw materials)

The place of collection of plant raw material	Loss on drying	Total ash	Extractable matter	Amount of hydroxycinnamic acids (in terms of chlorogenic acid)	Total polyphenols (in terms of pyrogallol)
Vinnytsia	13.00±0.60	9.14±0.50	35.35±1.16	1.51±0.07	3.82±0.26
Ternopil	12.11±0.54	8.89±0.43	33.94±1.15	1.48±0.07	3.77±0.18
Kharkiv	13.31±0.60	10.38±0.49	36.04±1.23	1.30±0.05	3.53±0.17
Poltava	12.17±0.53	8.99±0.42	33.38±1.26	1.53±0.07	4.25±0.20
Kyiv	11.73±0.49	8.79±0.40	35.42±1.35	1.59±0.08	4.42±0.20

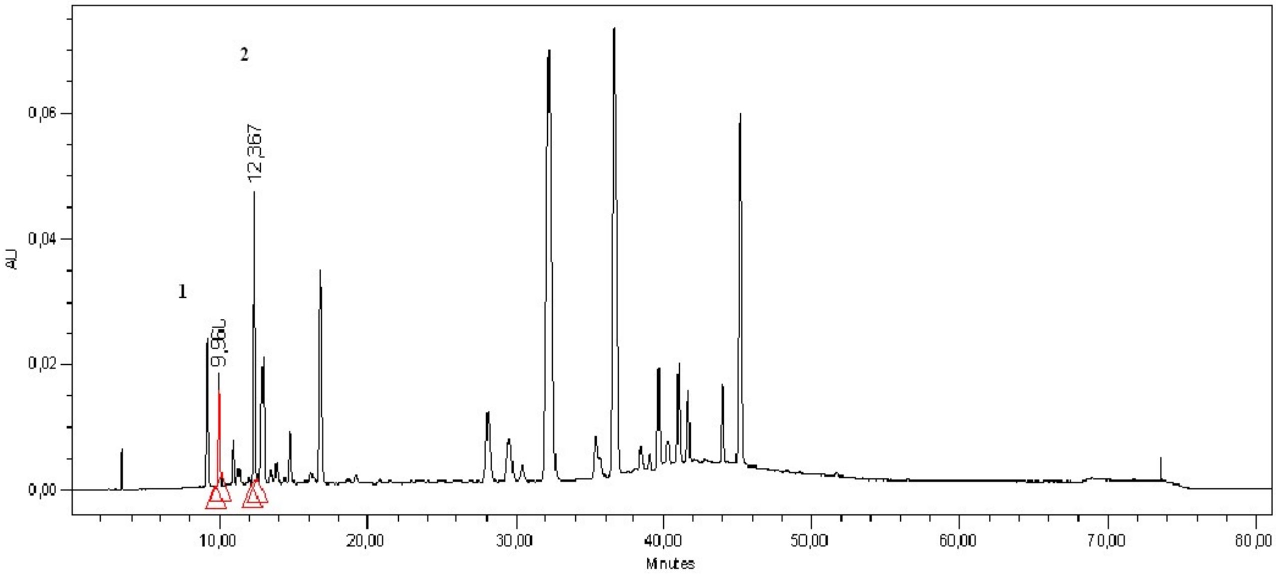


Fig. 6. HPLC chromatogram of hydroxycinnamic acids of the root and radix of *R. confertus*: 1 – neochlorogenic acid; 2 – chlorogenic acid

5. Discussion of research results

According to the literature, *R. confertus* has a tap root system, which is represented by a shortened and thickened main root with well-developed lateral roots [7]. Our research has shown that in annual plants, the underground organs are roots, which are united in a tap root system; two-three annual plants have a rhizome, which in process of age of a plant becomes massive, and the main shortens, thickens and branches root.

Therefore, depending on the phase of vegetation of the plant, medicinal plant raw materials of *R. confertus* are roots, roots and rhizomes what leads to increase plant raw material base. Sorting of underground organs should take place during harvesting and requires some botanical knowledge from the picker. It is not always possible, so, as practice has shown, in the plant raw material "Sorrel horse root" (which is sold on the Ukrainian market) contains roots and rhizomes.

It was determined distinctive macroscopic diagnostic features of roots and rhizomes of *R. confertus*: nature of the surface (there are longitudinal deep wrinkles and nodules (traces of lateral roots) in the root and shallow transverse or longitudinal wrinkles and nodules (traces of additional roots) in rhizomes) and fracture (fibrous, yellow or yellow-brown).

For the first time the anatomical structure of rhizomes of *R. confertus* was described and diagnostic features of this type of plant raw material are established:

– the cortex parenchyma is represented by aerenchyma (one-two-year rhizomes) and parenchymal densely arranged cells with thickened cellulose cell walls (two-three-year rhizomes);

– scleroids and clusters of sclerenchyma cells (two-three-year rhizomes), which are absent in annual roots;

– the pith is formed by a loose parenchyma with stellate, rarely hexagonal or quadrangular intercellular spaces of different sizes;

– simple starch grains and small druses in the cells of the cortex, pith and wood parenchyma;

– yellow content in the cells of the cortex and pith parenchyma in fresh plant raw materials.

The anatomical structure of the root of *R. confertus* has been well studied by several scientists and our studies have largely confirmed the known data. Diagnostic features of the root are the color of the cells of the periderm, the degree of development of the pith rays, the remainder of the primary xylem [4]. We found out that all the roots which we studied did not have cortex (bast) fibers, and the annual roots did not have scleroids, which was not previously indicated in the literature available to us and is a certain distinguishing feature of plant raw materials [4].

Analyzing the literature, it was found that most of the recent work is devoted to the study of medicinal plant raw materials (aboveground and underground parts) of different species of plants of the genus Rumex (*R. alpinus, R. crispus, R. patientia, R. acetosa, R. acetosella, R. nepalensis* et al) [10, 13, 14, 17]. The peak of popularity of morphological, anatomical and chemical studies of *R. confertus* was observed in the middle of the 20th century, and to date there is no monograph on this plant raw material in SPhU 2.0 and the European Pharmacopoeia and no identification of hydroxycinnamic acids by HPLC and determination of quantitative content of amount of hydroxycinnamic acids and total polyphenols by modern methods of analysis.

The monograph of SPhRF XIV "Sorrel horse root", in which the plant raw material is root, regulates the loss on drying – no more than 13 % (according to our research of root and rhizome – no more than 13.5 %), the total ash – no more than 10 % (according to our research – no more than 11 %), the quantitative content of anthracene derivatives in terms of 8-O-β-D-glucoside emodin – not less than 3 % (we did not determine) and does not regulate the content of extractable matter (according to our research – not less than 33 %), amount of hydroxycinnamic acids (according to our research – not less than 1.3 %) and the total polyphenols (according to the results of our research – not less than

3.5 %). Chlorogenic and neochlorogenic acids in the plant raw material were also identified by HPLC and we did not find information about the presence of these acids in underground organs of *R. confertus* in the literature available to us. It was established the boundary limits of loss on drying, total ash, content of extractable matter, amount of hydroxycinnamic acids in terms of chlorogenic acid and total polyphenols in terms of pyrogallol by comparing the values of numerical indicators of the series of plant raw materials of *R. confertus*, which was harvested in different regions of Ukraine. It could be taken as a basis for creating a draft monograph of SPhU 2.0 or a draft of quality control methods for medicinal plant raw materials root and rhizome.

Study limitations. A limitation of the study could be considered a relatively small number of plants of *R. confertus*, for which the type of underground organs was determined. It is advisable to expand the regions and conditions of plant growth (harvest plants in wetter places) and establish the ratio of components of underground organs (roots – main (first, second, third years old), lateral, additional, rhizomes (first, second, third years old)) and determine the numerical indicators for these components (loss on drying, total ash, content of extractable matter) and determined amount of hydroxycinnamic acids and total polyphenols. In addition, it is perspective to determine a quantitative content of anthracene derivatives in terms of 8-O-β-D-glucoside emodin both in series of plant raw materials of *R. confertus* and in various components of underground organs of this plant and identify the component composition of polyphenols by HPLC.

Prospects for further research. Promising areas for further research are to continue studying of underground organs of *R. confertus* to creating quality control methods of their standardization and developing of phytomedicines.

6. Conclusions

1. It was determined the type of underground organs of *R. confertus*: only roots (tap root system in annual plants) and rhizome and root (in two-three-year plants); establish their morphological and anatomical diagnostic features and determined numerical indicators.

2. The nature of surface (periderm) and fracture of underground organs are the diagnostically morphological features.

3. The diagnostically anatomical features were determined for rhizomes (type of tissue of cortex parenchyma; the presence and location of sclereids and sclerenchyma in biennial plants; the presence of simple starch grains, druses and cells with yellow content in freshly harvested raw materials) and root (the colour of the cell walls of the periderm; the degree of development of the pith rays, the remainder of the primary xylem; a distinctive feature of the annual root from two or three annuals is the absence of sclereids).

4. Limits of loss on drying, total ash, content of extractable matter, amount of hydroxycinnamic acids and total polyphenols were determined and identified chlorogenic and neochlorogenic acids in root and rhizome of *R. confertus*.

5. The obtained data will be used in further research in the development of the draft monograph of SPhU 2.0 or the draft methods of quality control of medicinal plant raw materials *R. confertus* and in the creation of phytomedicines.

Conflict of interest

The authors declare that there are no conflicts of interests.

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