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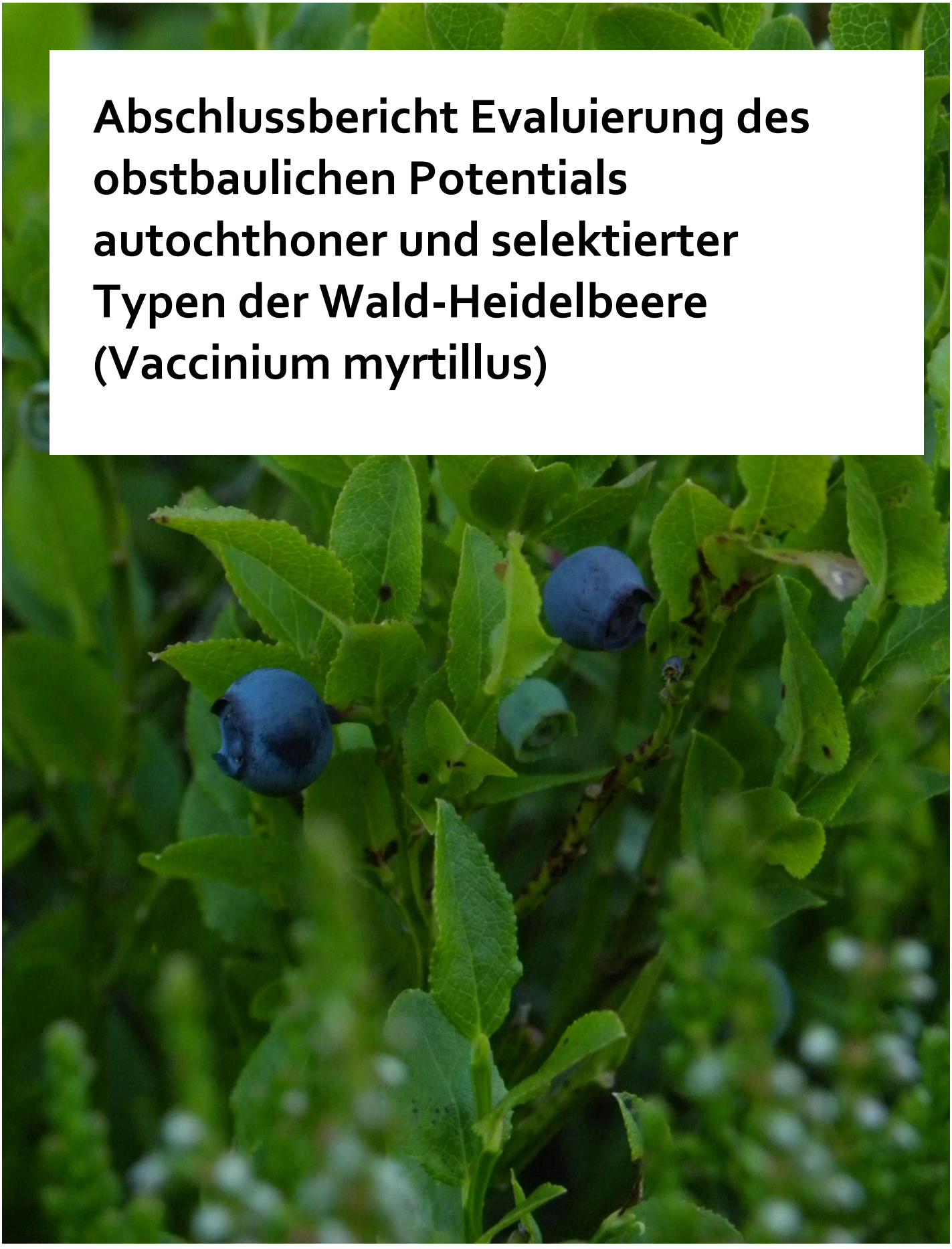
Abschlussbericht Evaluierung des obstbaulichen Potentials autochthoner und selektierter Typen der Wald-Heidelbeere (Vaccinium myrtillus)



Evaluierung des obstbaulichen Potentials autochthoner und selektierter Typen der Wald-Heidelbeere (Vaccinium myrtillus)

Evaluation of the fruit growing potential capacity of autochthonous and selected wild blueberry ecotypes (Vaccinium myrtillus)

Projekt Nr. 100801

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Projektlaufzeit:
01.06.2011 – 31.12.2019

Impressum

Medieninhaber und Herausgeber:
HBLFA Raumberg-Gumpenstein
Landwirtschaft
Raumberg 38, A-8952 Irdning-Donnersbachtal
raumberg-gumpenstein.at

Autochthonous *Vaccinium myrtillus* for Autochthonous Rural Value Creation? II: European Blueberry's Soil Ecology and Root Systems

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Keywords: dwarf shrub, habitat requirements, soil chemical properties, mineral nutrient content, nutrient requirements, rooting depth, root anatomy

Abstract

For a successful cultivation of *V. myrtillus*, its habitat requirements have to be known. Especially, the pH dependent soil chemical properties in the root-room are of utmost importance. Therefore, soil analyses in contrasting habitat types and plant analyses were done. Differences and similarities in the mineral nutrient contents in leaves and stems of *V. myrtillus* collected from different habitat types were investigated. *V. myrtillus* grows on very acid soils rich in humus but poor in plant available nitrogen. The calcifuge dwarf shrub is adapted to the low and disharmonic nutrient supply in the root-room, resulting from a relative excess of aluminium, iron and potassium and a complementary lack of calcium and magnesium at the exchange complex. The leaves and stems of *V. myrtillus* contain high amounts of manganese, which is abundantly available at low pH values. Furthermore, the plants have a relatively high absorption capacity for calcium and their requirements for nitrogen, potassium and phosphorus seems to be low. There are only little differences in the mineral nutrient contents in leaves and stems of *V. myrtillus* collected from contrasting habitat types. At higher altitudes, roots of *V. myrtillus* are restricted to the uppermost 20 cm, whereas at lower altitudes rooting depth is up to 50 cm.

INTRODUCTION

Vaccinium myrtillus L. is in Austria a widespread and abundant plant species (Fischer et al., 2008). This deciduous dwarf shrub has a wide range of altitudinal distribution. In Austria, *V. myrtillus* occurs from the submontane to the lower alpine belt. At lower altitudes, the shade-tolerant species can be found mainly in forests, whereas at higher altitudes *V. myrtillus* is often very abundant in open habitats, being a characteristic member of the dwarf-shrub communities. *V. myrtillus* is relatively frost-sensitive (Grime et al., 1988). Therefore, primarily above the forest line its distribution is dependent upon snow protection. *V. myrtillus* grows on a wide range of different soil types. In plant stands dominated by this species, soil water regime can vary between balanced and moderately wet. *V. myrtillus* is a typical calcifuge plant species (Ingestad, 1973; Grime et al., 1988). Therefore, it is widely distributed in landscapes with siliceous bedrocks and acid soils. Under certain soil conditions, *V. myrtillus* can be found also in landscapes with carbonatic bedrocks. If acid soils or carbonat-free, acid soil horizons isolate the plant roots from the carbonatic bedrock, growth of *V. myrtillus* is possible.

For a successful cultivation of *V. myrtillus*, its demands on soil conditions have to be known. Especially, the supply of nutrients and potentially toxic elements (e.g., aluminium) in the root-room is of utmost importance. Thus, the aims of this study were

(1) to investigate the soil conditions in plant stands dominated by *V. myrtillus*, (2) to examine its rooting depth in different altitudes, (3) to assess the nutrient supply in the root-room in different habitat types, (4) to estimate the nutrient requirements of *V. myrtillus* and (5) to get information about the influence of contrasting soil types on mineral nutrient contents in leaves and stems of *V. myrtillus*.

MATERIALS AND METHODS

Study Sites

We differentiated three habitat types at different altitudes and on contrasting soil types in Styria, Austria (Table 1). *V. myrtillus* was the dominant species at each site.

Methods

In each habitat type, composite soil samples for chemical analyses were taken from the 0-10 cm soil layer (O respectively A horizon) in the vegetation period. Soil analyses (pH, total organic carbon, total nitrogen, lactate soluble phosphorus and potassium content, water soluble phosphorus content, effective cation exchange capacity and exchangeable cations) were carried out according to the ÖNORM methods (Austrian Standards Institute). Plants of *V. myrtillus* were collected from the different habitat types at the peak of growing season (early in August). For plant analysis, leaves were separated from stems. Nutritive value (crude fibre, crude protein, crude fat, crude ash), carbon content and mineral nutrient contents of leaves and stems were determined by using standard methods. Unfortunately, we did not measure the above ground biomass of the sampled plants.

RESULTS AND DISCUSSION

In the habitat types investigated, the soils can be classified as Cambisol, Rendzina and Ranker (Table 1). These soil types are common and widespread in Austria. The humus form is moder. Tables 2 to 4 show the results of the soil analyses. The soils are characterized by very high humus content, a high total nitrogen content, a wide carbon to nitrogen ratio and an extremely high acidity. In the uppermost 10 cm, the soils are in the aluminium and iron buffer range (Ulrich, 1987, 1991). In humus-rich soils, total nitrogen content is generally high, but the wide carbon to nitrogen ratios indicate a relatively nitrogen-poor humus in the plant stands dominated by *V. myrtillus*. The soils investigated have low levels of lactate soluble phosphorus and medium levels of lactate soluble potassium. Due to the strongly acid soils, the water soluble phosphorus content is very high. The Ranker at the Planneralm has the lowest calcium, magnesium and base saturation, whereas aluminium, iron and potassium saturation is highest. Especially, the calcium content is very low primarily due to soil acidification. Despite a high humus content, the pH-value dependent effective cation exchange capacity is very low, leading to a low nutrient supply of essential nutrient cations such as calcium and magnesium to plant roots. Very acid soils in the aluminium and iron buffer range are generally characterized by a relative excess of aluminium, iron and potassium and by a complementary lack of calcium and magnesium at the exchange complex, resulting in a low and disharmonic nutrient supply to plant roots and soil organisms. Only calcifuge plant species such as *V. myrtillus* are adapted to the prevailing acid and nutrient stress in the soil mainly caused by the unfavourable ratios between nutrients and by the pH induced higher concentrations of potentially toxic elements (Bohner, 2008). The Rendzina developed over limestone at the Tauplitzalm has the highest pH-value, calcium saturation, calcium content, base saturation and effective cation exchange capacity, whereas potassium, aluminium, iron and manganese saturation is lowest. At this site, acid and nutrient stress for plant roots and soil organisms is comparatively lower.

Tables 5 and 6 show the results of the plant analyses. The leaves and stems of *V. myrtillus* have a low content of crude protein and crude ash, whereas the content of crude fat is relatively high. These are indications of a nutrient-poor soil with low levels of

plant available nitrogen and other macronutrients. The contents of crude protein, crude fat and crude ash are, with one exception, higher in leaves than in stems. In contrast, the content of crude fibre is comparatively higher in stems. Thus, leaves of *V. myrtillus* are preferential storage organs for protein, fat and mineral elements. The dwarf shrub stores some mineral nutrients such as calcium, magnesium, potassium and manganese mainly in the leaves, and others such as sodium, zinc, iron and copper primarily in the stems. Particularly, the contents of nitrogen, potassium and phosphorus are very low in leaves and stems, whereas the content of manganese is extraordinary high. The uptake of potassium and phosphorus by plants seems to be inhibited, whereas the uptake of manganese is promoted. This finding suggests that *V. myrtillus* has a low phosphorus requirement, because in very acid soils the concentration of phosphorus in soil solution is usually high (Bohner, 2008). According to Ingestad (1973), *V. myrtillus* has also a low requirement for potassium. In very acid soils, the uptake of manganese by plants is generally enhanced due to the increased availability at low pH values (Marschner, 1998). According to Grime et al. (1988), the leaves of *V. myrtillus* usually contain high concentrations of manganese. Surprisingly, the calcium content in the leaves is relatively high and the variation between the different sites is low, indicating a selective uptake of calcium by *V. myrtillus*. Also Ingestad (1973) observed a high uptake of calcium by this plant species. The carbon to nitrogen ratio is relatively high in the above ground biomass of *V. myrtillus*. It is comparatively narrower in the leaves than in the stems. In both plant parts, this ratio is wider than in the soil. The nitrogen to phosphorus ratio is higher in the leaves than in the stems. In both plant parts, this ratio never exceeds the critical value of 16, which is assumed to indicate phosphorus limitation (Gerdol, 2005). This finding is not in agreement with the results of Gerdol (2005), who observed that the growth of *V. myrtillus* is limited by phosphorus. At the Tauplitzalm, *V. myrtillus* grows also on extraordinary shallow Rendzinas developed over limestone rock. The thickness of the O horizon (root-room) is approximately 1 to 2 cm. Despite contrasting soil conditions, the mineral nutrient contents in the leaves and stems from plants collected at this site differ only slightly from those collected at the other sites. Only the uptake of calcium is marginally increased mainly at the expense of potassium. In sum, these results are consistent with Uhlig et al. (2001), who measured the mineral element contents in leaves of *V. myrtillus* in Norway.

At higher altitudes, roots of *V. myrtillus* are restricted to the uppermost 20 cm, whereas at lower altitudes rooting depth is up to 50 cm. Also Atlegrim et al. (1996) observed, that *Vaccinium* rhizomes and roots are generally shallow. According to Figures 1 and 2, shoot roots and side roots of *V. myrtillus* are characterized by a narrow ratio between secondary phloem and woody parts of the roots (secondary xylem). Within the secondary xylem, the vessels for water transport are placed. The cells of the ground parenchym and the vessels are lignified. This is the reason for the wiry consistence of the roots in the condition of secondary thickening. Within the secondary phloem, the sieve tubes for the transport of assimilates are placed. Around the secondary phloem a periderm (bark) is developed, which protects the roots against water loss and rottenness. The cell walls of the periderm are suberized and the cells of the periderm contain tanniferous substances. Therefore, *V. myrtillus* tolerates a certain degree of wetness in the soil.

CONCLUSIONS

V. myrtillus is growing on highly acid soils characterized by low levels of macronutrients and by a surplus of plant available manganese. The deciduous dwarf shrub is adapted to the low and disharmonic nutrient supply in these soils, leading to an inhibited uptake of individual nutrients by plants. In plant stands dominated by *V. myrtillus*, the soils are generally rich in humus but poor in plant available nitrogen. *V. myrtillus* has a high absorption capacity for manganese and calcium. Its requirements for nitrogen, potassium and phosphorus seem to be low. *V. myrtillus* grows on a wide range of different soil types. Some soil chemical properties (e.g., calcium, aluminium and base saturation, calcium content) vary considerably between the soil types. Nevertheless,

there are only little differences in the mineral nutrient contents in leaves and stems of *V. myrtillus* collected from contrasting habitat types. An acid humus layer (moder) of approximately 1 to 2 cm is sufficient for the incidence of *V. myrtillus* on limestone rocks.

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Tables

Table 1. Study sites.

Location	Altitude (m)	Parent material	Soil type	Cover *V. myrtillus* (%)	Tree layer
Aigen im Ennstal	760	Phyllite	Cambisol	85	Present
Tauplitzalm	1600	Limestone	Rendzina	46	Present
Planneralm	1750	Mica schist	Ranker	80	Absent

Table 2. Selected soil chemical properties (0-10 cm soil depth).

Location	pH $CaCl_2$	C_{org} (%)	N_{tot} (%)	C_{org}:N_{tot}	P_{CAL}[1]	K_{CAL}[1]	P_{H2O}[2]
					($mg\ kg^{-1}$)		
Aigen im Ennstal	2.7	45.7	1.51	30	19	100	69
Tauplitzalm	3.9	42.0	1.95	22	40	158	96
Planneralm	3.2	17.6	1.08	16	32	121	60

[1] P_{CAL} and K_{CAL} = lactate soluble phosphorus and potassium content.
[2] P_{H2O} = water soluble phosphorus content.

Table 3. Selected soil chemical properties (0-10 cm soil depth).

Location	Ca	Mg	K	Na	Al	Fe	Mn	BS[1]	CEC_{eff}[2]
	% ($BaCl_2$-extract)								($cmol_c\ kg^{-1}$)
Aigen im Ennstal	47.5	34.6	2.9	0.6	11.3	2.4	0.8	86	23.0
Tauplitzalm	64.5	29.5	2.1	0.2	2.5	1.0	0.2	96	50.2
Planneralm	14.7	15.9	9.3	0.9	48.7	10.0	0.5	41	10.2

[1] BS = base saturation ($BaCl_2$-extract).
[2] CEC_{eff} = effective cation exchange capacity ($BaCl_2$-extract).

Table 4. Element contents in an aqua regia-extract (0-10 cm soil depth).

Location	Ca	Mg	K	Na	Al	Fe	Mn
	($g\ kg^{-1}$)						
Aigen im Ennstal	2.1	1.0	0.3	0.05	1.2	1.5	0.05
Tauplitzalm	6.9	2.7	1.4	0.21	10.0	8.7	0.07
Planneralm	0.3	1.2	1.0	0.11	6.0	9.0	0.05

Table 5. Nutritive value, carbon content and mineral nutrient contents of leaves and stems in *V. myrtillus*.

Location	Plant part	CFi[2]	CPr[3]	CFa[4]	CAs[5]	C	N	S	P
		($g\ kg^{-1}$ DM)							
Aigen im Ennstal	Leaves	286	102	34	44	533	16.2	1.4	1.2
	Stems	388	82	27	41	532	13.1	1.8	1.1
Tauplitzalm	Leaves	288	103	29	43	519	16.5	2.0	1.1
	Stems	420	98	28	45	516	15.7	1.6	1.5
Tauplitzalm*[1]	Leaves	275	89	28	43	523	14.1	1.2	1.0
	Stems	401	66	20	29	540	10.6	0.8	0.8
Planneralm	Leaves	211	106	34	44	524	16.9	1.5	1.3
	Stems	379	66	26	26	539	10.6	0.9	1.0

[1] Tauplitzalm* = *V. myrtillus* on limestone rock.
[2] CFi = crude fibre.
[3] CPr = crude protein.
[4] CFa = crude fat.
[5] CAs = crude ash.

Table 6. Mineral nutrient contents and ratios of elements of leaves and stems in *V. myrtillus*.

Location	Plant part	Ca	Mg	K	Na	Mn	Zn	Fe	Cu	C:N	N:P
		(g kg^{-1} DM)				(mg kg^{-1} DM)					
Aigen im Ennstal	Leaves	9.5	2.2	8.5	55	842	37	124	6.0	33	14
	Stems	9.6	2.2	6.6	97	746	52	287	7.5	41	12
Tauplitzalm	Leaves	8.7	2.7	8.9	43	795	24	89	5.9	32	15
	Stems	6.8	2.3	8.8	212	570	44	287	8.6	33	11
Tauplitzalm*[1]	Leaves	10.4	2.7	6.4	58	567	27	100	5.5	37	14
	Stems	7.4	1.5	3.9	227	492	51	82	5.7	51	13
Planneralm	Leaves	9.1	2.7	8.7	47	547	20	65	4.6	31	13
	Stems	5.3	1.6	5.3	187	748	49	113	5.6	51	11

[1] Tauplitzalm* = *V. myrtillus* on limestone rock.

Figures

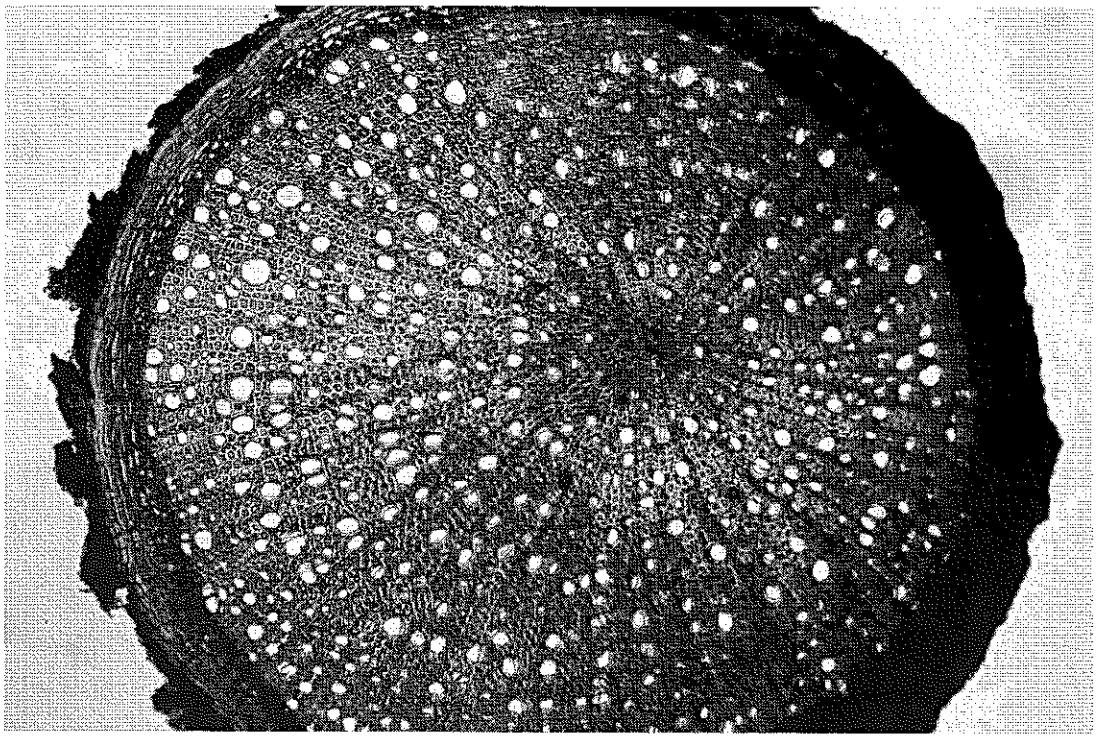

Fig. 1. Cross section of a shoot root (diameter 1.3 mm) of *V. myrtillus* in the condition of secondary thickening.

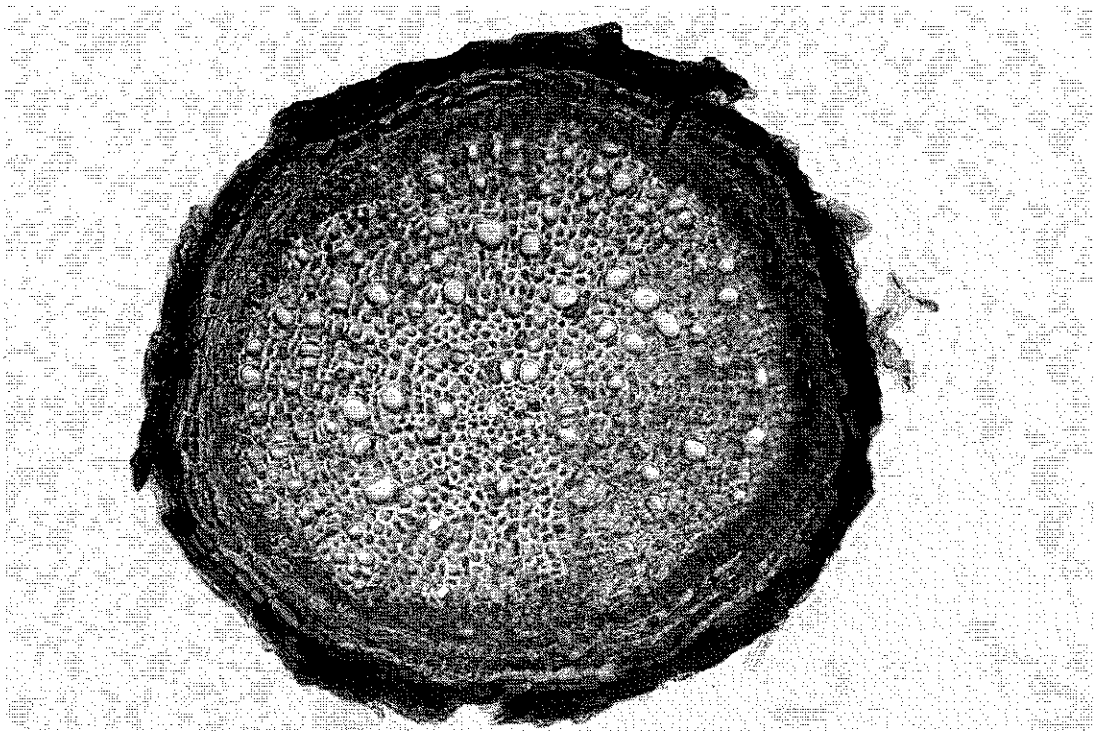

Fig. 2. Cross section of a side root (diameter 0.45 mm) of *V. myrtillus* in the condition of secondary thickening.