DESCRIPTION OF DIFFERENT HORSERADISH BASED ON THE VARIETY OF SPECIES

PhD thesis

Irinyiné Oláh Katalin

Budapest
2012

PhD School
Name: Doctoral School of Horticultural Sciences

Field: Crop Sciences and Horticulture

Head of Ph.D. School: Prof. Dr. Magdolna Tóth
Doctor of the Hungarian Academy of Sciences
Head of Department of Fruit Sciences
CORVINUS UNIVERSITY OF BUDAPEST,
Faculty of Horticultural Sciences

Supervisor: Dr. Laszlo Géczi
professor, PhD.
COLLEGE OF NYÍREGYHÁZA,
Technical and Agricultural Faculty
Department of Land Management and Rural Development

The applicant met the requirement of the PhD regulations of the Corvinus University of Budapest and the thesis is accepted for the defence process.

.....
Head of Ph.D. School

.....
Supervisor

1. PREMISES OF THE WORK AND THE AIMS SET

The production of horseradish in corporate size has an almost 100-year history. The production technology developed during decades is different from the others used in the world. Due to this the horseradish grown in the Hajdúság area is treated as ”Hungaricum”,i.e. traditional Hungarian product. Among the cultivation lands throughout the country only one remains. So nowadays the growth is reduced to the Hajdúság territory, in the villages on the East of Debrecen (Bagamér, Álmosd, Kokad, Újléta, Vámospércs) the growth of the horseradish is almost the only one opportunity of work and livelihood. The total size of the horseradish producing area is 1200-1500 ha with a total annual average yield of 7-8000 tons. As”Hungaricum” i.e. traditional Hungarian product, 90% of the yield is exported, mostly as raw product. The most of the product is sold in Germany. Beside the widespread grated horseradish the plant can be processed in several ways, such as horseradish powder, pellet, chips or flakes.

In spite of the more and more state recognised species, the more modern machinery, the integrated buying network and good selling conditions the growing has to face with several problems. Despite the folk selection the population grown in the Hajdúság is depreciated and morphologically not standardized though in the 1990s a horseradish cross breeding process started and due to this now 7 different Hungarian species can be found in the Hungarian Species List. The majority of the growers still use (by force) monoculture. These disadvantageous factors have been visible in the Hungarian horseradish production for years. The so-called”mycosis root” is common which means the rhizome with different rots. The other significant illness of the horseradish is the abnormal formation of lateral roots. The value of the rhizome is deteriorated by the mutation called the brown coloration of the inner tissues of the taproot or the brown coloration of the cambium. How these illnesses are formed different answers can be found in the professional literature. The white tatter of the horseradish (*Albugo candida* (pers.) KUNTZE) can also cause serious damage in the crown. All these factors lead to the decrease of the quality of the product and the protection against the illnesses of the crown and the pests mean extra cost. Against these problems the growers cannot guard by using agrotechnical methods effectively so the conscious species usage should be urged. It is also necessary to adopt the continuously changing market needs which are only possible by having a wide variety of species. As an example it can be mentioned that earlier the market required less hot horseradish nowadays there is a significant need for the stronger ones as well.

A solution might be the growth of controlled mother spawns and the production of such resistant or tolerant species that have higher crop and their inner content values assure the

competitiveness. For this such genome is available that has a great diversity in crop and illness standing ability so may serve well as a raw material for establishing new species.

The general aims of the thesis

The morphological characterization of the horseradish species collection and maintenanced by the College of Nyíregyháza, defining their crop ability, illness resistance ability and their inner values and establishing morphological complex by using the diversity of the genome.

The detailed aims of the thesis

- The morphological description of leaves and the roots of the variations of the above mentioned species collection.

- Systemization and the ranking of the morphological complexes of the horseradish species and varieties examined based on their morphological characteristics.

- Regarding the species and varieties examined and the morphological complexes
  - defining the crop ability,
  - defining susceptibility to infestation on leaves, *Albugo candida*,
  - defining the degree of the so-called ”germing” on the surface of the rhizome that is wet and dry rot and the brown coloration.

- Defining the vitamin C, mineral and allyl isothiocyanate contents via the varieties and strains of the variety collection as well as the horseradish morphological complexes.

2. MATERIAL AND METHOD

The materials and the place of the observations

The material of the experiences and observations was the horseradish gene collection of the Faculty of Technology and Agriculture of the College of Nyíregyháza. This collection includes the state recognised species as a result of domestic cross breeding, some species from the neighbouring countries and the varieties collected from the different part of the country. This thesis includes the evaluation of 78 different species of horseradish. The observations were taken place between 2002 and 2007 at the location of the DE AMTC KIK Nyíregyháza Research Centre. The research field was about 2000 sqm (0,18-0,25 ha) in every year. Regarding the varieties of the horseradish 30 were examined per species in every year.

Recording the morphological characteristics of the leaves and the roots

The morphological characteristics of the leaves were recorded in 2003 and 2004 during the vegetation period on 4 fully developed leaves and on secondary leaves. The description of the morphological features of the roots was done in every year between 2003 and 2007 when the rhizome were processed to goods. The recordings were done by bonitation, relying on the DUS and UPOV guidelines (beside others) for this plant and by observation.

In case of the primary leaves I recorded the size, shape, shine, bullate, wave, the fine or rough state of the texture, the crinkle, the curve of the top of leaves, the colour of the vein, the antocity of the petiole, the crown and its tendency to be bushy. In case of the secondary leaves I defined the degree of the serration and the slicing of the leaves.

I studied the shape, cover colour, hair, the number and the size of the lateral roots of the main root. I also studied the shape of the rosettes of the leaves (crown) and if it is opened (branching) or closed.

Examining the yield of the horseradish species and lines

For the examining the productivity of the horseradish species I used the autumn harvested, fully developed and cleaned rhizomes. The data collection was done between 2003 and 2007 in every year. Without considering the health state of the rhizomes I recorded the number of and the weight of the rhizomes ranked into classes. The classification was done based on the length and the diameter of the rhizomes and the customers' needs were also taken into consideration.

The characteristics yield of the different horseradish species and morphological characteristics was counted from the product of the average rhizome weight and crop density (44 000 plant/ha).

Surveying the extent of the crown infection caused by the *Albugo candida*

I examined the sensibility for the *Albugo candida* (white rust) during the vegetation period. In 2004- the infection was surveyed on randomly selected leaves with the same age by using a 10x10 cm gage. During the survey I did not pay attention to the size of the infection stains.

In the year of 2003 and 2007 3-3 times I defined by bonitation (on scale between 1-15) the measure of the *Albugo candida* leaves infection.

Surveying the rot illnesses and the abnormal formation of lateral roots

I recorded the root illnesses after harvesting during the goods producing process. The survey was done in the year of 2003., 2004., 2005 and 2007. On the surface of the rhizomes I defined three types of symptoms: 1) dry rot – chipped shuck, partly violet pigmentation, 2) wet rot – appears stainly, some parts the shuck can be scrapped off, 3) abnormal formation of lateral roots – under the crown abnormal sprig proliferation and shoot formation. During the recording I paid attention to the illness and not to its extent.

Surveying the discoloration

The measurement for determining the discoloration was done between 2003 and 2007 in the following way: 5-10 fully developed rhizomes were used from every breed and line and these rhizomes were cut at the end at an angle. On the cross-section at the wooden border brown discoloration, in the wooden part brown stains, namely the trachea and the browning and ruination of the trachea could be easily identified. I recorded these symptoms together, not separately and did not record the differences so hereafter it will be referred as inner coloration of the rhizomes or texture coloration.

Defining the nutritional values

For the nutritional analysis I used rhizomes harvested in the autumn. From one breed I examined 5 or 10 same seized, possibly first class rhizomes.

The vitamin C and mineral contents analyses were done in the Central Laboratory of DE ATC in 2002. The mineral content analyses were done on three breeds ('Bagaméri 93/1', 'Bagaméri delikát' and 'Danvit') with Optima 3300DV Inductively Coupled Plasma Optical Emission Spectrometer.

The allyl isothiocyanate analyses were done in NYF AMKI. The allyl mustard oil content from raw horseradish was detected by gas chromatography and mass spectrometry. The test materials (5 state recognised breeds, 10 high productivity breed and one *Magyar* and one *Dán* morphological complex type) were collected in 2006.

3. RESULTS

Leaves and roots morphological complex of the breeds and lines

Based on the results of the morphological records the shape of the leaves follow different elliptical forms (narrow elliptic, elliptic and wide elliptic) or it can be reversed heart shaped. Its size can be characterized by its length and highest width so we can separate short, medium and long or narrow, medium or wide leaves. The quotient of the two features gives the shape index of the leaves. The less is the shape index of the leaves of the breed the bigger is the crown. The colour of the leaves can be light green, medium or dark green, mat or light, regarding the texture it can be smooth or rough, the touch of the leaf can be smooth or rough, too. The colour of the veins can be green, middle green or white. The edge of the primary leaves can be completely smooth, or medium or strongly serrated. In the case of the secondary leaves the structure of the upper part of the leaves is common (lobular, flawed, segmental, sliced) but undamaged leaves may also be found. The top of the leaves of the horseradish is not or middle or strongly screwed (folding back). According to the stand of the crown I separated loose, slightly loose and standing ones. The tendency for bushing and the anthocyanin features of the petioles can be weak, medium or strong depending on the breed of the horseradish.

Regarding the shape of the rhizome I separated steadily thick (cylindrical) or loose or lightly loose under the crown. The rosette of the leaves can be closed or loose, in the former case the leaves slick to the centre bud and the other case they are separated from the bud. The surface of the main root is yellow and white or brass coloured and little, medium or strongly hairy. The number and the diameter of the lateral roots are a characteristics feature. There can be few or many and thin or thick lateral roots have also been separated.

With the above mentioned features the different varieties can be described well and can be compared.

Coherency between the morphological features of the leaves and the roots

A correlation can be found between the shape of the leaves, the tendency for the bushing and the anthocyanin colouring of the petioles. The elliptical leave shape does not have or have a weak correlation to the bushing tendency, the crown is usually slightly loose and the petioles does no tor just slightly anthocyaning. The middle width (wild elliptic) leaves of the horseradish have a slight or medium tendency for bushing, their crown is loose and their petioles have weakly or medium anthocyaning. The narrow elliptical types have strong tendency for bushing and their petioles have violet colour with standing crown.

The roughness of the texture have strong correlation with the colour and lightness of the leaves, the infection of the *Albugo candida*, the bullating, the violet colouring of the petiole and have a middle correlation with the waviness. The fine textured leaves are light or middle green and are not light. Their surface is smooth or sometimes mildly bullated, not or rarely wavy. They are very sensitive to white candida infection. Their petioles are strongly anthocyanin coloured at the joint to the rhizome crown. The rough and middle rough leaves are usually light, medium or dark green, bullated and wavy. Their sensitiveness to *Albugo candida* infection is weak or medium as well as their anthocyanin.

I also found strong correlation among the lightness and waviness and the medium bullating. The light leaves in some degree are bullated and wavy, the mat leaves are usually smooth and flat.

The correlation is medium between the loose or closed crown and the shape of the rhizome. The loose rosette types' rhizomes are open or strongly open under the crown and narrow at the bottom. The plants with closed crown are steadily thick or have a slightly open roots.

The shape of the main root is also connected to the number and thickness of the lateral root. These features are strongly connected to each other. The steadily thick rhizomes usually have several thin or medium thick lateral root meanwhile the narrowing ones have few and thick lateral root.

My research also covered the relation between the inner colouring and the morphological shape of the root. In the case of the open crowned plants and the narrowing rhizomes the number of the brown coloured texture is higher then in the case of the closed crowns and the steadily thick main root.

According to the results of the examination of the relation among the shape of the leaves and the rosette of the leaves, the shape of the root and the number of the lateral root correlation can also be found. The elliptical leaves are connected with closed crown, steadily thick or slightly narrowed rhizome with many lateral roots. The wide elliptical leaves have closed crown and a narrowing main root. The pike-like (narrow elliptical) leaves' rhizomes are loose and have few lateral roots. Also a strong relation can be found among the tendency for bushing and the openness or closeness of the rosette and the shape of the rhizome. Accordingly, the closed rosettes are slightly bushing while the loose ones are strongly. The steadily thick rhizomes have a weak tendency but those which narrow under the crown have stronger tendency for bushing.

Morphological complexes of the horseradish

By using the relations between the morphological complexes of the leaves and roots, I classified the horseradish breeds and lines into 4 morphological complexes with the help of cluster analyses and disscriminancy analyses. ***(Table 1.)***. I named each after its most characteristics representative and

described based on their morphological complex.

Table 1. Grouping the horseradish breeds and lines based on their morphological complexes

Morphologcal complex 1. Magyar type			
'Alsókapui'	'Debreceni fehér húsú'	'Nadály'	'Ruskovói'
'Bagaméri 222'	'Derecskei fehér húsú'	'Nagyfenesi'	'Ruzombereki'
'Bagaméri 223'	'Derecskei sima levelű'	'Nagykőrösi'	'Siófoki'
'Bagaméri 93/1'	'Eperjesi-2'	'Nagyváradi'	'Tel-Aviv'
'Bagaméri delikát'	'Gr. Enzerdorfi	'Német-Rev-1'	'Tinódi'
'Barazsúly'	'Grassdorfi'	'Novo-targi'	'Újlétai szeldelt levelű'
'Bayk-95'	'Horányi'	'Petrence'	'Újlétai-B'
'CS - 2'	'Kolozsvári'	'Podbielli'	'Vojticei'
'Csíkszeredai'	'MS Magonc'	'Pozsi'	'Zaluzice'i
			'Zólyomi'
Morphological complex 2. Spreewaldi type			
'Avasújvárosi'	'KL (Brigi)'	'Nyírnemes'	'Spreewaldi'
'Édes /MÁRTI/'	'Makói'	'Pellérdi'	'Spreewaldi MS'
'Grátzi-A'	'Mengusovcei'	'Pózna'	'Steierischer'
'Grátzi-B'	'Mihalovcei'	'Pozsonyi'	'Szakácsi'
'Hlohoveci'	'NFL-Nice'	'Rzezowi'	'Szikszói'
	'Nürnbergi'	'Sonkádi'	'Varasdini'
Morphological complex 3. Brassói type		**Morphological complex 4. Dán type**	
'Bánki-M'	'Ikervári'	'Bayk-4'	'Eperjesi-1'
'Bátai'	'Lúcsonyi'	'BP-530'	'Liptószentmiklósi'
'Brassói-1'	'Tormásligeti'	'CS - 1'	'Norda'
'Brassói-6'		'CS - 3'	'Sepsiszentgyörgyi'
		'Csavartlevelű /TRIŐR/'	'Westsik-telepi 5-ös'
		'Danvit'	

Yield of the horseradish breeds and lines

In the years of the examination the average yield of the gene collection was 9,4 t/ha which exceeds the factory yield. The lowest (under 8 t/ha) yield could be noted in the case of 'Podbielli', 'Bayk-95', 'Nagyváradi' *Magyar* type and 'Sonkádi', 'Mihalovcei' *Spreewaldi* type during the five years. The 'Eperjesi-1' and the 'Westsik-telepi 5-ös' *Dán* type horseradish had an extremely high value (above 12 t/ha). The average yield of the *Magyar* and the S*preewaldi* type is 9,2 t/ha, the *Brassói* type is

9,95 t/ha, the *Dán* type is 10,85 t/ha. Significant difference can be found between the *Magyar* and the *Dán* and the *Spreewaldi* and the *Dán* types.

Classification

The rate of the first class in the collection was 80 %. The first class rhizomes could be found in highest rate among the *Magyar* type 'Siófoki' (95 %), the *Dán* type 'CS-3' (94 %) and the *Spreewaldi* type 'Grasssdorfi' (93 %) while in lower percentage they appeared at the *Magyar* type 'Ruzombereki' (54 %), 'Nagyváradi' (59 %), 'Zaluzicei' (62 %).

Caharctersitically the *Brassói* and the *Dán* type have the most first class rhizomes (86 %). The *Magyar* (77, 56 %) and the *Spreewaldi* type (80,95 %) fewer first class root can be found but the deviation is significant as it can be seen above.

It is more profitable to grow those types that give higher percentage of the first class rhizomes since they can be sold more advantageously. From this point of view the first is the *Dán* type since they have the most first class rhizomes and their average weight is also very high. The breeds belonging to that group, the 'CS-3', 'Westsik-telepi 5-ös' and the ’Eperjesi -1' offer 90 % first class horseradish which with their weight above 310 grams are far above the average of the collection (250 g), but among the *Magyar* types the 'Eperjesi-2' and the 'Siófoki' are also notable. Among the other three types regarding the average weight of the first class rhizomes there is no statistical difference.

***Albugo candida* crown infection**

In the years of the research we could not find a breed or line that was not infected by the *Albugo candida* fungus. The crown of the *Magyar* type 'Podbielli', 'Novo-Targi' and 'Vojticei' lines were less infected which means that I could find only few a infection stain on them. The most infected were the 'Spreewaldi', 'Szakácsi', 'Nyírnemes', and 'Pózna' lines (all are *Spreewaldi* type). On the bonitation scale considering the average of two years they got 4 and 5 which means that the out planted horseradish had several white bullated stains caused by the causative agent.

In my experience no statistical difference among the *Magyar*, the *Brassói* and the *Dán* type could be noted regarding the sensibility to the illness. The *Spreewaldi* type significantly more sensitive to the causative agent then the other three types.

Texture browning

The inner colouration of the rhizome was noticeable at the lowest grade in the case of the 'Spreewaldi MS' (4 %) while the 'Lúcsonyi' (71,4 %) showed the highest.

The *Magyar* (30,4 %), *Spreewaldi* (30, 8%) and *Dán* (32, 4 %) types did not show

significant differences. The *Brassói* (51,2 %) type lines, however, showed the symptoms of text colouration in the highest number.

The rate of the symptom was the highest in 2004, in this year the spring was dry. The less coloured rhizome was counted in 2006 though the autumn was the driest in that year. In 2003, 2005 and 2007 the rate of the inner colouration was similar but in 2003 and 2005 there was a significant difference. In the rainiest year the browning was the highest till in the less rainy years it had a lower rate. This couples with the fact that the rainiest year had the driest spring and very wet summer, till the less wet year had a definitely dry autumn.

Illnesses appearing on the surface of the rhizome

The rate of the healthy roots was the highest at the *Magyar* types ('Tel-Aviv', 'Barazsúly' 'Bagaméri 222'), it was above 80%. In the average of the years examined the 'Ruzombereki' (*Magyar* type) and the ’Mihalovcei' (*Spreewaldi* type) rhizomes had some kind of illness, no healthy rhizomes could be found among them. We could not find such type or variety that raised only healthy rhizomes in the years examined. Unfortunately, in our experience the rate of the healthy rhizomes considering the whole stock was lower (43,5 %), till the ill ones was (56,5 %).
Regarding the surface illnesses of the rhizomes there was a statistical difference between the *Magyar* type (49,33 %) and the *Dán* (61,8 %). The *Spreewaldi* (53,47 %) and the *Brassói* (61,4 %) tpyes do not differ statistically.

The gene stock of the horseradish was affected by the dry rot by 34,03 %, the wet rot by 55,37 %, till the abnormal formation of the leaves was 10,6 %. In the case of some species only the symptoms of wet rot was observable (*Magyar* types: 'Eperjesi-2', 'Német-Rev-1'; *Brassói* types: 'Bátai', *Dán* types: 'Westsik-telepi 5-ös' and the 'Liptószentmiklósi'). The 'Mihalovcei' (*Spreewaldi* type) had 100 % dry rot but it was also very high in the case of the 'Nagyváradi' (97 %) and the 'Ruzombereki' (95,7 %) (*Magyar* types). The abnormal formation of the leaves was very high in the case of the 'Makói' (86,5 %) and the 'KL (Brigi)' (70,8 %) *Spreewaldi* type horseradish.
The *Magyar* and the *Spreewaldi* types both suffer from dry (48,23 % and 48,5 %) and wet (42,13 % and 35,25 %) rot. The *Brassói* and the *Dán* types and lines are attacked by mainly wet (61,46 % and 82, 6%-ban) rot. The abnormal formation of the leaves – though was not significant at any of the types – appeared the less at the *Dán* (2,97 %) type. The highest was at the *Spreewaldi* type(16,24 %) but the difference is not significant from the *Magyar* (9,63 %) and *Brassói* (13,52 %) types.

According to my measures the average weights of the ill roots were higher in all the cases then the healthy ones. The weight of the healthy horseradish never reached the 300 grams meanwhile the weight of the ill rhizomes in several cases exceeded this value. This tendency is true

for the types as well, so the ill rhizomes were heavier (235-248 g) then the same types healthy ones (213-240,5 g). As an expectation we can mention the *Brassói* type where the ill ones were (248,3 g) and the healthy ones were (222,5 g) so there is no significant difference. Regarding the average weight of the healthy plants no significant difference can be found but in the case of the ill plants the *Dán* type does differ from the others (288,5 g).

If we examine the effect of the years on the appearance of the illnesses on the surface of the rhizomes we can see that the rate of the infection was the highest in 2003 (57%) and in 2007 (68 %), there was not significant difference between the two years. We measured a lower rate, but still over 40 % in 2004 and 2005 but there is no significant difference between the two years.
The dry rot was the lowest in 2004 (13,72 %), and wet rot was the highest (74,56 %) in the same year. These are significantly different from the other years. In the other years the symptoms' rate was the same. In the year mentioned the dry spring was followed by a very rainy summer that might be favourable for the wet rot. In 2003, 2004 and 2005 the abnormal formation of the leaves was about 11-18 % without showing significant difference. The less horseradish suffering from this appeared in 2007 (2,46 %).

Nutrition values of the horseradish types

The Vitamin C content in the case of the 'Bagaméri 93/1', 'Bagaméri delikát' and 'Petrence' representing the *Magyar* type exceeds the 100 mg/100g. The *Dán* type 'CS-1' and 'CS-3' varieties and the 'Danvit' type have low Vitamin C content, it is between 67,7 and 66,9 mg/100g, and the deviation is high in the case of the *Spreewaldi* type (between 66,9 and 127,5 mg/100 g).

The allyl mustard oil content was the highest in the 'Debreceni sima levelű' variety (347 mg/100 g raw weight), the smallest was the 'Csíkszeredai' (237 mg/100 g raw weight), both are *Magyar* types. The *Magyar* types – except the 'Csíkszeredai' – and the *Spreewaldi* ('Pózna', 'Édes /MÁRTI/') types have more then the average allyl content (297-347 mg/100 g raw weight). The 'Lúcsonyi' and the 'Brassói-6' *Brassói* type horseradish and the *Dán* types are rather treated as "sweet" since their allyl isothiocyanate content is low, between 244 and 290 mg/100 g raw weight.
The allyl isothiocyanate content of the examined, domestic grown horseradish species and lines are high above the results of the foreign ones according to the professional literature.

In case of the minerals the potassium was the highest in the roots and in the leaves. The potassium content of the leaves was higher then the roots. The phosphorus content was low in the roots and leaves as well.. The calcium content was relatively high, mostly in the leaves. The leaves contain 5 and 6 times more calcium then the roots. The sulphide content of the roots was the highest int he 'Danvit', *Dán* type. The sulphide content of the leaves was higher then the roots'. Among the

micro elements the natrium content was high. The zinc is the only element from which more can be found in the roots then in the leaves. The relatively high boron content of the rhizomes and leaves is also worth noticing.

New scientific results

1. The varieties of the collection may be classified into 4 easily identifiable morphological complexes, according to the results of the morphological analysis of leaves and roots. These are the following, each named after its most characteristic representative. The Morphological Complex 1 is the *Magyar,* the Morphological Complex 2 is the *Spreewaldi,* the Morphological Complex 3 is the *Brassói,* the Morphological Complex 4 is the *Dán* types.

The *Magyar* Complex is characterised by erect, elliptic, shiny, dark green, crinkled leaves and a rough leaf texture; veins are green or medium green, the crown is closed and the rhizome is conical. Petioles contain no anthocyanin pigments or only in a limited concentration.

The *Spreewaldi* Complex does not differ from the previous complex regarding rhizome characteristics (shape and crown) and canopy; the leaves of varieties belonging to this complex are also elliptic, however, they have a fine texture, they are not crinkled, with a medium or light green colour and medium green or white veins. Petioles contain anthocyanin pigments in low or medium concentration.

The *Brassói* Complex may be distinguished from the previous ones mainly by the shape of leaves and the characteristics of the rhizome. Varieties in the complex are characterised by erect, narrow, elliptic, shiny and smooth leaves, a fine but mostly rather medium rough leaf texture, with a medium green colour and green or medium green veins. Petioles have a strong anthocyanin coloration. The crown is typically loose, the rhizome is rather wide below the crown and bushy.

The *Dán* Complex are characterised by wide, elliptic or reversed heart shaped, shiny, crinkled leaves with a rough tissue. Leaves are medium or light green, with medium green or white veins. Petioles contain anthocyanin pigments in medium concentration. The canopy is prostrate. The crown is closed but the rhizome is wide or moderately wide under the crown.

2. I found out that the horseradish belonging to the *Magyar* and the *Spreewaldi* types have lower yield then the *Dán* types, the *Brassói* types are between the two without any significant difference. The *Dán* types' average rhizome volume is almost 20% higher then the *Magyar* types, moreover the rate of the first class rhizomes is also higher. Because of the above mentioned reason growing *Dán* types is more profitable.

3. I found out that average weight of the rhizomes of the *Magyar* and *Spreewaldi* types is lower then the *Dán* and the *Brassói* types. This difference in the size is mainly connected to the shape of the rhizome. The cylindric, steadily thick roots of the *Magyar* and the *Spreewaldi* types are lighter then the narrowing rhizomes of the *Brassói* and the *Dán* types.

4. I found out that leaves of the *Spreewaldi* types are attacked by the *Albugo candida* in a greater extent then the horseradish belonging to the *Magyar*, *Brassói* and *Dán* types. I showed correlation between the measure of the infection and the light and the bullate and organolepthical experienced roughness of the leaves. The texture of the leaves of the *Spreewaldi* types are smoother, their surface is mat and smooth meanwhile the others are rough or medium rough, have some bullates and light.

5. I found out that the Vitamin C content of the *Magyar* horseradish is higher then the *Dán* types. The allyl mustard oil content of the *Magyar* and the *Spreewaldi* types are higher that is why they are tang. The *Brassói* and the *Dán* types are "sweet" because their allyl isothiocyanate content is low.

4. CONCLUSIONS AND SUGGESTIONS

Morphological complex of the leaf and the root

The horseradishes examined show a wide variety regarding their morphological features of the leaf and the root. By statistical methods it can be justified that there is strong relation among the features of the leaves and the roots. There is also a correlation among the morphological characteristics of a leaf and its resistance against the *Albugo candida* and among certain characteristics of the root and the texture browning. In the future it might worth examining the correlation of the existence of other illnesses.

It can be said that some features appear together, there is a tight correlation among them. That made me possible to separate the lines of the gene collection into a so-called shape circles, these are the followings: 1. *Magyar*, 2. *Spreewaldi*, 3. *Brassói*, 4. *Dán* types. These types can be characterized by following the policies of DUS and UPOV.

Yield

The yield of the examined horseradishes and lines fluctuate between wide limits (8-12 t/ha). Usually the *Magyar* and the *Spreewaldi* types have lower yield then the *Brassói* and the *Dán* types. This can be explained by the fact that rate and the average weight of the first class rhizomes of the *Dán* types are higher then the others.

The size difference of the rhizomes is connected to their shape. The *Magyar* and the *Spreewaldi* types characteristically have cylindrical, steadily thick roots and their weight is smaller then the narrowing, so-called parsnip like *Brassói* and *Dán* types rhizomes. That is the reason why they have higher yield.

According to the growers' experience the parsnip-like rhizomes' weight is higher than the steadily thick ones but during the processing the parts cut is also more that should be treated as loss. So the future observation should include the measure of the loss regarding the side roots and the time necessary for the process. Beside, it might be worth examining that under what density the different types reach their maximum yield.

Illness resistance ability

The different types of the horseradish gene collection are infected by the differently. Though the growers say that the Danish horseradish have higher illness resistance ability, during my research I did not find significant difference among the *Magyar*, the *Brassói* and the *Dán* types, but the *Spreewaldi* types are significantly more sensitive to the *Albugo candida* than the others. According to the Paerson type correlation examination the different level of infection – the appearance of the *Albugo candida* – have a correlation with the morphological characteristics of the crown, such as the texture of the leaves. The leaves of the plants of the *Spreewaldi* type are smoother, mat and light meanwhile the others have rough or medium rough leaves. It is possible that the texture of the leaves, the thickness of the cuticle are important factors against the *Albugo candida* infection.

The statement above can be fully justified if we perform a histology examination on the leaves of the different horseradish types.

Since under the same growing conditions the different horseradish species show different inner colouration this feature can be treated as standard of the given type. The *Brassói* type showed

the highest rate but there was not significant difference among the other types. The illness is common among the rosette of the leaves type ones that appear mostly in the *Brassói* type. At the same time the appearance of this symptoms shows correlation with the quantity and the distribution of the rain. In more rainy years the number of the coloured rhizomes increased if there was not much rain during spring.

Regarding the illnesses appearing on the surface of the rhizomes the *Magyar* types are healthier than the *Dán* types. Generally, the most common was the rot, the abnormal formation of the leaves was infinitesimal. The abnormal formation of leaves affected the *Dán* types less but the number of the wet rot was the highest. I experienced the most abnormal formation of leaves in the case of the *Spreewaldi* type and the *Albugo candida* appeared here the most frequently. This justifies the statements of others, in the professional literature it is mentioned that the fungus of the *Albugo candida* cause abnormal formation of the leaves with the help of rain water. Since there is no scientific agreement about the factors facilitating the abnormal formation of the leaves further examinations are necessary for defining these factors.

Based on my research it can be said that lots of autumn rain favour the abnormal formation and the rot as well. At the same time the spring rain does not affect the existence of wet rot but increases the number of the dry rot rhizomes.

The average weight of the ill rhizomes exceeds the healthy ones, expect the *Brassói* types, these tendency can be statistically justified. This might be explained that the bigger main roots are probably loose so the illnesses can attack them more easily than the smaller ones.

Inner content

Based on the inner content examinations there is a correlation among the horseradish species and the allyl isothiocyanate contents. The *Magyar* and the *Spreewaldi* types always proved to be tangier than the the *Brassói* and the *Dán* types. The *Dán* types have a lower Vitamin C content than the *Magyar* types, but their mineral content values were similar.

Due to the limited number of elements and the lack of repetitions the results achieved should be treated as a pre-test result and they should be repeated by taking into consideration the market's needs. It might be important to examine the inner content of the state recognised species (as control) and some perspectivical species (illness resist ones with high yield) for several years.

The production values of the types of the horseradish

By summarizing the results it can be seen clearly that the four types established can be well separated from each other.

The *Magyar* types have by erect, elliptic, shiny, dark green, crinkled leaves and a rough leaf texture and cylindrical, closed rosette rhizomes. Their average yield is 9 t/ha, the rate of the first class rhizomes is 77 %, their weight is about 240 g. The leaves are attacked by the *Albugo candida* weakly or moderately. About one third of the rhizomes are affected by colouring, the rate of the illnesses appearing on the surface is 50 % that is mainly rot, the rate of the abnormal formation is infinitesimal. Dry and wet rot appear at same rate. The Vitamin C and the allyl mustard oil content of the roots are high. This means a pleasant tang that meets the requirements of the process and consumer parts. The productivity of the *Dán* types is better than the *Magyar* types but the latter's rhizome shape is better for the processing and fresh market sales. Though according to factory experiences the *Magyar* horseradish tends to have abnormal formation we could not proof this. The reason might be the crop rotation and the carefully selected mother spawns. In my opinion by taking into consideration the above mentioned among the *Magyar* types we can find such perspectivical types that can be grown economically. These types are for example the Siófoki, and the Eperjesi-2 types.

The *Spreewaldi* types horseradish has similar values in the field of yield, classification of the rhizomes and the illnesses appearing on the surface or within the plant like the *Magyar* types. However, their elliptic with a medium or light green colour and medium green or white veins are very sensitive to the *Albugo candida* so they require more protective intervention which means higher growing costs.

The *Brassói* types are the most different ones morphologically from the others. Their leaves are erect, narrow, elliptic, shiny and smooth and the crown is typically loose, the rhizome is rather wide below the crown and bushy leaves which make this type a well marked one. The resistance ability of the leaves does not differ from the *Magyar* and the *Dán* types. Due to its bulky, parsnip like rhizomes the rate of the first class rhizomes is 86 %, their average weight is 260 g, their productivity is about 10 t/ha. The disadvantage of the rhizomes that the open rosette makes it difficult to harvest and process manually and the cleaning loss is higher than in the case of the others. Another disadvantage of the type is the increased appearance of the tracheamicozy, it can even 50%.

Beside the *Magyar* types from the growers' point of view the *Dán* types' yield also reaches the 11 ton/ha. The rate of the first class rhizomes is 86 %, their weight is 280 g. The *Albugo candida* infects their wide, elliptic or reversed heart shaped, shiny, crinkled leaves with a rough tissue relatively seldom, the abnormal formation is also infinitesimal but the rhizomes are very sensitive to wet rot. Due to its productivity and illness resistance ability this type is becoming more common in the factory growing but since it has low inner values (Vitamin C- and allyl- izitiociny) it will never

be a exclusive type in the growing.

5. PUBLICATIONS PUBLISHED ON THE TOPIC OF DISSERTATION

NOT IF articel

Oláh, K., Géczi L. (2005): Tormafajták és vonalak morfológiai változatossága. In.: A fajtaválaszték fejlesztése a kertészetben. (szerk. Tóth M.) Kertgazdaság (különszám). Budapest. 177-187. p.

Oláh, K. (2008): Nitrogén műtrágyázás hatása a torma termésmennyiségére és szövetbarnulására. In.: Talajvédelem (különszám). (szerk.: Simon L.) Talajtani Vándorgyűlés kiadványa. Talajtani Vándorgyűlés. „Nyíregyháza, 2008. május 28-29. 403-409. p.

Other estimated articles (scientific not educational!)

Géczi, L., **Oláh, K.** (2007): A torma beltartalmi értékei. Zöldségtermesztés 38 (3). 18-23. p.

Oláh, K. (2008): Különböző nitrogén-dózisok hatása a torma gyűrűs szövetbarnulására, terméshozamára és annak minőségi megoszlására. Zöldségtermesztés 39 (3). 18-21. p.

Conference publication in Hungarian (full paper)

Géczi, L., **Oláh, K.** (2003): Tormafajták és vonalak vizsgálata különös tekintettel betegség ellenálló képességükre. SZAB Kertészeti Munkabizottságának Tudományos Ülése „Integrált kertészeti termesztés". Tessedik Sámuel Főiskola, Szarvas. 57-65 p.

Oláh, K. (2007): Növényvédelmi kísérlet a torma fehérsömör (*Albugo candida (pers.)* Kuntze) betegsége ellen. In.: „Versenyképes mezőgazdaság". (szerk.: Szabó B., Varga Cs.) Nyíregyházi Főiskola, Bessenyei György Kiadó, Nyíregyháza. 67-70. p.

Oláh, K. (2007): Tormafajták allilizotiocianát - tartalma. In.: „Versenyképes mezőgazdaság". (szerk.: Szabó B., Varga Cs.) Nyíregyházi Főiskola, Bessenyei György Kiadó, Nyíregyháza. 63-67. p.

Conference publication in Hungarian (abstract)

Oláh, K., Géczi, L. (2005): Tormafajták és vonalak morfológiai változatossága." Lippay-Ormos-Vas" Tudományos Ülésszak. Budapesti Corvinus Egyetem. Budapest. 364. p. Összefoglaló

International conference publication (full paper)

Géczi, L., **Oláh, K.** (2005): Productivity and Ability of Resistance to Illness of Species and Lines of Horseradish. In: Proceedings of the International Scientific Conference „Innovation and Utility in the Visegrad Fours". Volume 2. Agriculture and Food Industry. Oktober 13-15. 2005. Nyíregyháza Hungary. (Ed.: Simon L.) Continent – Ph., Nyíregyháza. 317-323. p Full paper

Oláh, K. (2007): Productivity of horseradish varieties in consideration of assorted rhizoma distribution. In: 7th International Multidisciplinary Conference**,** Volume 2. May 17-18. 2007. Baia Mare, Romania, 285-290 p. Full paper

Book, chapter of book, lecture notes in Hungarian

Oláh, K., Irinyi B. (2006): A konzervipari zöldségtermesztés technológiai kockázatai és lehetőségei a régióban. A friss piacra szánt zöldségnövények termesztési és piaci lehetőségei a régióban. In Versenyképes kertészet II. (szerk. Szabó B.) Tantárgyi segédlet NYF MMFK, ROP-

3.3.1.-05/1.-2005-08-0005/37 3-60. p.