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MORPHOLOGICAL CHARACTERIZATION OF NORDIC HORSERADISH (*ARMORACIA RUSTICANA*)

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Abstract

Wedelsbäck Bladh K., Yndgaard F., Liljeroth E., Asdal A., Suojala-Ahlfors T., Solberg S.Ø., Kolodinska Brantestam A., 2019: Morphological characterization of Nordic Horseradish (*Armoracia rusticana*). – Botanica, 25(1): 74–83.

Morphological diversity was studied in 101 accessions of horseradish (*Armoracia rusticana*) collected from old gardens in Denmark, Norway, Finland and Sweden. The characterization work was performed over three years, where a total of 19 descriptors from the UPOV guidelines TG/191/2-2001 were recorded each year. The results showed high diversity among the studied accessions, both for leaf and rhizome characters. A morphotype with long leaves and a high leaf length/leaf width quota was the most common, but also elliptic and heart-shaped leaf types were found. Some characters showed stability over the years, although there were variations in the results. Correlations between descriptors were found and five different clusters of descriptors were identified. In two of the clusters, only leaf characters were found, whereas the rhizome characters were divided into three other clusters. Correlation between descriptors can be used to reduce the number of descriptors for further studies of horseradish. The results showed that there is a high diversity both in leaf and rhizome characters, despite that horseradish is a vegetatively propagated plant.

Keywords: *Armoracia rusticana*, horseradish, morphological characterization, vegetative propagation.

INTRODUCTION

Horseradish (*Armoracia rusticana* Gaertn., Mey. et Scherb.) was mentioned in literature as early as 2000 years ago (Courter & Rhodes, 1969; Beck, 2005). In earlier times, it was mostly used as a medicinal plant to treat different diseases (Wedelsbäck Bladh & Olsson, 2011; Agneta et al., 2013), but in the 16th century, it was also used as a condiment to different foods (Grieve, 1979). Still, in most records from old literature, the medical use of the root is described. More seldom the characters of leaves, flowers and roots are mentioned, and in those cases information about the shape of the basal leaves is not clear.

In the 16th century, more informative descriptions of the leaf morphology were available. In "das Gartenbuch" (Hortus, 1528) horseradish was depicted with long lancet shaped leaves with a wide and large rhizome accomplished with an illustration of the characters. Two woodcuts, one by the English botanist John Gerhard (1545–1612) and one by the German botanist Leonhart Fuchs (1501–1566) are present from that time. In these woodcuts, two different leaf shapes and rhizome types can be identified. Gerhard showed lancet leaves with acute base and rhizome with three taproots and a high density of side roots, while Fuchs showed a plant with broader leaves, cordate leaf base and a single tiny rhizome (Courter & Rhodes, 1969; Meyer et al., 1999).

The lancet-shaped type was predominant in the Nordic floras in the 18th and 19th centuries (Linnaeus, 1755; Liljeblad, 1798; Lindley, 1838). In the flora of 'Svensk botanik', horseradish was also described as having lancet-shaped leaves, but it was accomplished with an illustration of a plant with ovate-shaped leaves (Palmstruch & Quensel, 1805). In the late 19th and in the 20th century, the descriptions of the plant changed and in some literature both leaf shapes were included (Fristedt, 1873; Becker-Dillingen, 1938).

Weber (1949) has studied leaf shapes more carefully and described two types: 'Common' and 'Bohemian'. 'Common' type has broad leaves and a hollow petiole type, which originated from Eastern Europe. The type is most used in the commercial production as it produces roots of good quality, but is susceptible to white rust and turnip mosaic virus (TuMV). 'Bohemian' type has smoothed narrow leaves, a solid-petiole type and is also called 'Marliner Kren' or 'Bayersdorf strain' and originated from South Europe. This type lacks root quality for marketing purposes with characters such as brown inner coloration and high number of root hairs and side roots at the rhizomes (Kjeldsen Bjørn & Villebro, 2003). It also has a low yield, but is resistant to the two abovementioned diseases (Weber, 1949). Stokes (1955) has also described two types: 'Bohemian', typically grown in homegardens, and 'Common', commercially grown type (Stokes, 1955).

Rhodes et al. (1965) have made morphological characterization of 30 cultivars and identified three different types based on characters such as size, shape and angle of the leaves and resistance to different diseases. Type 1 (Bohemian) has smooth lancet-like leaves and a leaf base angle of less than 60°, a leaf length/leaf ratio above 3.0 with plants resistant to TuMV and white rust. Type II has smooth to slightly crinkled ovate leaves rounded at the base, a leaf angle between 60–90° and a leaf length/leaf width ratio between 2.4–3.0. The plants are susceptible to TuMV, which is expressed as a ring spot symptom. The type III includes 'Common' type with crinkled cordate radical leaves, a leaf angle over 90° and a leaf length/leaf width ratio of less than 2.4 with susceptibility to TuMV and white rust (Rhodes et al., 1965).

Nowadays, characterization of horseradish plants mainly follows the UPOV guidelines set up by The International Union for the Protection of New Varieties of Plants. The guidelines have been adopted with the aim to protect the breeders' rights and new varieties of crop plants. The guidelines are widely used by different gene banks, although they are more adapted to commercial varieties and less suitable for landraces showing higher differences between plant individuals. Despite that the UPOV system is the most helpful tool for morphological characterization of horseradish accessions today. Undoubtedly, more knowledge is needed on traits for effective characterization of variation in morphology of this species.

Apart from the morphological characterizations in Illinois by Rhodes et al. (1965), more recent studies have been performed in Hungary (Oláh, 2012). Also in Italy a newly established horseradish collection, originating from the Basilicata region, has been characterized (Sarli et al., 2012), the collection has also been evaluated for the variation in glucosinolates concentration and root growth affected by nitrogen and sulphur (Rivelli et al., 2016). However, until now, morphological characterization has not been carried out for Nordic horseradish accessions, and the morphological diversity in these countries is unknown.

This study is the fourth part in a series on Nordic horseradish evaluation, where the previous studies have dealt with historical use, origin and introduction to the Nordic countries (Wedelsbäck Bladh & Olsson, 2011), evaluation of glucosinolates in Nordic horseradish (Wedelsbäck Bladh et al., 2013b) and the genetic relationship between Nordic horseradish accessions revealed by means of DNA markers (Wedelsbäck Bladh et al., 2013a). The aim of this study was to characterize the morphological diversity in Nordic horseradish and to identify different types of horseradish among the Nordic accessions.

MATERIALS AND METHODS

Plant material

A project on collection of different Nordic horseradish accessions was initiated by the Nordic Gene Bank in 2002 (since 2008 Nordic Genetic Resource

Centre – NordGen). The aim was to collect accessions grown in gardens or close to gardens at the same location for more than 50 years. This collection and some representative accessions from already existing Danish collection of European origin were included in this study. A total of 101 accessions with one to ten rhizomes from different parts of the Nordic countries including Denmark (16 accessions marked with D), Finland (15 accessions marked with F), Norway (6 accessions marked with N) and Sweden (64 accessions marked with S) were investigated. More information about the accessions can be found in two previously published studies (Wedelsbäck Bladh et al., 2013a, 2013b).

Characterization of accessions

After collecting and propagating the accessions, the plants were first characterized in their country of origin, i.e. in Denmark at the Danish Institute of Agricultural Sciences (DIAS) in Årslev (55°30' N, 10°48' E), in Finland at MTT (Agrifood Research Finland) in Piikkiö (60°23' N, 22°30' E), in Norway at Bioforsk in Landvik (58°20' N, 08°31' E) and in Sweden at Svalöf Weibull AB, Landskrona (55°52' N, 12°49' E) in 2004. Later all of the accessions were replanted and also characterized at NordGen, Alnarp in southern Sweden (55°39' N, 13°05' E) in 2012 and 2013.

All the characterizations were carried out in the following way. In early May, root cuttings (30 cm in length) from the mother plants were randomly planted in the soil at a 45° angle. The distance between plants was 0.6 m in all directions. Fertilizer weed control and irrigation were applied according to local practices. The leaves were characterized in July and the rhizomes in September. Three plants per accession were characterized, and the average values of the results were calculated.

The characterization followed the UPOV guidelines TG/191/2-2001 (UPOV, 2001). They contain 29 morphological descriptors of which 19 were selected for this study (Table 1). Three of the descriptors, Leaf blade: length (L.LG), Leaf blade: width (L.WT) and Leaf: petiole length (P.LG), were treated as quantitative variables and measured in cm, while the other 16 characters were scored (1–9) according to the UPOV system for horseradish. The convention of the corresponding scale is that '1' means that the character in question is not or very little expressed and '9' means that the character in question is complete or very strongly expressed.

Statistical analysis

The statistical system R (R Core Team, 2018) was used for the analyses. The R function *aov* was used for the analysis of variance. For the hierarchical cluster analysis of the dissimilarities between the members of the clusters, the function *hclus*t in R was used. Because the different descriptors vary regarding range, the data were normalized using the function *scale* in R so the descriptors all have a mean of 0 and standard deviation of 1. The dissimilarities were calculated from the scaled data matrix of the accessions by the function *dist* in R. It calculated the Euclidian distances between the accessions based on the nineteen descriptors and produced a dissimilarity matrix. The hierarchical cluster analysis was used to determine the clusters. Furthermore, we used

Table 1. Characters used in the characterization of the horseradish accessions following the guidelines TG 191/2 2001; abbreviations are used after Sarli et al. (2012)

Leaf	Abbreviation	Rhizome	Abbreviation
Leaf blade: shape	(L.SH)	Rhizome shape, longitudinal	(R.SH)
Leaf blade: length	(L.LG)*	Rhizome: curvature	(R.CV)
Leaf blade: width	(L.WT)*	Rhizome: diameter at top	(R.DMT)
Leaf blade ratio: length/width	(L.LG/WT)	Rhizome: diameter at base	(R.DMB)
Leaf blade: green colour	(L.GRN)	Rhizome: weight	(R.WT)
Leaf blade: twisting tip	(L.TW)	Rhizome: surface texture	(R.HR)
Leaf blade: undulation	(L.UND)	Rhizome: density of side roots	(R.RT)
Leaf: petiole length	(P.LG)*	Rhizome: density at base	(R.RTB)
Leaf: petiole anthocyanin at base	(P.ANT)	Rhizome: internal colour	(R.ICL)
		Rhizome: brownish flesh	(R.BC)

*Objectively measured in cm.

the function *heatmap* in R, which is comparable to a "two way cluster analysis", where the margins of a graph show the dendrogram of the individuals and the variables, respectively (Fig. 1). The graph expresses the dissimilarity results from an analysis of the accessions on the available descriptors as different colours. For example, the accessions of cluster 7 in, the box colour for descriptor L.WT is the same for three accessions (Fig. 1). However, they differ for descriptor L.SH, where accession N13 shows a yellow colour in the heat map and the other two a red colour. The rightmost descriptor cluster, containing R.CV, R.RT and R.RTB, identified as number 5, three accessions have a similar response for each of three descriptors.

For the principal component analysis (PCA), the function *princomp* in R was used. A total of 101 accessions represented by 64 accessions from Sweden and 37 accessions from the other Nordic countries were included in the statistical analysis.

RESULTS

The results showed that accessions varied in all the studied characters. All types of leaf shapes from narrow elliptic to ovate were found. However, 80% of the Swedish and 68% of the other Nordic accessions had an elliptic to broad elliptic shape. The leaf length (L.LG) varied from 16 to 100 cm, the leaf width (L.WT) from 8 to 29 cm and the petiole length (P.LT) between 10 and 58 cm. The leaf blade colours (L.GRC) of the Swedish accessions were in most cases medium or dark green, while most of the other Nordic accessions had a light to medium green colour. Only a few accessions with very weak or very strong leaf blade undulation were found. The anthocyanin coloration at the base (P. ANT) was more common among the Swedish accessions compared to the other Nordic accessions. Most accessions had rhizomes with a straight curvature, while the rest of the accessions were slightly curved. Only a small part of the accessions had strongly curved rhizomes. Less than one third of the accessions had strong or very strong brown coloration of the rhizomes. Most accessions had white internal colour of the rhizomes.

Significant variation in accessions was found for all 19 descriptors. Significant variation in years was also detected, but only for 11 of the 19 characters (Table 2). We applied correlation analysis to examine how the characters correlate in different years and the highest correlation was found between year 2012 and 2013, with correlation coefficients ranging from 0.25 to 0.93, with the highest correlation for R.HR and the lowest for L.WT. The poorest correlation was found between year 2004 and 2013 (Table 3). Since accession contributed much more to the general variation than years, measured as the sum of squares, we used averages across years in the further statistical analyses.

Fig. 1 shows a heat map plot, which is a multivariate statistical tool to visualize the relationship between the different accessions and between the different descriptors in a two-way cluster analysis. The plotted grid shows a box for each factor combination, which is encoded with a colour depending on the size of the dissimilarity index. Identical colour indicates the same response. The heat map also plots two dendrograms. One from a cluster analysis showing the hierarchy of values for accessions based on the measured descriptors and a corresponding one for the descriptors based on the available accessions. The clusters seen in the dendrograms were identified by the function *hclust* method "complete" in R. The "fusion level" method indicated that the accessions were grouped into seven clusters (Table 4) and the descriptors into five clusters.

Results from the complete cluster analysis are also shown in Table 4. Most accessions from Denmark were grouped in clusters 1 and 5, while the accessions from Norway are both in cluster 1, 3 and

Table 2. Average scores in 2004, 2012 and 2013, respectively for the various descriptors (see Table 1 for explanations). Results across all accessions

Year	L.SH	L.LG	L.WT	L.LG/WT	L.TW	P.ANT	R.SH	R.DMT	R.DMB	R.HR	R.ICL
2004	2.74	41.2	17.6	2.41	3.93	3.14	2.15	4.84	4.19	4.00	1.23
2012	2.22	48.5	16.2	3.11	4.52	4.13	2.00	4.05	5.12	4.69	1.23
2013	2.14	47.8	15.0	3.33	4.39	4.68	1.88	4.27	5.24	4.75	1.39

See abbreviations in Table 1.

Table 3. Correlation matrixes showing the correlation coefficients between years for the significant descriptors (see Table 1 for code explanations, where 2004 = 04, 2012 = 12, and 2013 = 13)

Code	L.SH04	L.SH12	L.SH13	Code	*R.SH04*	*R.SH12*	*R.SH13*
L.SH04	100	23	33	R.SH04	100	48	54
L.SH12	23	100	51	R.SH12	58	100	63
L.SH13	33	51	100	R.SH13	44	63	100
Code	L.LG04	L.LG12	L.LG13	Code	R.DMT04	*R.DMT12*	*R.DMT13*
L.LG04	100	69	40	R.DMT04	100	20	20
L.LG12	69	100	67	R.DMT12	20	100	73
L.LG13	40	67	100	R.DMT13	20	73	100
Code	L.WT04	L.WT12	L.WT13	Code	R.DMB04	R.DMB12	R.DMB13
L.WT04	100	18	24	R.DMB04	100	17	6
L.WT12	18	100	25	R.DMB12	17	100	81
L.WT13	24	25	100	R.DMB13	6	81	100
Code	L.LG.L.WT04	L.LG.L.WT12	L.LG.L.WT13	Code	R.HR04	*R.HR12*	*R.HR13*
L.LG.L.WT04	100	66	50	R.HR04	100	29	21
L.LG.L.WT12	66	100	57	R.HR12	29	100	93
L.LG.L.WT13	50	57	100	R.HR13	21	93	100
Code	L.TW04	L.TW12	L.TW13	Code	*R.ICL04*	*R.ICL12*	*R.ICL13*
L.TW04	100	31	28	R.ICL04	100	84	47
L.TW12	31	100	62	R.ICL12	84	100	59
L.TW13	28	62	100	R.ICL13	47	59	100
Code	P.ANT04	P.ANT12	P.ANT13				
P.ANT04	100	16	36				
P.ANT12	16	100	71				
P.ANT13	36	71	100				

The code explanations shown in Table 1, where 2004 = 04, 2012 = 12, and 2013 = 13.

Table 4. Member accessions in each cluster and main characters composed the cluster (D accessions are from Denmark, S accessions from Sweden, N accessions from Norway and F accessions from Finland). The member accessions are from the Heat map (see Fig. 1)

Cluster	Main characters that composed the cluster	Member accessions
1	Long and wide leaves and long petioles; the leaves weak twisted and weak undulated; rhizomes of high diameter and a rough surface; low number of side roots in top and bottom of the rhizomes.	D1, D14, D24, D25, D4, D7, N16
2	Accessions with elliptic leaf shape, rhizomes with high diameter and high the root weight. Low brown coloration of the rhizomes and high number of side roots.	D22, F10, F18, F19, F20, F22, F4
3	Long leaves, dark green, twisted and strong undulated. The long petioles have no colour and the roots are low in weight.	D21, N20, N8, N9
4	Accessions with short leaves and anthocyanin coloration at the petioles. Obtriangular shape of the rhizomes with brown coloration.	S8, S12, S15, S16, S22, S24, S25, S26, S29 S32, S33, S34, S35, S36, S37, S42, S68
5	Leaf shape broad elliptic to ovate with anthocyanin coloration of the petioles. Accessions with no coloration of the petioles long and more elliptic leaf shapes are found in small sub group.	D10, D11, D12, D19, D26, D5, D8, F17, F2, F21, F3, F5, S11, S19, S20, S21, S27, S30, S41, S53, S54, S55, S59, S6, S60, S62, S63, S65, S69, SYoug
6	Short, narrow leaves with short petioles. Two subgroups, one with narrow elliptic leaves and one with broad to ovate shaped leaves.	F23, F24, F8, F9, S1, S10, S13, S17, S18, S2. S23, S31, S38, S39, S4, S40, S45, S46, S47, S48, S49, S5, S50, S51, S52, S56, S57, S58, S64, S66, S67, S70, S9
7	Elliptic leaf shape with a high index of LLG/LWT. The leaves are pale, weak twisted with small undulation in the margin. Long petioles and a high root diameter.	D15, N13, N2

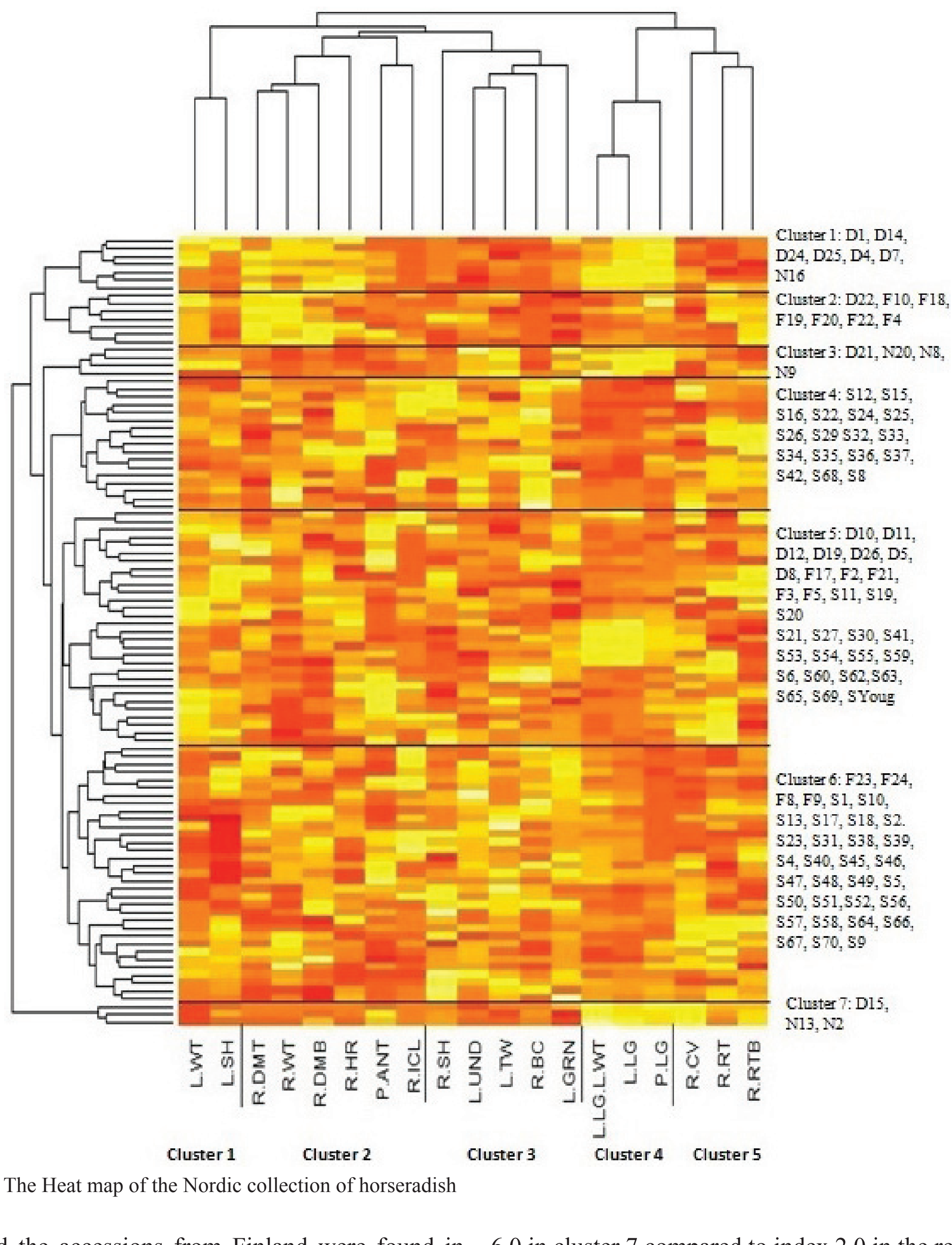

Fig. 1. The Heat map of the Nordic collection of horseradish

7, and the accessions from Finland were found in cluster 2, 5 and 6. The accessions from Sweden were concentrated in clusters 4, 5 and 6. Based on the mean values of the main characters, we could identify patterns in morphology (Table 4). Accessions with long leaves and long petioles were found in cluster 1, 3 and 7. The leaf length/leaf width ratio for the accessions was around 4.0 in cluster 1 and 3, and around 6.0 in cluster 7 compared to index 2.0 in the remaining clusters. For further overviewing, the values of the first two principal components were plotted as arrows in the *biplot* (Fig. 2), which is a graphical presentation of variances and the generalized distances between the individuals. The length of the arrows is a measure of the contribution. The left part of the plot was dominated by accessions from Denmark,

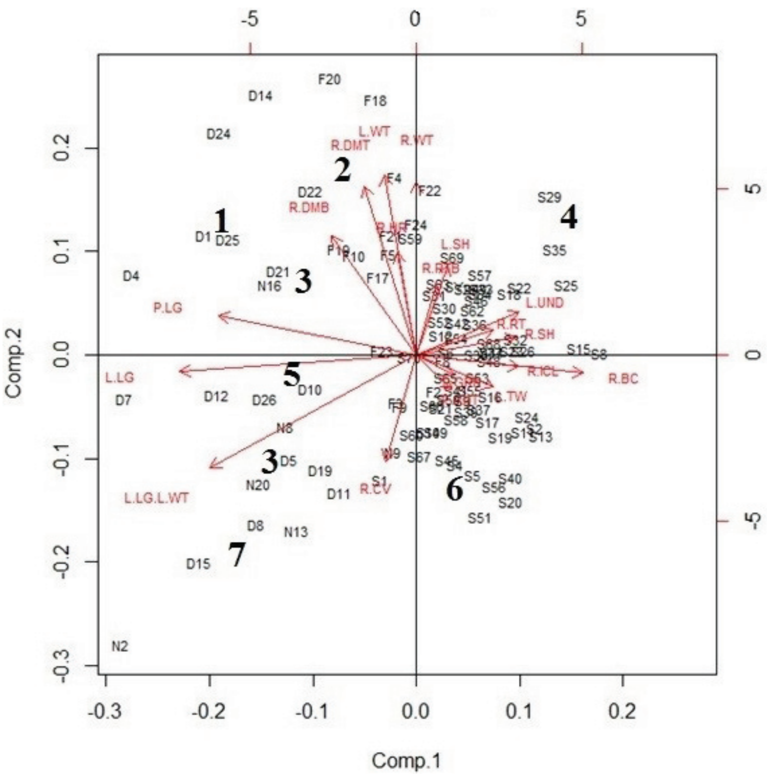

Fig. 2. Biplot of the Nordic collection of horseradish

cf. cluster 1, while the right part was dominated by accessions from Sweden, cf. cluster 4. Accessions from Finland were found close or a little to the left of the component 2 axis, cf. cluster 2. The accessions from Norway were found in between the Danish and Finnish accessions, cf. cluster 1 and 3. The most important contributions of variance to component 1 in the negative direction were L.LG, L.LG.L.WT and P.LG. The corresponding values in the positive directions were L.UND, R.SH, R.ICL and R.BC. The most important contributions to variance component 2 in the negative direction were L.LG.L.WT and R.CV. The corresponding values in the positive direction were L.SH, L.WT, R.DMT, R.DMB, R.WT and R.HR. The first principal component explained 17% of the total variation and the second component further 12% of the variation. The accumulated variation explained by the first seven components was 67%.

The studied accessions included all types of leaf shapes and root shapes, and the descriptors, like the accessions, could be divided into different clusters. The type with long leaves and a high quota for the leaf index was most common, but also types with elliptic and heart shaped leaves were found. A correlation between the studied characters was also found, where the characters were separated in five different clusters. In two clusters, only characters for the leaves were found; Leaf shape and Leaf width in the first cluster and Leaf length, Leaf index (length/width) and Petiole length in the second. The characters for the root were divided in three different clusters, with two clusters containing only root character and one with a combination of leaf and root characters.

DISCUSSION

When characterizing plants, many different factors such as local growth conditions and year, need to be considered. The environmental factors influence plant morphology making it difficult to compare accessions grown at different locations. However, the result from our study showed that the diversity between accessions contributed much more to the general variation than the variation caused by location and different trial years. Thus, the collection of Nordic horseradish accessions investigated in this study covers a high morphological diversity that appears to be stable. We found differences based on geographical origin, since the Swedish accessions were separated from the accessions from the other Nordic countries by using the cluster analysis.

Our results showed that there was a high correlation between some of the studied characters. Therefore, it would be possible to reduce the number of characters in future studies, which would allow characterization of a higher number of accessions to a lower cost and workload. Selecting one or two characters from each of the five identified clusters will still make it possible to divide the accessions in different clusters shown in the heat map (Fig. 1). The characters L.SH, R.HR L.TW, L.LG. L.WT, R.SH, P.ANT and R.CV could be selected in the first place. In addition, the characters P. LG, P.ANT and R.BC could be useful since they appear to be related to the sinigrin, gluconasturtiin and glucobracissin content in the rhizomes.

Wedelsbäck Bladh et al. (2013b) have investigated the correlation between morphological characters and the content of three glucosinolates, i.e. sinigrin, gluconasturtiin, glucobracissin, where the highest correlations, 0.45 and 0.35, have been found between rhizome brown coloration (R.BC) and the two glucosinolates, gluconasturtiin and glucobracissin, respectively. The same study has also found significant correlation between P.ANT and sinigrin content, and between P.LG and glucobracissin content. In the first case, a negative correlation, and in the second case, a positive correlation has been found.

The AFLP marker analysis by Wedelsbäck Bladh et al. (2013a) has also shown a separation between the accessions from different Nordic countries and between subgroups within countries. However, by comparing these two studies, we could not find any correlation between the grouping of the accessions based on morphology and AFLP data, meaning that we found different clustering patterns in the two studies. For conservation issues, the use of molecular data for characterization is a useful complement in order to cover as broad genetic diversity as possible. Also other studies on related *Brassica* crops have shown low or no correlation between molecular marker analysis and morphological studies, e.g. AFLP markers (Qi et al., 2008) and RAPD markers in *Brassica napus* (Fahmi et al., 2012). The results in our studies are in line as well with the study made by Tomsone et al. (2012), where Latvian horseradish accessions have been evaluated according to the phenol content and molecular markers (RAPD analysis). In their study, no correlation has been found between accessions in the clustering within the two different tests (Tomsone et al., 2012). Similar results have been found by Agneta et al. (2014), when Italian horseradish accessions were studied. Glucosinolate concentration and root yield traits do not correlate to AFLP markers since various clustering patterns are found. As suggested by Agneta et al. (2014) and Tomsone et al. (2012), genes involved in determining yield and the GLS concentration are not linked with any of the AFLP markers analysed (Agneta et al., 2014).

Susceptibility to different diseases is an important factor, when selecting accessions for production and conservation. Weber (1949) has found various degrees of resistance to be connected to different leaf shapes, i.e. 'Common' type is more susceptible to white rust and turnip mosaic virus (TuMV) compared to 'Bohemian' type. Knowledge about the susceptibility to diseases among the collected accessions is essential for future conservation and utilization of the Nordic accessions, especially since accession investigated in the study included all types of leaf shapes and it was difficult to identify types as described by Weber (1949) and Rhodes et al. (1965). There were, however, some similarities with the types described by Weber (1949), as the accessions in the clusters 1, 3 and 7 had characters comparable with 'Bohemian' type, long leaves and a high quota for the leaf index. Accessions grouped in cluster 2 were similar to Type II, with slightly crinkled ovate leaves rounded at the base (Rhodes et al., 1965), while accessions of cluster 4 showed equivalence to the type having wide elliptic shaped leaves.

The accessions in the Hungarian study (Oláh, 2012) have been divided in different groups according to leaf shapes, anthocyanin coloration, root shape, etc. Correlations between some of the characters have been found, although the same results were not found in our study. In the Italian study (Sarli et al., 2012), the accessions have been divided into four groups based on leaf and rhizome characters. The first group consists of plants with rhizomes of high weight and high diameter with long broad and dark green leaves. Some similarities were found between accessions in their first group and the accessions in cluster 1 of our investigation. Still, it is difficult to compare the accessions from Hungary and Italy with the accessions from the Nordic countries, although the same UPOV system has been used in the different studies. To map the morphological diversity of horseradish in Europe, a joint study with accessions from different countries needs to be carried out.

In our study, we found differences based on geographical origin: the Swedish accessions differed from the accessions from the other Nordic countries in the cluster analysis. However, the AFLP marker analysis has shown a more clear separation between the accessions from the different Nordic countries, and between subgroups within countries (Wedelsbäck Bladh et al., 2013a).

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MORFOLOGINĖ KRIENŲ (*ARMORACIA RUSTICANA*) CHARAKTERISTIKA ŠIAURĖS ŠALYSE

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Santrauka

Buvo tiriama krienų (*Armoracia rusticana*) 101 kolekcinio pavyzdžio, surinkto senuose Danijos, Norvegijos, Suomijos ir Švedijos soduose, morfologinė įvairovė. Augalų vertinimas buvo vykdomas trejus metus, aprašant 19 požymių, remiantis UPOV TG / 191 / 2–2001 gairėmis. Nepaisant to, kad krienai yra vegetatyviškai dauginami augalai, rezultatai parodė didelius skirtumus tarp tiriamų augalų lapų ir šakniastiebių. Dažniausias morfotipas buvo augalai ilgais lapais, tačiau taip pat buvo aprašyti augalai elipsės ir širdies formos lapais. Tarp augalų nustatyti dideli lapų ilgio / pločio skirtumai. Buvo nustatyti ryšiai tarp augalų pagal jų požymių įvertinimą ir išskirtos penkios jų grupės. Dvi grupės išsiskyrė pagal lapų charakteristiką, o pagal šakniastiebius augalai sudarė tris grupes. Nustatyta koreliacija tarp augalų požymių yra naudinga sumažinant jų skaičių tolesniuose krienų tyrimuose.