ACTA SCIENTIARUM POLONORUM *Acta Sci. Pol., Agricultura 11(1) 2012, 67-77*

COMPARISON OF EDIBLE POTATO CULTIVARS BY MEANS OF SOME METHODS OF MULTIDIMENSIONAL ANALYSIS

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Abstract. Yield and quality characteristics of three potato cultivars, that is Aster, Muza, and Ania, were examined in an experiment conducted in years 1999-2001. Total tuber yield, starch content, dry matter content, and vitamin C content were determined. Data analysis was based on multidimensional methods, that is interprofile analysis and cluster analysis. The levels of both the yield and component contents were different depending on the cultivar and growth conditions. It was confirmed by means of the profile lines of the examined cultivars, which had different courses in each year of study. Coefficients of similarity r_c indicate that the profiles of the cultivars were not similar (comparisons were made between pairs). The most dissimilar were the profiles of Aster and Ania, influenced by the conditions of the 2000 growth season, as well as of Muza and Ania in the year 1999. Cluster analysis revealed that Muza and Ania formed one cluster (were the most similar) in the years 1999 and 2000, and Ania and Aster in the year 2001.

Key words: interprofile analysis, cluster analysis, potato starch, vitamin C

INTRODUCTION

In agricultural science, many measurements are frequently taken of one object, thanks to which it is described in terms of many characteristics. However, only one characteristic is subject to analysis when one-dimensional analysis is used (most often analysis of variance). Multidimensional analyses, which include profile analysis and cluster analysis, offer the possibility to compare the objects studied in terms of all the measurements (characteristics).

Profile analysis encompasses a number of tests which make it possible to examine similarity of profiles. The profile of a multidimensional object is a set of treatment means of individual characteristics. In the chart, the means are joined with lines. An application of this method is limited by a condition: all the variables have to be on the scale of the same range. Thus, the results are frequently transformed into the common scale [Jędrzejczak and Nowaczyk 2006].

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Cluster analysis, based on the variables that describe the objects, aims at sorting different objects into groups (clusters) in a way that the degree of association between two objects is maximal if they belong to the same group and minimal otherwise [Jain *et al*. 1999, Holland 2006, Stanisz 2007].

Studies on edible potato are frequently conducted on several cultivars which are compared with one another in terms of yields and quality. The characteristics that are commonly included in the qualitative assessment of potato tubers are as follows: starch content, dry matter content, and vitamin C content. The above contents are predominantly cultivar-related but may be, to a great extent, modified by agronomical factors and weather conditions during the growth season [Roztropowicz 1989, Bombik and Boligłowa 1994].

Application of multidimensional methods enables the experimenter to compare the tuber quality of the examined cultivars by taking into account all the studied characteristics. The objective of the comparisons is usually to answer the question of whether the studied objects are similar. Profile analysis includes the creation of profiles for the individual cultivars which are then paired, and comparisons between the pairs are made. Similarity coefficient r_c, which indicates whether the profiles are similar or dissimilar, is computed for each pair of profiles [Cohen 1969, Paunonen 1984, Brzeziński 2007, McCare 2008].

The objective of the work was to check the applicability of multidimensional analyses for edible potato studies, in particular for performing a simultaneous assessment of selected cultivars in terms of many characteristics.

The purpose of the assessment was to check if, and to what extent, the examined cultivars were "similar" to each other, the measure of the similarity being the shape of multi-character profiles and type of cluster created. Moreover, due to its methodological attitude, the work aimed at comparing the results by means of two methods: profile analysis and cluster analysis.

MATERIAL AND METHODS

Tubers of three edible potato cultivars, Aster, Muza and Ania, were examined. Aster is a very early edible potato cultivar registered in the year 1990. It is a high-yielding cultivar characterised by medium starch content (about 14.0%). It is suitable for the production of chips, crisps, and dried products. Muza is a high-yielding cultivar of intermediate maturity, registered in 1993, characterized by medium starch content (about 15%). It is used for the production of chips and dried products. Ania is a late edible cultivar registered in 1994, characterised by very high yield potential, high share of marketable tuber yield, and medium starch content (about 14.6%). It is utilized in the industrial production of chips.

Tubers for the analysis were obtained from a three-year (1999-2001) field experiment set up on soil of very good rye complex, quality class IVb. The experiment was located at the Experimental Farm in Zawady (52°06' N; 22°56' E) which is part of the Siedlce University of Natural Sciences and Humanities. The experiment was designed as an arrangement involving the complete confounding of 3^3 interaction, with four repetitions. The design was based on the work by Przybysz [1993]. The methodology of the experiment is presented in detail in the work by Rymuza and Bombik [2004].

As indicated by the Sielianinow's coefficients presented in Table 1, the study period (1999-2001) was characterized by a substantial variation of thermal conditions as well as precipitation distribution and amount.

Table 1. Sielianinow's coefficent values
Tabela 1. Wartości współczynników Sielianinowa (k)

Month – Miesiąc							Mean values for the growth season Średnia dla okresu wegetacyjnego
March marzec	April kwiecień	May maj	June czerwiec	July lipiec	August sierpień	September wrzesień	
				1999			
0.72	2.94	0.66	1.98	0.32	1.34	0.58	1.22
				2000			
1.67	1.23	0.48	0.29	2.64	0.74	1.73	1.25
				2001			
0.77	2.67	0.58	0.70	0.75	0.38	2.98	1.26

$k \leq 0.50$ – strong drought – silna posucha, $0.50 \leq k \leq 0.69$ – drought – posucha, $0.70 \leq k \leq 0.99$ – slight drought – słaba posucha, $k \geq 1$ – no drought – brak posuchy, according to Bac *et al.* [1993] – według Baca i in. [1993]

The assessment of weather conditions of the three growth seasons revealed that the growth season of 2001 was the coldest. Moreover, it was characterized by the greatest precipitation, which was unevenly distributed. The years 1999 and 2000 were much warmer with low precipitation, in May and July in particular.

The examined cultivars were described in terms of the following characteristics: total tuber yield, starch content, dry matter content, and vitamin C content.

In order to check all the variables, they were transformed into the common scale. Following the work by Jędrzejczak and Nowaczyk [2006], the obtained results were converted into the common nine-grade interval scale according to the formula:

$$x'_i = \frac{8\left(x_i - x_{min}\right)}{x_{max.} - x_{min.}} + 1$$

where:

x'_i – value of a characteristic after transformation,

x_i – transformed value of a characteristic,

$x_{min.}$, $x_{max.}$ – the smallest and the greatest values of a characteristic.

An application of the nine-grade scale makes it possible to strengthen it semantically because grade 1 can be described as "a very small value", grade 5 "the medium value", and rank 9 "a very high value" [Dayan 1999].

Values of the transformed mean values of the examined characteristics were statistically analysed. The obtained means were grouped in order to obtain profiles, which were then compared by means of the coefficient of profile similarity r_c using the Cohen's formula [Cohen 1969]:

$$r_c = \frac{\sum_{i=1}^{n} A_i B_i + nm^2 \quad m\left(\sum_{i=1}^{n} A_i + \sum_{i=1}^{n} B_i\right)}{\sqrt{\left(\sum_{i=1}^{n} A_i^2 + nm^2 \quad 2m\sum_{i=1}^{n} A_i\right)\left(\sum_{i=1}^{n} B_i^2 + nm^2 \quad 2m\sum_{i=1}^{n} B_i\right)}}$$

where:

n – number of characteristics in a profile,

m – medium point of the scale,

A_i, B_i – transformed values of the characteristics that comprise the profiles of cultivars A and B under comparison.

Coefficient of profile similarity assumes values that range from -1 to 1. Coefficient value that approaches -1 indicates that the profiles under comparison are increasingly dissimilar. By contrast, the coefficient values approach 1 when the profiles are more and more similar [Paunonen 1984, Brzeziński 2007, Allik *et al*. 2010].

Consecutive pairs of profiles A and B were analysed, that is Ania and Muza, Aster and Ania, and Muza and Ania.

Cluster analysis was conducted using software Statistica 6.0. The analysis yields dendrograms, which illustrate clusters of similar objects. Object grouping was performed with the method of single bond and the Euclidean distance was chosen as a measure of distance. While selecting measures of distance, the authors aimed at obtaining the most useful results [Dubes 1993, Everitt 1980, Everitt *et al*. 2001].

RESULTS

The graphical depiction of the lines that represent the profiles of the examined cultivars indicates that the multi-character profiles of the cultivars differed between one another both in the individual years and over the three-year period (Figs 1-4). The inference is supported by the coefficients of profile similarity r_c (Table 2).

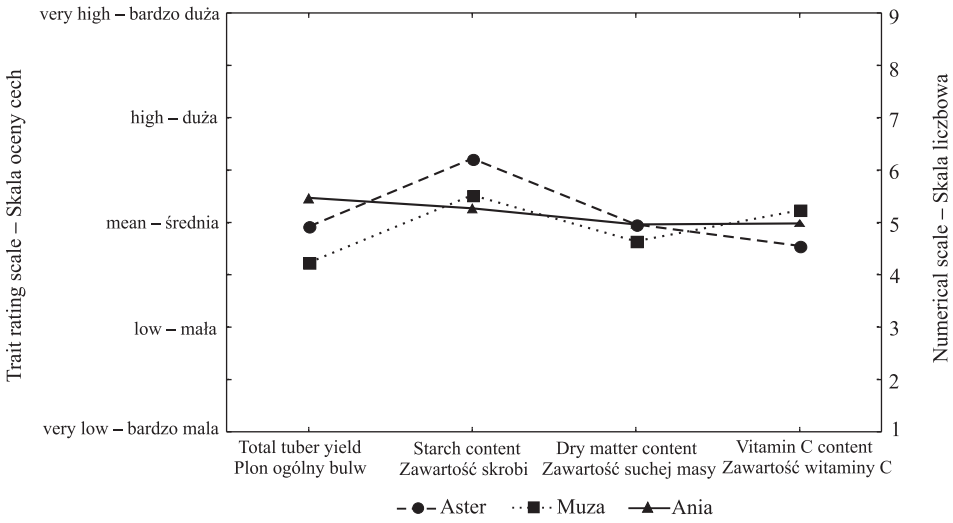

Fig. 1. Profiles of the characteristics of the studied potato cultivars in 1999

Rys. 1. Profile cech badanych odmian ziemniaka w 1999 roku

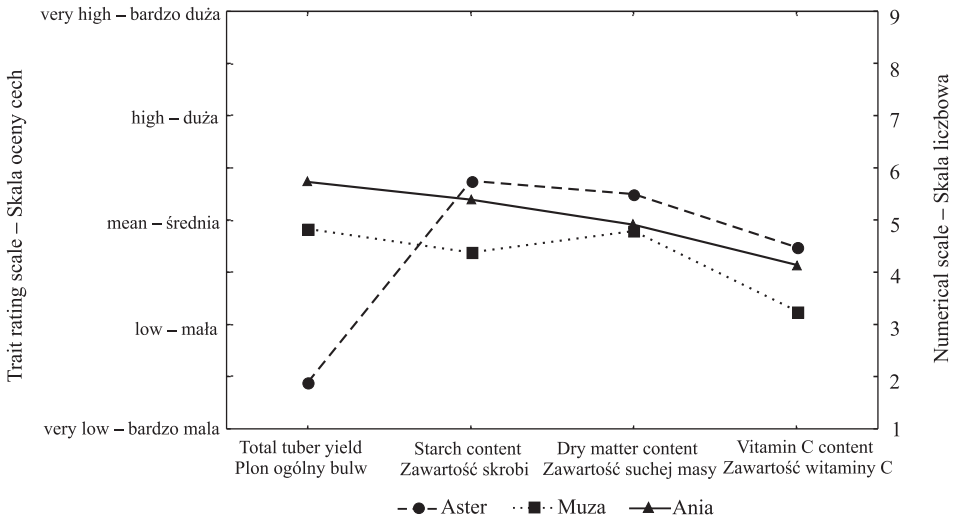

Fig. 2. Profiles of the characteristics of the studied potato cultivars in 2000
Rys. 2. Profile cech badanych odmian ziemniaka w 2000 roku

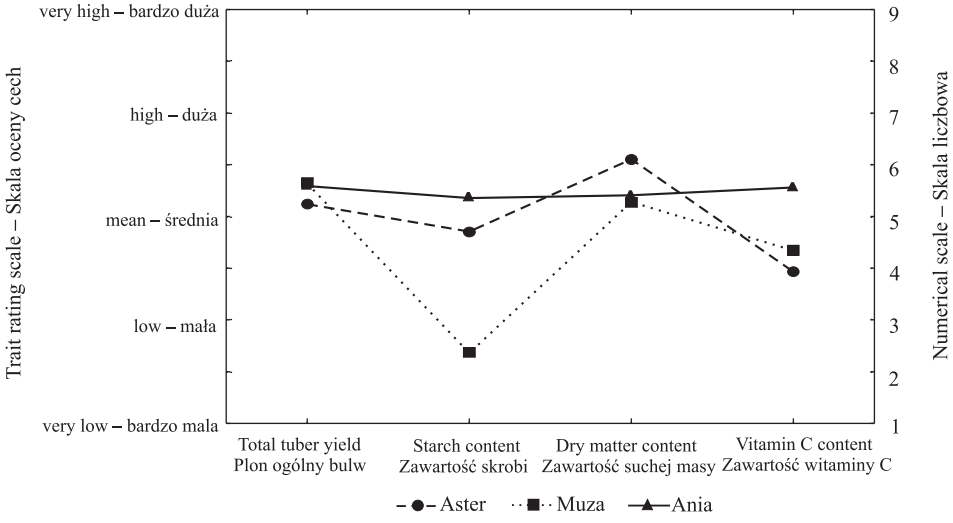

Fig. 3. Profiles of the characteristics of the studied potato cultivars in 2001
Rys. 3. Profile cech badanych odmian ziemniaka jadalnego w 2001 roku

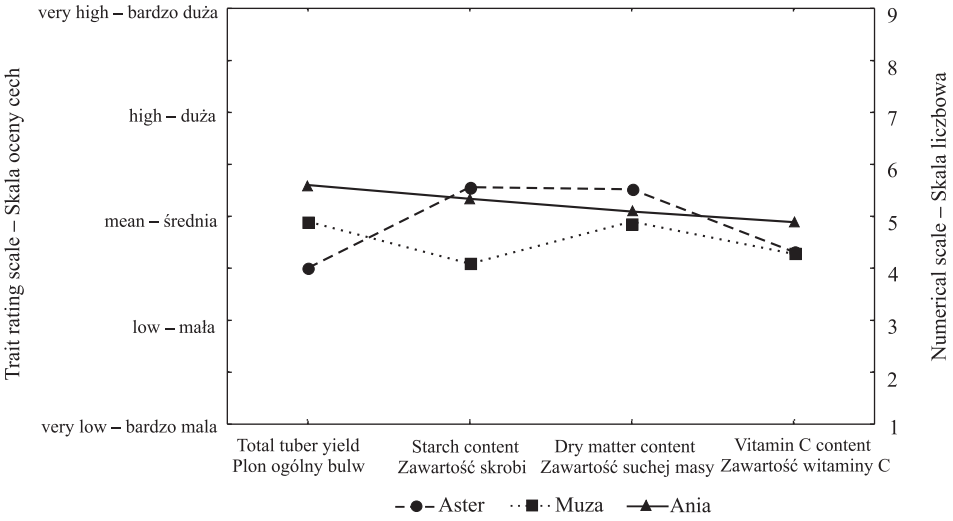

Fig. 4. Profiles of the characteristics of the studied potato cultivars (means for 1999-2001)
Rys. 4. Profile cech badanych odmian ziemniaka (średnia w latach 1999-2001)

Table 2. Values of the coefficients of similarity of profile pairs (rc) of the edible potato cultivars
Tabela 2. Wartości współczynników podobieństwa par profilów (rc) badanych odmian ziemniaka jadalnego

Profile A_iB_i	Year – Rok			Mean values for years 1999-2001 Średnia z lat 1999-2001
	1999	2000	2001	
Aster and Muza	0.45	0.14	0.43	0.01
Aster and Ania	0.42	-0.40	-0.06	-0.28
Muza and Ania	-0.37	0.51	-0.30	-0.37

In 1999, profile similarity of Aster and Muza was observed, as well as of Aster and Ania, the respective coefficients r_c amounting to 0.45 and 0.42, respectively. Values of the characteristics of the examined cultivars fluctuated close to the mean value. Tubers of cultivar Aster were characterised by slightly higher values of starch and dry matter contents, and the total yield compared with Muza. At the same time, values for tuber yield, and dry matter and vitamin C contents were at a similar level in the profile of Aster and Ania. Due to the growth conditions of 1999, the profiles of Muza and Ania were most dissimilar and their similarity coefficient amounted to -0.37. The dissimilarity resulted from differences in tuber yield values, which exceeded the mean value for Ania, whereas for Muza they remained much lower than the mean value. Starch and vitamin C contents in the cultivars were similar (Fig. 1).

The similarity of Muza and Ania in the year 2000 amounted to $r_c = 0.51$ and the values of most characteristics included in the profiles of the cultivars fluctuated around the mean value. Profile similarity of Muza and Aster was small ($r_c = 0.14$). The greatest differences between the profiles were found for tuber yield and vitamin C content. The most dissimilar were the profiles of Aster and Ania. As can be seen in Figure 2, the tuber yield of Aster was at a very low level, whereas for Ania it exceeded the mean value.

In the last year of the study, Ania and Aster, as well as Ania and Muza were quite similar (r_c = -0.06 and -0.30, respectively). By contrast, the profiles of Aster and Muza were similar with the similarity value of 0.43. Figure 3 indicates that Aster and Muza were the most different in terms of starch content. Muza accumulated small amounts of starch, whereas the amounts accumulated by Aster were close to the mean value.

As shown in Figure 4, the profiles of the examined cultivars differed substantially between one another over the three-year period, which is reflected in the values of coefficients r_c indicating very small similarity of Aster and Muza profiles (0.014), and the dissimilarity of Ania and Aster as well as Ania and Muza profiles, whose coefficients r_c amounted to -0.28 and -0.37, respectively. Values of tuber yield and vitamin C content for Ania were higher in comparison with the remaining cultivars.

Comparison of cultivars by means of cluster analysis indicates that over the period of the years 1999-2001, Ania and Muza were similar cultivars. They formed a cluster as far as tuber yield and vitamin C content were concerned. The cultivars differed from Aster, which was assigned to the second cluster (Fig. 5, Table 3).

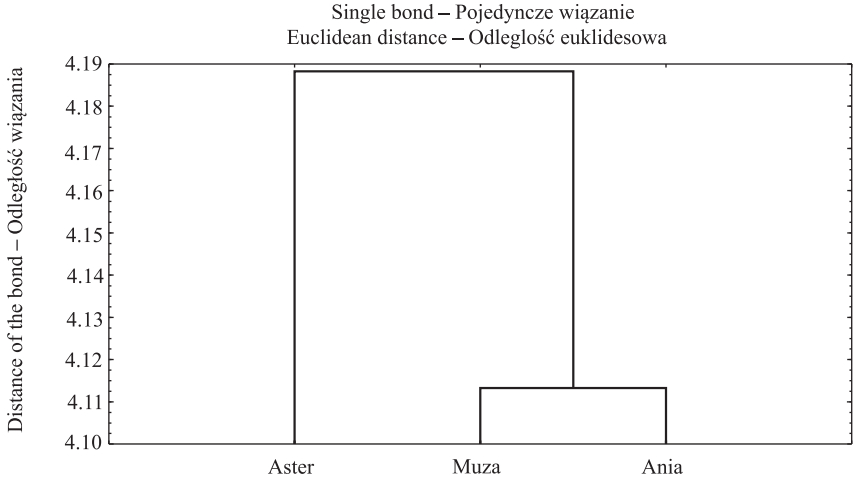

Fig. 5. Tree diagram for the cultivars studied over the three-year period (1999-2001), including values of the studied characteristics

Rys. 5. Diagram drzewa dla badanych odmian w trzyleciu (1999-2001) z uwzględnieniem wartości badanych cech

In 1999, the values of the examined characteristics for Ania and Aster placed them in one cluster. The second cluster included Muza, which had a lower tuber yield and higher dry matter content (Fig. 6, Table 3).

Table 3. Values of the characteristics of the potato cultivars studied in years 1999-2001
Tabela 3. Wartości cech badanych odmian ziemniaka w latach 1999-2001

Year Rok	Tuber yield Plon bulw $t \cdot ha^{-1}$	Starch content Zawartość skrobi %	Dry matter content Zawartość suchej masy %	Vitamin C content Zawartość witaminy C mg%
		Aster		
1999	32.6	14.8	21.3	21.4
2000	31.9	14.2	22.5	23.9
2001	28.3	12.7	19.3	20.2
Mean Średnia	30.9	14.5	21.0	21.8
		Muza		
1999	28.9	15.0	22.9	22.2
2000	36.3	14.6	21.2	22.1
2001	35.9	13.5	20.9	22.0
Mean Średnia	33.7	14.2	21.7	22.1
		Ania		
1999	35.2	14.5	21.4	24.5
2000	41.9	14.9	22.4	24.2
2001	28.0	13.4	19.4	21.9
Mean Średnia	35.0	14.3	21.0	23.5

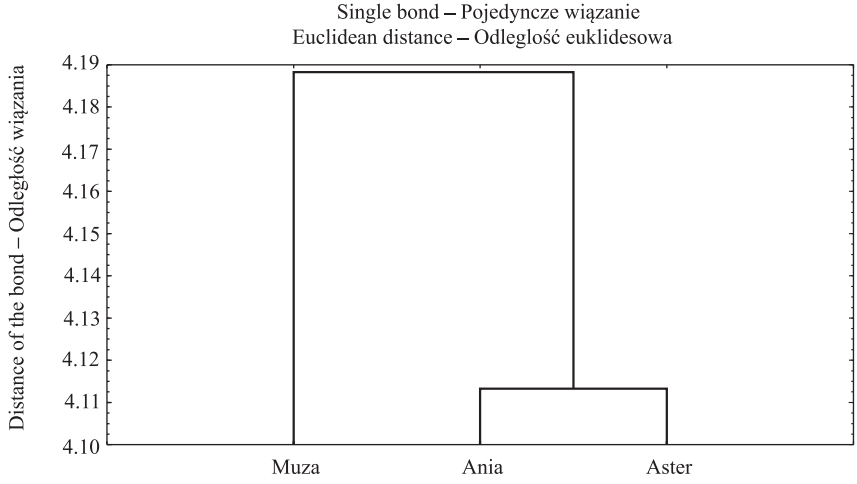

Fig. 6. Tree diagram for the cultivars studied in 1999, including values of the studied characteristics
Rys. 6. Diagram drzewa dla badanych odmian w 1999 roku z uwzględnieniem wartości badanych cech

Cluster analysis demonstrated that in the year 2000 Muza and Aster formed one group so they were the most similar. The cultivars produced lower tuber yields and accumulated more starch in tubers compared with Ania, which formed the second cluster (Fig. 7, Table 3).

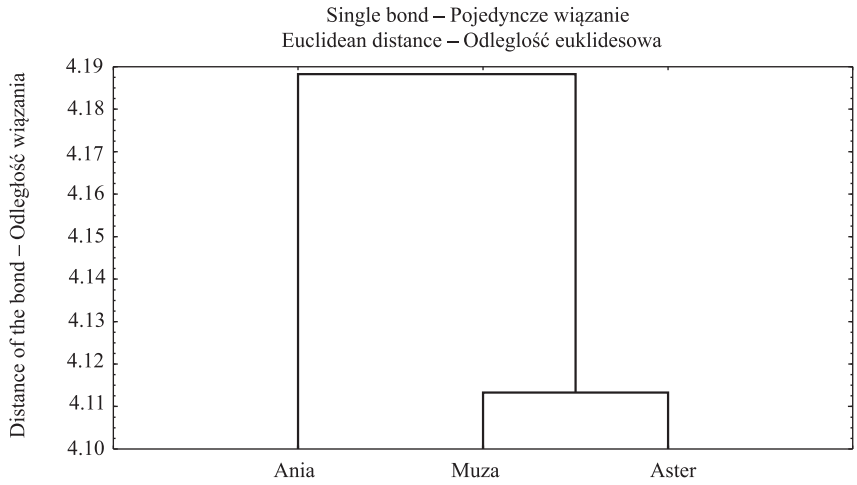

Fig. 7. Tree diagram for the cultivars studied in 2000, including values of the studied characteristics

Rys. 7. Diagram drzewa dla badanych odmian w 2000 roku z uwzględnieniem wartości badanych cech

Due to the growth conditions of the last year of study, Aster and Ania formed one cluster, like in 1999. The cultivars produced low yields, compared with Muza, which probably resulted in them forming one cluster (Fig. 8, Table 3).

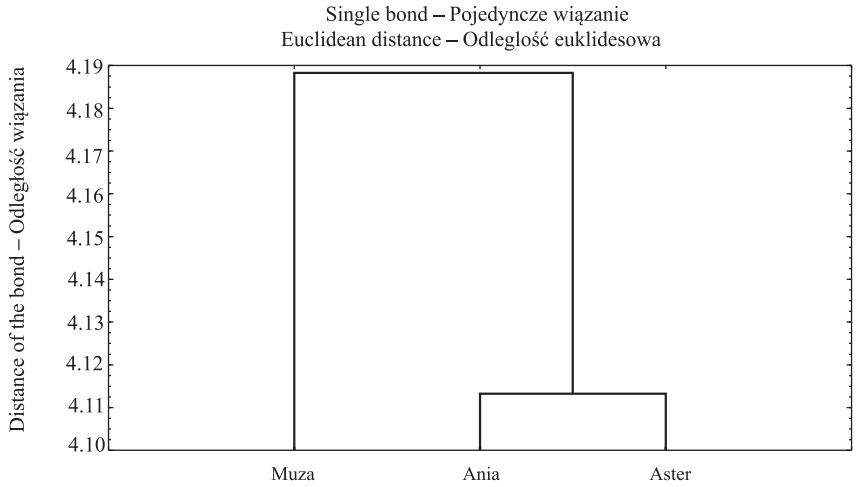

Fig. 8. Tree diagram for the cultivars studied in 2001, including values of the studied characteristics

Rys. 8. Diagram drzewa dla badanych odmian w 2001 roku z uwzględnieniem wartości badanych cech

CONCLUSIONS

Multidimensional analyses make it possible to compare objects with respect to many attributes at a time. As a result, they can be applied in the studies on edible potato. Studies of this kind quite often include the evaluation of tuber quality of specific cultivars in terms of several or more characteristics (for example starch content, dry matter content, as well as vitamin C content).

The results obtained in the profile analysis, or more precisely the treatment means of the characteristics (after transformation aimed at making them comparable) are placed in a chart and linked with lines to obtain profiles. What is produced is a graphic and clear form of presentation of the results. It is the unquestionable advantage of such analysis. Other advantages include description which can be applied following the transformation of data into a common interval scale. The comparison of only two profiles (cultivars) is the disadvantage of the method.

The basic idea of cluster analysis is to divide objects into a number of groups of "similar" objects which, at the same time, are not similar to the objects that belong to the remaining groups. The analysis yields a graphical presentation of data, which clearly shows individual clusters and their objects.

The analyses conducted in the present study demonstrated that the examined cultivars were more or less different from each other, the differences being, to a great extent, influenced by the growth conditions. The profile analysis showed that the most similar were the profiles of Aster and Ania in 2000, Muza and Ania in 1999, and Aster and Muza in 2001.

Moreover, the cluster analysis indicated that Ania and Aster were similar in 1999 and 2001, Muza and Aster in 2000, and Muza and Ania over the whole three-year period.

Profile charts and cluster dendrograms were undoubtedly influenced by the fact that the cultivars assessed in the study were, as had been assumed while selecting the experimental design, characterised by different growth periods (very early Aster, intermediate Muza, and late Ania) as well as genetically-conditioned, and thus different, rate of nutrient uptake.

The results demonstrated in the present work refer to potato cultivars which are not extensively cultivated; some of them (for example Ania) have been excluded from the Register of Cultivars. However, selection of cultivars was not that important as the work is methodological.

REFERENCES

Allik J., Realo A., Mõttus R., Kuppens P., 2010. Generalizability of self-other agreement from one personality to another. Pers. Ind. Diff. 48,128-132.

Bac S., Koźmiński C., Rojek M., 1993. Agrometeorologia [Agrometeorology]. PWN Warszawa [in Polish].

Bombik A., Boligłowa E., 1994. Zmienność cech jakości ziemniaka jadalnego spowodowana nawożeniem dolistnym [Variability of the quality traits of edible potato caused by in-leaf fertilization]. Fragm. Agron. 2, 52-57 [in Polish].

Brzeziński J., 2007. Analiza interprofilowa [Interprofile analysis]. [In:] Metodologia badań psychologicznych [Psychological studies methodology], PWN Warszawa, 559-574 [in Polish].

Cohen J., 1969. A profile similarity coefficient invariant over variable reflection. Psych. Bull. 47(5), 1074-1090.
Dayan A., 1999. Skale odczuć [Sense scale]. [In:] Badania rynku [Market studies], Assimil Kraków, 79-85 [in Polish].
Dubes R.C., 1993. Cluster analysis and related issues. [In:] Handbook of Pattern Recognition & Computer Vision, Word Scientigic Publishing London.
Everitt B.S., 1980. Cluster analysis. Qual. Quant. 14(1), 75-100.
Everitt B.S., Landau S., Leese M., 2001. Cluster analysis. 4th ed., Arnold London.
Holland S.M., 2006. Cluster Analysis. Department of Geology, University of Georgia Athens.
Jain K.A., Murty M.N., Flynn P.J., 1999. Data clustering: a review. ACM Computing Surveys (CSUR) New York, USA, 31, 264-323.
Jędrzejczak E., Nowaczyk L., 2006. Zastosowanie analizy interprofilowej w badaniach hodowlanych papryki rocznej (*Capsicum annuum* L.) [Application of interprofile analysies in breeding studies of annual capsicum (*Capsicum annuum* L.)]. Coll. Biom. 36, 159-170 [in Polish].
McCare R.R., 2008. Note on some measures of profile agreement. J. Pers. Psych. 91(1), 111-123.
Paunonen S.V., 1984. A note on Cohen's Profile Similarity Coefficient r_c. J. Class. 1, 125-131
Przybysz T., 1993. Planowanie i analiza statystyczna wieloczynnikowych doświadczeń nawozowych [Planning and statistical analysis of multifactor fertilization experiments]. Zesz. AR w Krakowie, Sesja Nauk. 37, 391-405 [in Polish].
Roztropowicz S., 1989. Środowiskowe, odmianowe i nawozowe źródła zmienności składu chemicznego bulw ziemniaka [Environmental, cultivar, and fertilization sources of the chemical composition variability of potato tubers]. Fragm. Agron. 1, 35-75 [in Polish].
Rymuza K., Bombik A., 2004. Plonowanie wybranych odmian ziemniaka jadalnego w zależności od dawki nawozów mineralnych i przedplonu [Yield of chosen edible potato cultivars depending on mineral fertilization doses and forecrop]. Fragm. Agron. 1(81), 56-68 [in Polish].
Stanisz A., 2007. Przystępny kurs statystyki z zastosowaniem STATISTICA PL na przykładach z medycyny. T. 3. Analizy wielowymiarowe [Approachable statistics course with the use of STATISTICA PL on medical examples. Vol. 3. Multidimensional analyses]. StatSoft Kraków, 113-161 [in Polish].

PORÓWNANIE ODMIAN ZIEMNIAKA JADALNEGO Z WYKORZYSTANIEM NIEKTÓRYCH METOD ANALIZY WIELOWYMIAROWEJ

Streszczenie. W eksperymencie przeprowadzonym w latach 1999-2001 badano plonowanie oraz cechy jakościowe bulw trzech odmian ziemniaka: Aster, Muza i Ania. Oznaczono plon bulw ogółem i plon skrobi. Z cech jakościowych określono: zawartość skrobi, zawartość suchej masy oraz zawartość witaminy C. Analizę danych oparto na metodach wielowymiarowych, tj. na analizie interprofilowej oraz analizie skupień. Wykazano, że metody te pozwalają na porównanie odmian ziemniaka jadalnego pod względem ich jakości, w przypadku, gdy analizowanych jest wiele cech jednocześnie. Analiza profilowa wykazała, że najbardziej podobne były odmiany: Aster i Muza z sezonu wegetacyjnego 1999 i 2001 oraz odmiany: Muza i Ania z 2000 roku. Analiza skupień wykazała natomiast podobieństwo odmian Muza i Aster w roku 1999 i 2000 oraz odmian Ania i Aster w 2001 roku.

Słowa kluczowe: analiza interprofilowa, analiza skupień, skrobia ziemniaka, witamina C

Accepted for print – Zaakceptowano do druku: 05.03.2011