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Phenotypic proximity and remoteness of seedless vine varieties depending on their ampelographic characteristics

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Abstract: The degree of the phenotypic similarity and differences between 61 seedless vine varieties was studied by grouping them according to economically important phenological, agrobiological and technological indicators. A multidimensional statistical approach is applied – a cluster analysis, which provides possibilities of establishing relatively homogeneous groups (clusters), based on a set of certain indicators. As the cluster analysis does not perform any tests for the statistical significance of the results, it is combined with a factor analysis, which provides information on the reasons leading to the distribution of the individual varieties in different clusters and the merging of others into one cluster. The applied factor analysis transformed all the studied indicators into seven main components, explaining 76% of the total variance. The transformation of these traits to the corresponding number of factors and the indicators in them, which explain that the varieties belong to the separate clusters, was established. The limits of the phenotypic similarity and differences between the studied seedless vine varieties and the conditional parameters of the polymorphism with their economically significant ampelographic characteristics were determined. The presented grouping can be used for taxonomic purposes, as well as in the selection to create new seedless vine varieties. By applying targeted agro-technical measures, the desired change in the indicators of the first and second factors in the individual groups of traits can be actively influenced.

Keywords: seedless vine varieties; phenological; agrobiological; technological ampelographic indicators

There are more than 100 seedless varieties of vines in the world, which are characterised by various agrobiological and technological characteristics. Most of them are newly created hybrids between seed dessert and seedless varieties having complex pedigrees. This large polymorphism often complicates the economic and ampelographic classification of this group of varieties having great economic importance (Al-Obeed et al. 2010; Correa et al. 2014; Ilnitskaya et al. 2019; Roychev 2019).

Grapes are of great economic importance and are cultivated on a large scale (Hussein et al. 2022). They are considered among the most important and most widespread fruits in Iraq and the world, where they can be grown in various types of soils, including sandy soils, fertile soils, and soils of little depth.

The Eurasian grapevine (*Vitis vinifera L.*) is the most widely cultivated and economically important horticultural crop in the world (Eyduran et al. 2015). The present results illustrate that the historical table

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grape cultivars grown in Turkey contained diverse and valuable sugars, organic acids, phenolic acids, vitamin C and demonstrated that they have an important antioxidant capacity for human health benefits.

The sultana grapevine (*Vitis vinifera L.*) is one of the most important commercial seedless table-grape varieties and the main source of seedlessness for breeding programmes around the world (Costenaro-da-Silva et al. 2010).

For the objective study of the phenotypic variability, mathematical and statistical methods have long been applied in viticulture and vine selection, which, depending on the environment and purpose, cover and analyse a huge number of varieties and traits (Roychev 2011; Joshi et al. 2015; Andras-Sauca et al. 2018; Barreales et al. 2019; Letchov et al. 2021).

The combined application allows obtaining more in-depth ampelographic information about the nature and significance of the individual indicators in the grouping of gthe enotypes, and the selection of elite hybrid forms should be carried out based on the traits that explain the largest extent of the general variation (Roytchev 2007). Preliminary information on the phenotypic remoteness or proximity of different vine varieties increases the efficiency in the selection of parental pairs for sexual hybridisation in the creation of new vine varieties.

Several publications are known in which the application of mathematical methods analysed the complex correlations between the ampelographic indicators of seed and seedless vine varieties (Boselli et al. 2000; Coelho et al. 2004; Gris et al. 2010; Leão et al. 2011; Baiano, Terracone 2011; Atak et al. 2012; Ibacache et al. 2016; Zhang et al. 2017; Kaplan et al. 2019; Roychev et al. 2020).

The aim of this study is to group seedless vine varieties according to the parameters of their economically important agrobiological characteristics and to present opportunities for the use of their phenotypic proximity and remoteness in the ampelography, selection work, intraspecific classification and in solving practical problems.

MATERIAL AND METHODS

The experimental work included 61 seedless varieties of vines, in the full fruiting stage, grown in the selection range of the Agricultural University-Plovdiv. For five consecutive years, three groups of ampelographic indicators were determined for each variety: phenological (phases and periods – days) – budding, flowering, veraison (grape softening), grape growth, budding – flowering, flowering – veraison (softening), veraison (softening) of the grape – technological maturity, budding – technological maturity; agrobiological – developed eyes (%), fruiting shoots (%), fertility rate, average yield from the vine (kg), average yield per decare (kg); technological – average weight of a bunch (g), length of a bunch (cm), width of a bunch (cm), bunches (%), grapes (%), skins (%), mesocarp (%), average weight per 100 grapes (g), grape length (mm), grape width (mm), sugars (%), acids (g/dm^3), grape detachment (g), grape pressure resistance (g) (Roychev 2012). All the studied phenological indicators included five repetitions; the indicators from the other groups included 25 repetitions, they are assigned to 25 individual vines. The average values of each variety for each indicator are presented in Tables 1–3.

A multidimensional statistical approach was applied – a cluster analysis, which provided possibilities to establish relatively homogeneous groups (clusters), based on a set of certain indicators, which was performed using the Ward agglomeration method, and the measure of similarity in the intergroup bonding used the quadratic Euclidean distance.

The dendrogram obtained through it has clearly differentiated clusters. The divergence coefficient is higher than that of the other clustering methods. The data are pre-standardised. As the cluster analysis does not perform any tests for statistical significance of the results, it is combined with a factor analysis, which provides information on the reasons leading to the distribution of the individual varieties in the different clusters and the merging of others into one cluster. Through it, the studied indicators are reduced to factors that correlate with each other and it is determined which of the idicatiors have the strongest influence on the clustering (Landau, Everitt 2004).

In the present study, the factor analysis was performed by the principal components analysis (PCA) as the experimental data satisfied the Bartlett Test of Sphericity (< 0.05) and the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (> 0.5), as the determinant of the correlation matrix is a positive number. The factor matrices for the individual groups of indicators were obtained by the method of the main components and the rotation of the Varimax factors. The statistical software IBM Statistics SPSS 25 (Field 2013) was used to process the statistical data.

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Table 1. Agrobiological indicators of the seedless vine varieties

No.	Name	Developed eyes (%)	Fruiting shoots (%)	Fertility rate	Average yield per vine (kg)	Average yield per decare (kg/dka)
1	Russalka	82.076	85.54	1.45	8.6058	2 544
2	Ranno bez seme	65.12	68.024	1.194	3.3968	1 256.6
3	Flame seedless	81.196	83.266	1.328	8.4154	2 083.4
4	Russalka 3	73.314	85.548	1.348	6.2048	1 730
5	Kishmish moldavski	84.886	61.578	0.746	6.0488	1 648.6
6	Trakyska perla	76.792	71.604	1.274	6.2718	1 843.8
7	Russensko seedless	81.476	69.358	0.86	3.8466	1 360.4
8	Kishmish luchistii	85.618	73.486	1.022	5.1502	1 439.6
9	Kondarev 10	61.742	64.502	0.94	7.5592	1 811
10	Kondarev 6	66.18	70.402	0.914	8.4126	2 024
11	Bialo drebno bez seme	82.264	67.462	0.676	5.267	1 444.2
12	Russalka 1	78.738	57.228	0.752	6.4758	1 771.8
13	Vita	80.384	90.716	1.154	6.594	1 616.6
14	Nedelchev VI-4	72.072	52.884	0.636	5.804	1 608
15	Vanessa seedless	81.47	70.592	1.134	4.7186	1 329.4
16	Zornitsa	76.71	72.532	1.148	4.5486	1 605.2
17	Tangra	68.274	65.356	1.14	7.4298	1 806.4
18	Ruby seedless	80.616	78.676	1.068	7.5398	2 721.6
19	Beauty seedless	85.846	63.236	0.856	4.7484	1 288.6
20	Dilight	77.496	74.328	1.242	5.2112	1 504.2
21	Hybrid 720-19	63.242	69.808	0.81	6.244	1 727.4
22	Kishmish Hyshrau	79.76	32.34	0.53	3.5408	927.8
23	Hybrid V-6	60.014	40.084	0.598	6.202	1 710.2
24	Slavyanka	55.272	33.124	0.556	4.738	1 371.8
25	Corinth seedless	86.682	52.08	0.392	4.7642	1 277
26	Thompson seedless	80.8	63.832	0.662	5.0638	1 395.6
27	Early superior seedless	78.178	29.21	0.3	2.5296	824
28	Hybrid 23-4	84.26	69.47	1.132	3.993	1 013.8
29	Raucha biala	70.498	56.362	0.774	4.3142	1 467
30	Early kishmish	61.604	59.698	0.81	3.1864	1 122.2
31	Superior seedless	73.484	31.642	0.368	3.9168	1 374.8
32	Rusbol	91.438	87.22	1.476	4.3892	1 527.8
33	Jangier	85.432	72.574	0.854	4.5	1 588
34	Perlette	83.162	60.738	1.098	4.5156	1 579.4
35	Corinth black	85.772	84.416	1.446	4.8234	1 720.8
36	Russalka 2	72.226	62.95	1.338	8.9262	2 041.2
37	Russalka 3A	71.544	75.252	1.3	7.87	2 066
38	Rushaky	72.7	70.614	1.006	4.4282	1 522
40	Kishmish Irtishor	65.894	68.564	0.98	6.8744	2 033.2
41	Kishmish black	60.602	68.498	0.554	3.7214	1 390.4
42	Korsa kishmish	70.776	63.032	0.976	4.4438	1 337
43	Hybrid 36-16	83.332	62.91	0.98	9.1332	941.235
44	Sultanina	72.264	68.016	0.68	3.907	1 407.6

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Table 1 to be continued

No.	Name	Developed eyes (%)	Fruiting shoots (%)	Fertility rate	Average yield per vine (kg)	Average yield per decare (kg/dka)
45	Corinth white	82.772	86.604	1.47	7.2374	2 147
46	Askery	68.234	76.55	0.914	3.0968	1 095
47	Nimrang × Sultanina	80.372	65.41	0.952	4.1966	1 516.6
48	Italia × Sultanina	78.754	77.92	1.096	4.8712	1 513.8
49	Kishmish VIRA	84.48	65.604	0.874	4.4576	1 609
50	Kishmish Vatkana	78.404	62.886	0.956	4.16	1 523.8
51	Nishava	67.544	65.866	1.07	5.1736	1 728.2
52	Red seedless	77.086	60.672	0.602	4.515	1 649
53	Tarnow	64.056	64.516	0.89	4.1872	1 458.2
54	Hybrid 21-17-41	60.362	72.518	0.94	5.5606	1 777.2
55	Kolarovets	78.116	68.762	1.286	8.6786	2 606.4
56	Russalka 5A	76.626	72.944	1.236	7.2288	2 585.6
57	Sultana muscata	74.882	63.254	0.778	4.1182	1 325.2
58	Gigant	86.09	65.316	0.848	6.5656	2 119
59	Focha seedless	58.968	62.838	1.152	4.7938	1 720.2
60	Sultanina gigas	78.2	65.944	0.752	6.3488	2 034.6
61	Russalka 5B	81.028	73.158	1.146	5.962	1 995
Average		75.323	66.34	0.959	5.544	1 632.863

Table 2. Phenological indicators of the seedless vine varieties (in days)

No.	Name	Budding	Flowering	Veraison	Grape-growth	Budding – flowering	Flowering – veraison	Veraison – technological maturity	Budding – technological maturity
1	Russalka	6.2	5.4	5.8	40	68.2	44.6	29.2	131.2
2	Ranno bez seme	7.6	10.6	10.4	32	70.8	51.8	31	132
3	Flame seedless	5.6	7.2	14.8	35.2	61.2	56.6	42.2	137.4
4	Russalka 3	6	7	8	44.2	65.6	57.8	33.8	142.8
5	Kishmish moldavski	7.2	6	10.6	40.2	67.8	44.4	33	141
6	Trakyska perla	7.6	7.4	7.2	56.6	67	73.2	36	162.6
7	Russensko seedless	7	13	8.4	47.6	65	67.8	42.4	153.4
8	Kishmish luchistii	10.8	8.6	11.4	52	58.2	71.8	43.6	153.8
9	Kondarev 10	5.8	14.8	13.8	43.6	64.8	72.4	44	153.4
10	Kondarev 6	7.2	15.2	10.8	52.6	66	75.6	37	153.8
11	Bialo drebno bez seme	7.2	8.2	8	47	56.4	64.6	54.4	156.8
12	Russalka 1	8.4	6.2	7.8	54.4	67.4	63.8	46.6	167.4
13	Vita	5.6	8.4	8	53.6	60.4	67.6	47	159
14	Nedelchev VI-4	8.2	5.6	11.2	48.6	67.4	64.4	44.4	161.8
15	Vanessa seedless	6.8	8.6	11.4	64.8	54.6	55	42.6	162.6
16	Zornitsa	7.6	9.4	11.2	56.2	65	75.8	47.2	167
17	Tangra	7.8	6.6	13.4	56.6	62.8	74.8	58	174.6
18	Ruby seedless	6	14.4	12.6	45.2	68.2	68.2	65.2	175.8
19	Beauty seedless	7.4	5.4	7.4	44	70.4	40.8	28.2	128.8
20	Dilight	6.2	5	7.2	45	61	45.8	23.8	130.2

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Table 2 to be continued

No.	Name	Budding	Flowering	Veraison	Grape-growth	Budding – flowering	Flowering – veraison	Veraison – technological maturity	Budding – technological maturity
21	Hybrid 720-19	7	5.6	6.8	48.4	63.4	45.6	20.4	132.6
22	Kishmish Hyshrau	7.4	6.2	7.4	52.8	61	50	31	143.6
23	Hybrid V-6	6.6	5.4	8	62.4	61.4	59.6	34.2	157
24	Slavyanka	7.4	5.6	7.8	59.6	59.2	54.4	38.2	152.4
25	Corinth seedless	5.6	6.6	7.8	60.8	67.6	58.8	39	158.4
26	Thompson seedless	6.4	6.4	8	54.6	58.4	52.8	51.8	160.6
27	Early superior seedless	5.8	8	7.4	42.8	57.4	44.2	24.6	116.6
28	Hybrid 23-4	6.2	7.2	11.6	53.6	53.8	56.8	39.6	150.2
29	Raucha biala	5.8	10.2	8.8	42.2	53.2	43.6	33.8	134.2
30	Early kishmish	6.4	9.6	10.4	43.6	58.6	42.2	30	131.4
31	Superior seedless	6	7	14.4	41.4	57	44	37.2	134
32	Rusbol	7.4	10.4	9.6	64.2	55.8	41	28	152.2
33	Jangier	5.8	10.8	8.4	63.8	52.2	40.8	28.2	146.6
34	Perlette	6.2	12.8	17	55	55.8	48	45	148.2
35	Corinth black	6.6	10.6	8.6	63.6	46.8	65.4	32.6	153.6
36	Russalka 2	6.2	13	17.6	54.8	52	51.4	46.6	147.4
37	Russalka 3A	6.6	8.4	10.2	59.8	58	58.6	36.2	150.2
38	Rushaky	5.8	8.4	11.6	55.6	53.6	53.2	42.8	150.4
39	Kishmish tjurkmenski	5.8	15.8	19	51.8	51.4	49.4	47	148.2
40	Kishmish Irtishor	5.6	8.8	12.6	55.8	56.6	54.6	39.2	147.4
41	Kishmish black	5.8	10.4	15.4	59.4	54.4	59	38.6	152.8
42	Korsa kishmish	6.6	10.4	13	58.8	56.4	58.4	40.8	152.8
43	Hybrid 36-16	6.4	11	9.6	61	55.2	39.8	34.4	154
44	Sultanina	7.4	11.2	12	57	50.8	61.6	40.6	148.2
45	Corinth white	7	10.8	10	62	51	62.6	33.6	145.6
46	Askery	6	7	8.8	64.4	61.2	56.2	37.8	154.6
47	Nimrang × Sultanina	6.4	12.2	9.8	54.2	58.8	56	43.4	156
48	Italia × Sultanina	6.8	13.6	13.8	62.2	56	60.2	34	156.8
49	Kishmish VIRA	5.6	13	13.4	60.4	59	58.6	43.8	159.6
50	Kishmish Vatkana	6	12	13.2	60.6	58.4	56	44	157.2
51	Nishava	8.6	9.8	11.2	55.6	60.2	52.6	43.8	156.4
52	Red seedless	6.6	14	14.2	58	58.6	57.8	44	158.2
53	Tarnow	7.8	7.8	10.6	56	56.4	53.8	44.2	150.6
54	Hybrid 21-17-41	7.2	13.2	9.6	57	50.4	60	41	149.8
55	Kolarovets	7.8	11.4	11.2	62.4	51.8	55.6	40.4	166.6
56	Russalka 5A	6.4	14	14.8	66.2	55.2	66.8	39.4	162
57	Sultana muscata	8	10	16	53.2	56	47.2	58.4	165
58	Gigant	7.8	8.6	8.8	68.8	70.2	70.8	38	179
59	Focha seedless	7.8	7.2	8.2	64	40.8	68.4	38.8	176.6
60	Sultanina gigas	7.2	13.8	14.6	66.6	56.8	67.8	43	176.4
61	Russalka 5B	6.4	14.8	15.4	68.6	54.8	68.8	45.2	166.4
Average		6.79	9.61	10.92	54.47	58.91	57.20	39.71	152.54

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Table 3. Technological indicators of the seedless vine varieties

No.	Name	Average mass of bunch (g)	Length of banches (cm)	Widht of bunches (cm)	Bunches (%)	Grapes (%)	Skins (%)	Mesocarp (%)	Average mass of 100 grapes (g)
1	Russalka	389.20	19.36	13.80	2.29	97.71	3.41	96.59	209.60
2	Ranno bez seme	257.20	16.94	13.04	2.01	97.99	8.17	91.83	217.40
3	Flame seedless	281.60	21.28	12.00	2.42	97.58	9.55	90.45	216.80
4	Russalka 3	438.80	19.62	14.66	2.56	97.44	6.66	93.34	452.60
5	Kishmish moldavski	356.80	21.98	12.86	2.54	97.46	6.80	93.20	343.60
6	Trakyska perla	472.00	23.74	15.20	4.41	95.59	4.92	95.08	192.60
7	Russensko seedless	286.40	16.04	11.26	3.40	96.60	6.74	93.26	320.60
8	Kishmish luchistii	354.40	21.10	12.46	2.98	97.02	5.79	94.21	256.80
9	Kondarev 10	906.00	23.58	15.18	1.91	98.09	6.48	93.52	506.80
10	Kondarev 6	892.60	25.82	16.54	2.15	97.85	6.12	93.88	460.40
11	Bialo drebno bez seme	362.20	18.00	12.48	2.40	97.54	7.29	92.71	337.20
12	Russalka 1	711.00	20.38	14.66	2.45	97.55	5.55	94.45	812.00
13	Vita	168.80	19.04	9.18	2.39	97.61	7.67	92.33	245.40
14	Nedelchev VI-4	557.00	21.38	12.52	1.96	98.04	5.57	94.43	519.40
15	Vanessa seedless	175.00	13.80	8.20	2.44	97.56	9.74	90.26	176.00
16	Zornitsa	399.00	22.98	11.98	2.00	98.00	3.94	96.06	429.20
17	Tangra	409.60	19.00	13.68	2.39	97.61	6.75	93.27	553.60
18	Ruby seedless	769.20	27.82	14.70	1.33	98.69	5.45	94.55	374.20
19	Beauty seedless	288.20	18.14	10.50	5.24	94.76	9.46	90.54	148.60
20	Dilight	255.40	17.88	12.06	3.61	96.40	8.22	93.38	192.20
21	Hybrid 720-19	306.00	19.30	11.54	1.95	98.05	8.09	91.92	358.40
22	Kishmish Hyshrau	340.20	16.32	12.16	5.75	94.25	7.44	92.56	406.00
23	Hybrid V-6	467.20	20.86	13.72	2.66	97.34	6.17	93.83	378.20
24	Slavyanka	526.60	21.30	13.96	2.68	97.32	7.11	92.89	282.20
25	Corinth seedless	387.80	21.28	13.90	4.22	95.78	8.29	91.71	353.00
26	Thompson seedless	343.20	18.90	14.72	2.64	97.36	7.52	92.48	302.60
27	Early superior seedless	219.20	17.96	11.60	7.42	92.58	8.55	91.45	343.00
28	Hybrid 23-4	219.40	14.42	9.62	3.18	96.82	7.82	92.18	227.20
29	Raucha biala	160.20	10.66	8.26	2.77	97.23	8.12	93.28	137.60
30	Early kishmish	216.00	12.68	9.18	4.29	95.71	11.81	88.19	81.40
31	Superior seedless	257.40	19.72	11.36	7.36	92.64	7.16	92.84	404.20
32	Rusbol	155.60	15.52	8.82	2.35	97.65	8.91	91.08	139.00
33	Jangier	126.80	16.26	9.36	5.16	94.84	8.33	91.67	140.80
34	Perlette	317.80	14.52	10.10	1.99	98.01	7.10	92.90	220.20
35	Corinth black	97.20	14.24	8.54	4.07	95.99	11.45	88.55	45.20
36	Russalka 2	400.80	16.66	11.40	2.16	97.84	7.34	92.66	283.80
37	Russalka 3A	361.60	20.84	12.36	1.96	98.04	4.88	95.12	349.60
38	Rushaky	154.20	14.44	8.20	1.90	98.10	9.29	90.71	134.20
39	Kishmish tjurkmenski	126.40	13.78	7.94	3.53	96.47	8.08	91.92	216.60
40	Kishmish Irtishor	422.60	21.98	14.78	4.24	95.76	9.20	90.78	370.80
41	Kishmish black	250.20	21.24	10.52	2.55	97.45	7.70	92.30	194.00
42	Korsa kishmish	191.80	13.24	9.44	4.35	95.65	10.58	89.42	94.00

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Table 3 to be continued

No.	Name	Average mass of bunch (g)	Length of banches (cm)	Widht of bunches (cm)	Bunches (%)	Grapes (%)	Skins (%)	Mesocarp (%)	Average mass of 100 grapes (g)
43	Hybrid 36-16	252.00	15.72	12.30	4.72	95.28	9.25	90.55	206.80
44	Sultanina	762.80	24.66	13.22	2.23	97.77	7.75	92.25	250.60
45	Corinth white	156.60	25.10	10.40	7.39	92.61	10.50	89.46	54.00
46	Askery	207.80	16.48	9.44	3.70	96.30	8.52	91.39	176.20
47	Nimrang × Sultanina	634.00	19.72	13.20	2.53	97.47	10.72	89.28	194.40
48	Italia × Sultanina	355.00	16.82	7.44	2.04	97.96	8.88	91.12	237.00
49	Kishmish VIRA	326.80	17.68	13.02	1.93	98.07	8.07	92.05	258.20
50	Kishmish Vatkana	373.40	17.80	10.86	2.49	97.51	4.88	95.12	217.00
51	Nishava	707.00	20.46	13.38	1.58	98.42	5.86	94.14	289.60
52	Red seedless	533.60	23.24	12.48	2.53	97.47	7.51	92.49	203.40
53	Tarnow	333.60	16.64	11.70	1.69	98.31	11.68	88.32	167.40
54	Hybrid 21-17-41	327.80	18.60	11.94	2.40	97.60	7.66	92.34	336.00
55	Kolarovets	408.40	24.64	9.80	2.83	97.17	5.87	94.13	234.60
56	Russalka 5A	365.60	18.72	12.64	1.83	98.17	4.65	95.35	304.80
57	Sultana muscata	402.80	23.64	11.66	3.28	96.72	5.05	94.95	297.80
58	Gigant	861.60	26.82	16.34	2.23	97.77	6.79	93.21	311.40
59	Focha seedless	415.80	20.84	12.86	3.96	96.04	8.64	91.37	227.40
60	Sultanina gigas	357.20	17.78	13.16	2.02	97.98	8.26	93.36	322.00
61	Russalka 5B	576.80	25.78	13.82	2.42	97.58	7.91	92.11	303.00
Average		379.30	19.26	11.94	3.05	96.95	7.60	92.47	280.03

RESULTS AND DISCUSSION

In the present study, the classification of the varieties was conducted in order to improve the selection activity through two mathematical and statistical approaches. The combined application of a cluster analysis and analysis of the main components makes it possible to obtain more complete information about the contribution and importance of the different indicators in grouping varieties into clusters.

The grouping of the studied 61 seedless varieties depending on the degree of similarity of their phenological indicators – the duration of phenophases and periods, is expressed in the formation of three clusters (Figure 1). The first of cluster consists of Kishmish VIRA, Red seedless, Kishmish Vatkana, Nimrang x Sultanina, Nishava, Vanessa seedless, Kolarovets, Slavyanka, Russalka 3A, Hybrid V-5, Askery, Corinth seedless, Corinth black, Corinth white, Sultanina, Hybrid 21-17-41, Koshmish black, Korsa kishmish, Italia × Sultanina, Thompson seedless, Sultana muscata, Russalka 2, Kishmish tjurkmenski, Perlette, Rushaky, Tarnow, Hybrid 23-4, Kishmish Irtishor, Rusbol, Jangier, Hybrid 36-16. The predominant varieties are characterised by a longer period of veraison (softening) of the grapes, up to 16–18 days in Sultana muscata, Perlette and Russalka 2. The diversity in the interaction between their phenological characteristics is manifested in a narrower range and the grapes of most of these varieties ripen at approximately the same time - in the second half of August and early September.

The second cluster includes: Russalka 5A, Russalka 5B, Sultanina gigas, Focha seedless, Gigant, Tangra, Ruby seedless, Russalka 1, Nedelchev VI-4, Thracian pearl, Zornitsa, Rusensko without seeds, Kondarev 10, Kondarev 6, Kishmish luchistii, V and Bialo drebno without seeds. These varieties stand out with a relatively long period of the flowering-veraison (softening) of the grapes – up to 76 days in Zornitsa and budding – technological maturity – up to 179 days in Gigant. This cluster also includes varieties with a longer period of veraison (softening) of the grapes – technological maturity, where it is

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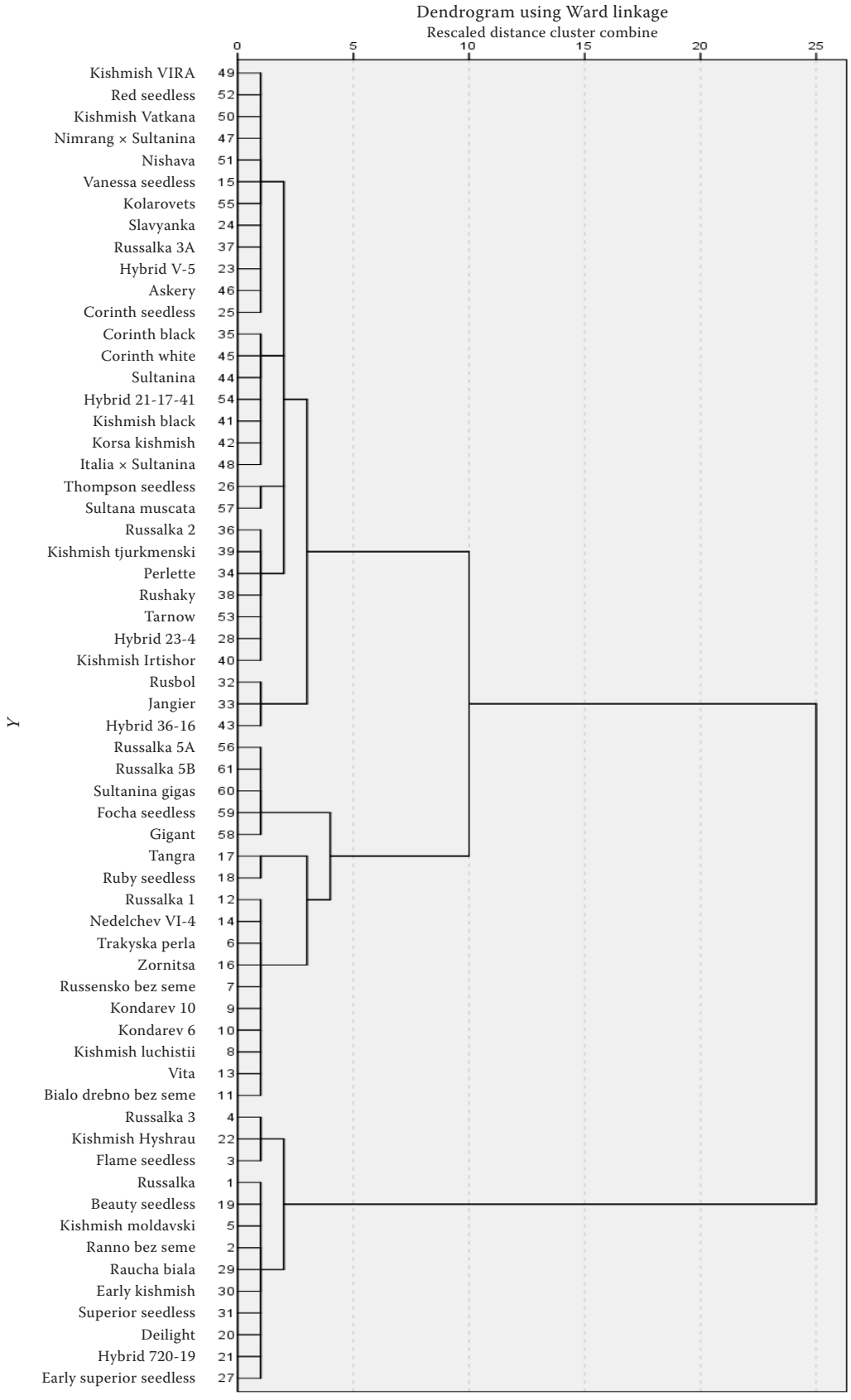

Figure 1. Dendrogram for the clustering of the seedless varieties according to the phenological indicators

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Table 4. Factor matrix for the phenological indicators of the studied seedless vine varieties

Indicators	Component		
	F_1	F_2	F_3
Budding (days)	0.569		
Flowering (days)		0.786	
Veraison (softening) of the grape (days)		0.880	
Grape growth (days)			0.846
Budding – flowering (days)			–0.806
Flowering – veraison (softening) of the grape (days)	0.834		
Veraison (softening) of the grape – technological maturity (days)	0.657		
Budding – technological maturity (days)	0.876		
Percentage of total variation %	30.45	24.89	19.37
Cumulative percentage of total variation %	30.45	55.34	74.71

the largest in the Ruby seedless – 65 days. The varieties Russalka 3, Kishmish Hyshrau, Flame seedless, Russalka, Beauty seedless, Kishmish moldavski, Ranno bez seme, Raucha biala, Early kishmish, Superior seedless, Delight, Hybrid 720-19 and Early superior seedless form the third cluster, which is as far as possible from the other varieties, at a Euclidean distance of 25 units. The grapes of this group of varieties ripen the earliest. The varieties with a shorter period of grape growth (Ranno bez seme – 32 days) and length – at budding – flowering (up to 71 days in Ranno bez seme) predominate. This includes varieties with the shortest period of veraison (softening) of the grapes – technological maturity, up to 20 days in Hybrid 720-19.

After applying a component analysis, it was found that three factors have eigenvector values greater than one and the studied phenological indicators in the factor matrix are transformed into three main components (Table 4, Figure 2). The indicators budding, flowering-veraison (softening) of the grape, veraison (softening) of the grape-technological maturity and budding-technological maturity have high factor weights in the first component and explain 30.45% of the total variation. This factor should be considered as a summary for the indicated indicators, which have maximum relative weights for the division of the varieties into groups. The results of the factor analysis on the phenological indicators show that the budding-technological maturity and flowering – veraison (softening) of the grape are the most important in the formation of the first component These are the main indicators influencing the variability of the varieties. The second main component summarises the phenophases flowering and veraison of the grape and explains 24.89% of the variation, and the third component – grape growth and budding-flowering – explains 19.40%. The total of the three factors explain 74.71% of the total variance. The indicators of the first and second factors are decisive for the variation in the phenology of the studied seedless varieties as well as through various agrotechnical measures carried out during their duration, there may be some influence on the ripening time of the grapes.

The studied seedless varieties, depending on their agrobiological characteristics, are grouped into two generalised clusters (Figure 3). Hybrid 720-19, Nishava, Focha seedless, Hybrid V-6, Russalka 3, Corinth black, Russalka 1, Hybrid 21-17-41, Kondarev 10, Tangra, Trakyska perla, Kondarev 6, Kishmish Irtishor, Russalka 2, Sultanina gigas, Russalka 5B, Flame seedless, Russalka 3A, Corinth white, Gigant,

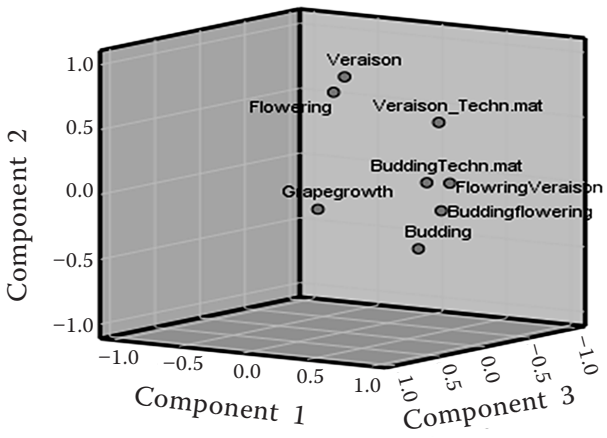

Figure 2. Design of the factors of the phenological indicators on the factorial three-dimensional plane

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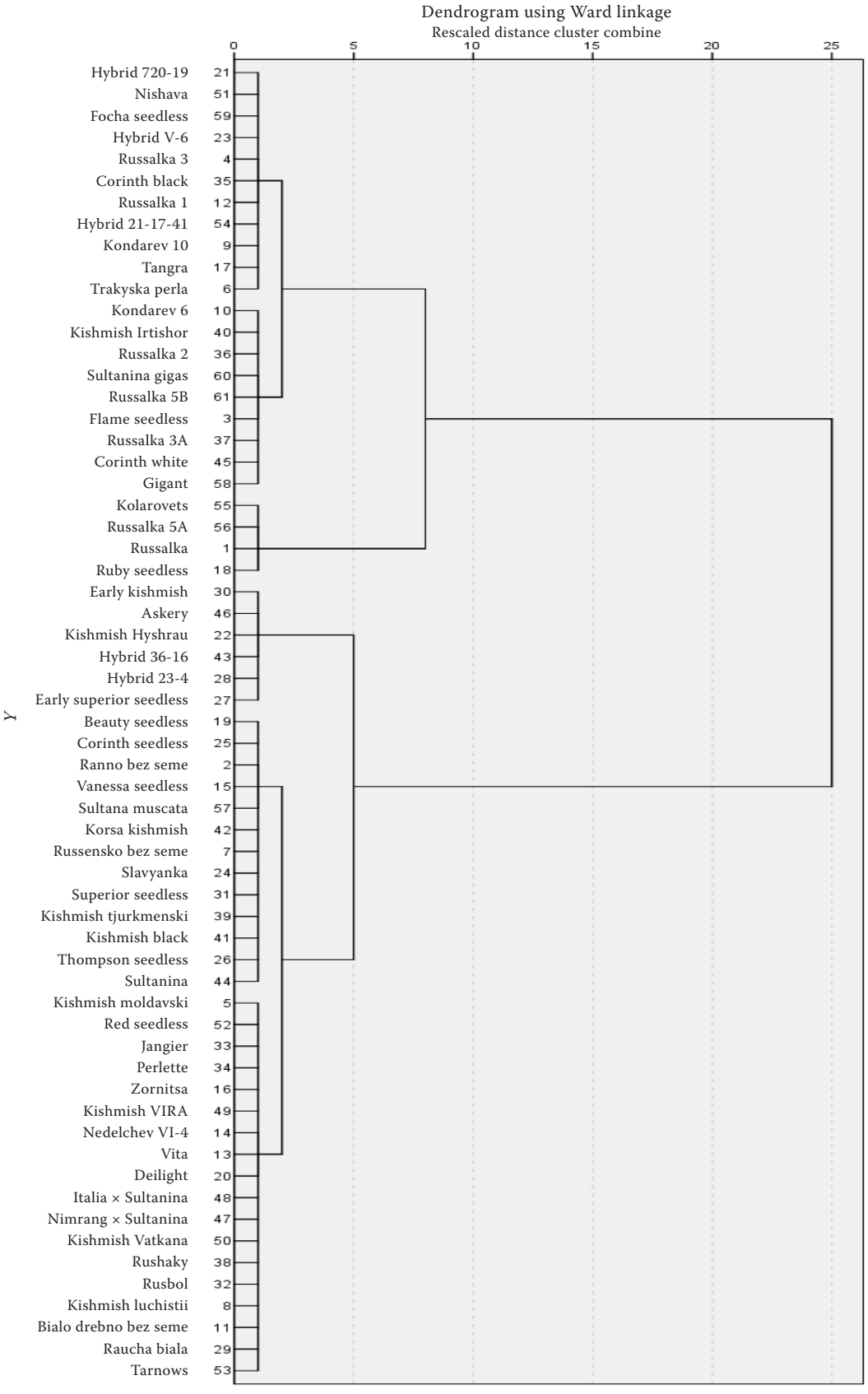

Figure 3. Dendrogram for the clustering of the seedless varieties according to the agrobiological indicators

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Table 5. Factor matrix for the agrobiological indicators of the studied seedless vine varieties

Indicators	Component	
	F_1	F_2
Developed eyes (%)		0.823
Fruiting shoots (%)		0.693
Fertility rate	0.657	
Average yield per vine (kg)	0.863	
Average yield per decare (kg/dka)	0.877	
Percentage of total variation	45.40	3.10
Cumulative percentage of total variation	45.40	75.50

Kolarovets, Russalka 5A, Russalka and Ruby seedless form the first cluster. This group is dominated by varieties with relatively high average yields per vine and per decare – up to 8.9 kg per vine in Russalka 2 and up to 2721.6 kg per decare in Ruby seedless.

The second cluster includes the other seedless varieties included in the study, which are characterised by a moderate percentage of developed eyes, a fertility rate in the range of 0.3 in Early superior seedless to 1.48 in Rusbol. This cluster is dominated by varieties with a lower average yield per vine and per decare, which, in Early superior seedless, is 2.53 kg per vine and 824 kg per decare, respectively. The varieties of the second aggregated cluster are significantly larger than those indicated in the first and are divided into three subclusters, but the differences between them in fertility and yield are too small and have no significant practical significance, regardless of whether their grapes are used for fresh consumption or raisins.

The studied agrobiological indicators are transformed into two main components (Table 5, Figure 4). In the first one, the components with the highest weights are: the fertility rate, average yield per vine and average yield per decare, which explains 45.40% of the total variance, and in the second one, the components are the developed eyes and fruiting shoots, which explains 30.10% of the total variation. These indicators are of the greatest importance in the formation of clusters and are the reason for the distribution of the varieties in different groups.

The total change, 75.50%, is due to the indicators in these two factors, which have the greatest impact on the grouping of the varieties in the respective cluster.

According to the peculiarities of the technological indicators, the studied seedless vine varieties are grouped in two generalised clusters (Figure 5). The first of them includes Corinth seedless, Russalka 3A, Bialo drebno bez seme, Thompson seedless, Hybrid 720-19, Flame seedless, Russalka 3, Kishmish Irtishor, Slavyanka, Russalka 5B, Kishmish Hyshrau, Sultanina gigas, Zornitsa, Tangra, Nedelchev VI-4, Delight, Kishmish tjurkmenski, Kishmish moldavski, Perlette, Tarnow, Kondarev 10, Kondarev 6, Gigant, Russalka 1, Hybrid V-6, Sultana muscata, Russensko bez seme, Early superior seedless, Superior seedless, Ruby seedless. Here, varieties with a low percentage of bunches predominate, 1.33% in Ruby seedless, and a high average weight of a bunch, reaching 906 g in Kondarev 10, as well as an average weight of one hundred grapes (up to 553.6 g in Tangra). This is due to the larger size of their grapes, as the length reaches 26.2–26.3 mm in Kondarev 10 and Kondarev 6, and the width reaches 1–21.34 mm in Russalka. A significant part of the varieties in this group have a tensile strength higher than the average for the

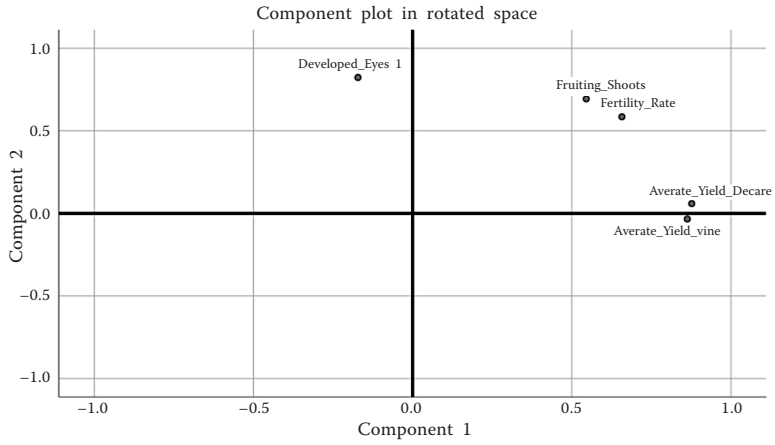

Figure 4. Design of the factors of the agrobiological indicators on the factorial two-dimensional plane

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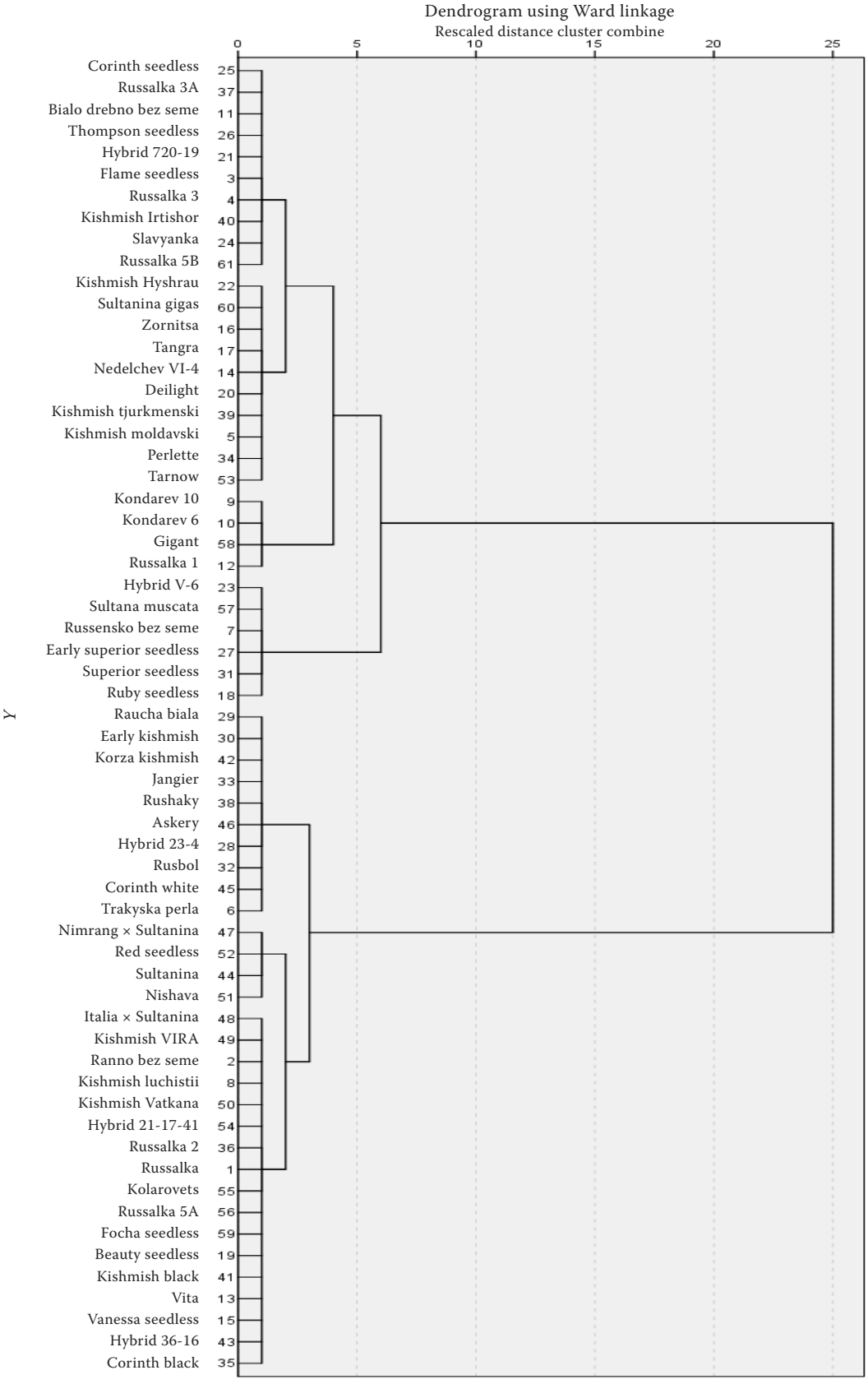

Figure 5. Dendrogram for the clustering of the seedless varieties according to the technological indicators

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Table 6. Factor matrix for the technological indicators of the studied seedless vine varieties

Indicators	Component			
	F_1	F_2	F_3	F_4
Average mass of a bunch (g)	0.799			
Length of a bunch (cm)	0.647			
Width of a bunch (cm)	0.780			
Bunches (%)		0.840		
Grapes (%)		–0.840		
Skins (%)	–0.751			
Mesocarp (%)	0.740			
Average mass of 100 grapes (g)	0.863			
Length of a grape (mm)	0.898			
Width of a grape (mm)	0.906			
Sugars (%)				–0.372
Acids (g/dm^3)			0.762	
Detachment (g)				0.488
Pressure (g)	0.591			
Percentage of total variation (%)	22.78	21.72	19.27	15.39
Cumulative percentage of total variation (%)	22.78	44.50	63.77	79.16

whole collectiveness, reaching 625 g in Perlette, and an endurance pressure of the grape, up to 1961.4 g in Russensko bez seme. The second cluster mainly consists of varieties with a lower acid content, where the minimum value of this indicator is 3.6 g/dm^3 in Russalka, a low tensile strength, the lowest in Beauty seedless – 179 g, and pressure – 445 g in Rusbol. The varieties in this cluster are characterised by a low to moderate average mass of a bunch, which is the smallest in Corinth black – 97.2 g, and small to medium-sized grapes, where the smallest are in Corinth black with a length and width of 6.78 mm and 6.44 mm, respectively.

The studied technological indicators in all the seedless varieties were transformed into four factors, explaining 79.16% of their total dispersion (Table 6, Figure 6). The average mass of a bunch, length and width of a bunch, skins, mesocarp, average mass of a hundred grapes, length and width of a grape and pressure (22.78%) have the maximum weight factor in the first main component. The second factor includes bunches and grapes (21.72%), the third one is formed only by acids (19.27%), and the fourth one includes - sugars and tensile strength (15.39%). These results show that the indicators influencing the grouping of the varieties into clusters, according to their degree of similarity, are indicated in the first three factors, explaining 63.77% of the total variation.

The grouping of the studied seedless varieties depending on all the phenological, agrobiological and technological indicators of their ampelographic characteristics is expressed in the formation of three generalised clusters (Figure 7). The first one includes the varieties Bialo drebno bez seme, Thompson seedless, Corinth seedless, Slavyanka, Tarnow, Kish-

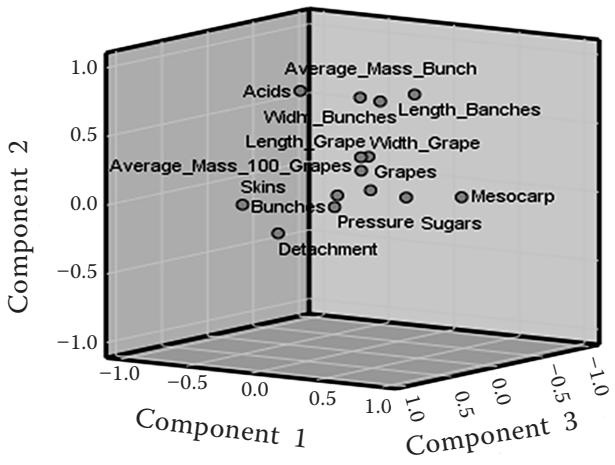

Figure 6. Design of the factors of the technological indicators on the factorial plan

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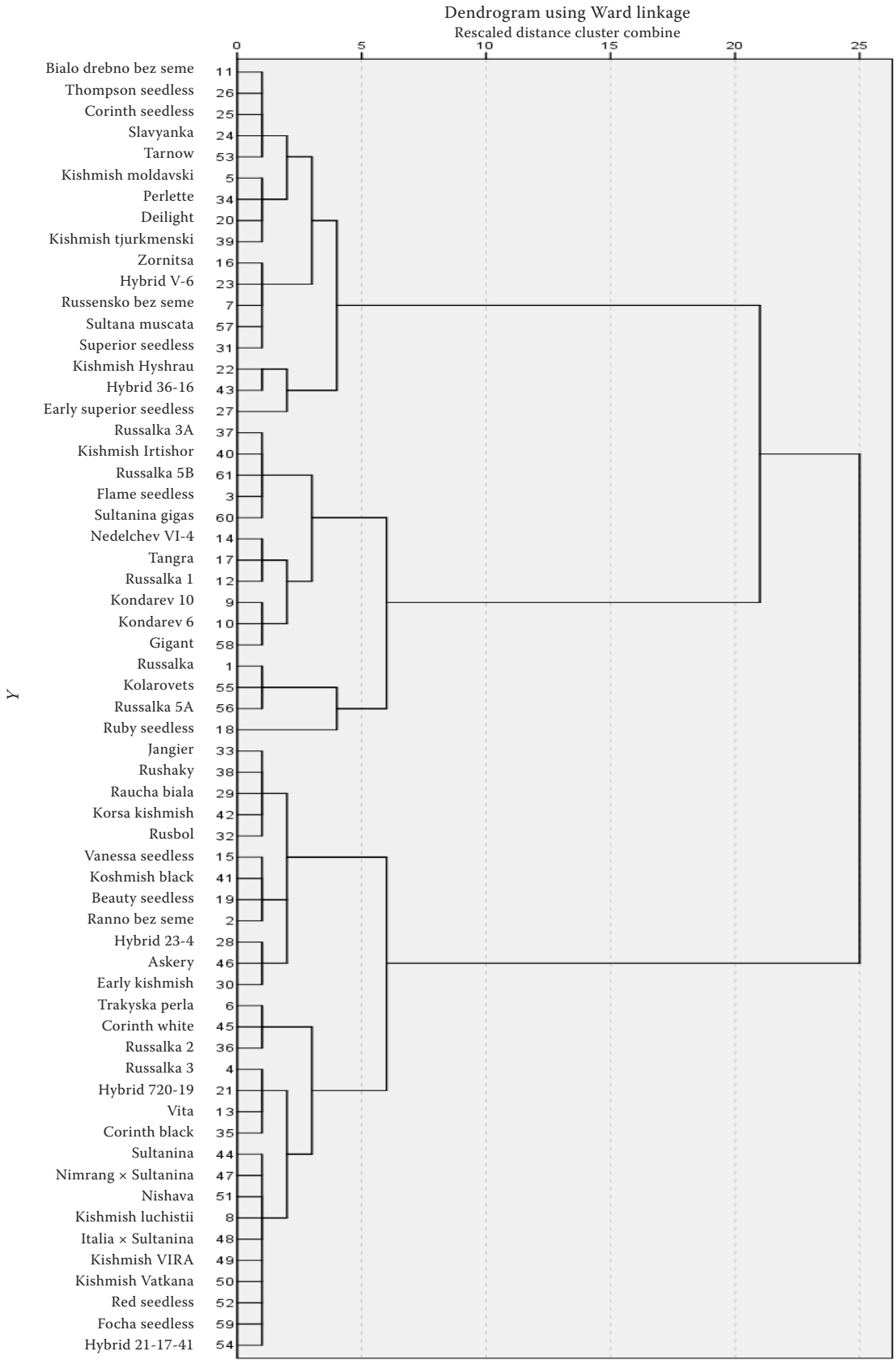

Figure 7. Dendrogram for the clustering of the seedless varieties according to the phenological, agrobiological and technological indicators

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mish moldavski, Perlette, Delight, Kishmish tjurkmenski, Zornitca, Hybrid V-6, Russensko bez seme, Sultanina muscata, Superior seedless, Kishmish Hyshra –16 and Early superior seedless. These varieties are characterised by an average yield of vines ranging from 2.5 kg in Early superior seedless to 9.13 kg in Hybrid 36-16, an average weight of hundred grapes – from 167.4 g in Tarnow to 494.2 g in Zornitsa. Varieties with a low fertility rate predominate, with the minimum being 0.392 in Corinth seedless.

The second cluster consists of Russalka 3A, Kishmish Irtishor, Russalka 5B, Flame seedless, Sultanina gigas, Nedelchev VI-4, Tangra, Russalka 1, Kondarev 10, Kondarev 6, Gigant, Russalka, Kolarovets, Russalka 5A, Ruby seedless. In this group, there are varieties with a high average vine yield, reaching 8.6 kg in Russalka and a high average vine yield per decare – up to 2721.6 kg per decare in Ruby seedless. Most varieties have a longer bunch length, reaching 27.82 cm in Ruby seedless, and a shorter period of growth of the grapes and a relatively long period of budding – technological maturity, reaching up to 179 days in Gigant. The varieties in this cluster are characterised by a relatively higher aver-

Table 7. Factor matrix for the phenological, agrobiological and technological indicators of the studied seedless vine varieties

Indicators	Component						
	F_1	F_2	F_3	F_4	F_5	F_6	F_7
Developed eyes (%)							0.740
Fruiting shoots (%)		0.678					
Fertility rate		0.768					
Average yield per vine (kg)		0.773					
Average yield per decare (kg/dka)		0.792					
Average mass of a bunch (g)	0.498						
Length of a bunch (cm)			0.630				
Width of a bunch (cm)			0.645				
Bunches (%)				–0.931			
Grapes (%)				0.931			
Skins (%)	–0.815						
Mesocarp (%)	0.809						
Average mass of 100 grapes (g)	0.849						
Length of a grape (mm)	0.843						
Width of a grape (mm)	0.840						
Sugars (%)							0.707
Acids (g/dm^3)			0.817				
Detachment (g)					0.472		
Pressure (g)	0.691						
Budding (days)						0.459	
Flowering (days)					0.730		
Veraison (softening) of the grape (days)					0.826		
Grape growth (days)						0.822	
Budding – flowering (days)						–0.475	
Flowering – veraison (softening) of the grape (days)						0.462	
Veraison (softening) of the grape – technological maturity (days)					0.520		
Budding – technological maturity (days)						0.738	
Percentage of total variation %	22	11	10	10	9	8	6
Cumulative percentage of total variation %	22	33	43	53	62	70	76

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age weight of a hundred grapes, with the highest value of this indicator being Tangra - 553.6 g. It should be noted that the varieties in this group have larger grape sizes.

The third cluster is formed by the remaining 29 seedless varieties. It is dominated by varieties with a lower average vine yield, and it is minimal in Early kishmish (3.19 kg), which is due to the smaller size of the bunch. It also includes varieties with a higher skin content – up to 11.80% for Early kishmish and 11.45% for Corinth black.

The applied factor analysis transformed all the studied indicators into seven main components, explaining 76% of the total variance (Table 7, Figure 8). In the first one, the average weight of a bunch, the percentage of skins, mesocarp, the average weight per hundred grapes, the length and width of the grape and the pressure (22%) have the maximum weight factors. The second component mainly covers the agrobiological indicators – fruiting shoots, fertility rate, average yield per vine and per decare (11%). The third one consists of the length and width of the bunch and the acid content (10%). The percentage of bunches and grapes related to the mechanical analysis of the bunch form the fourth factor (10%). The detachment, the flowering of the phenophases, the veraison (softening) of the grape and the period of veraison (softening) of the grape-technological maturity distinguish the fifth factor (9%). The budding of the phenophases, grain growth, budding-flowering, flowering-veraison (softening) of the grape and budding-technological maturity form the sixth factor (8%). The last one consists of the percentage of developed eyes and sugar content (6%). Given the indicated shares of each of the factors in relation to the total variation, it should be considered that the characteristics of the first component have the greatest importance on the distribution of the seedless varieties in the different clusters.

The identified indicators with the highest weight factor are of the greatest importance for improving the qualities of the studied varieties and would be useful in future selection programmes. Clustering shows that the varieties located in the first and last cluster in each of the realised clusters are the most distant in terms of the studied indicators. Including them in a general population will be most effective.

CONCLUSION

The ampelographic description of the phenotypic features of the vine is an important element in the assessment of its qualities, as well as with regards to the prospects for future research. The set of different applied research methods makes it possible to assess the diversity of the varieties, on the one hand, and their adequate identification and classification, on the other. The large volume of varieties included in the study allows for the objective consideration of their specific features and application of the results in the cultivation of vines. Taking the changes in the climatic conditions of the respective region into account, adequate forecasts for the main phenological stages of the vine could be achieved.

The grouping of the studied seedless varieties, depending on all the phenological, agrobiological and technological indicators of their ampelographic characteristics, is expressed in the formation of three generalised clusters, determined by transforming the indicators in seven main components. Depending on the share of each of the

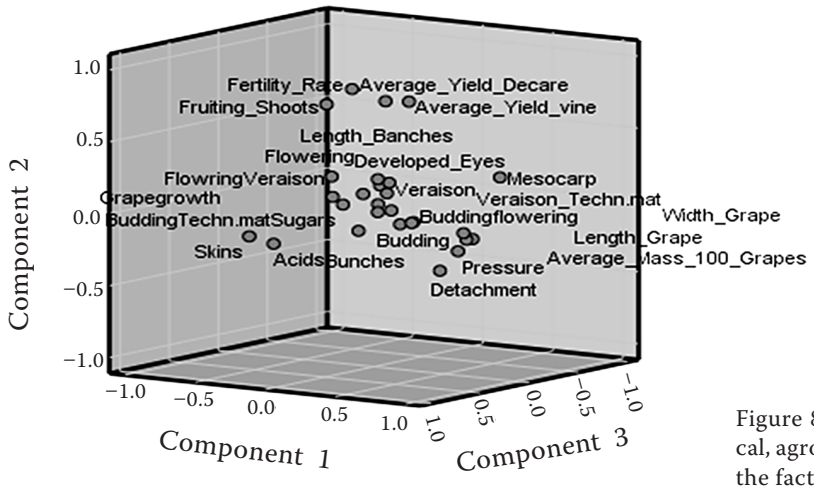

Figure 8. Design of the factors of the phenological, agrobiological and technological indicators on the factorial plane

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factors in relation to the total variation, the traits of the first component have the highest importance in the distribution of the seedless varieties in the different clusters, which are the average weight of a bunch, the percentage of the skins, mesocarp, the average weight of a hundred grapes, the length and width of the grape and the pressure resistance of the grape.

The established boundaries of the phenotypic similarity and differences between the studied seedless vine varieties reveal the conditional parameters of the polymorphism in their economically significant ampelographic characteristics. The established limits of the phenotypic similarity and differences between the studied seedless vine varieties reveal the conditional parameters of polymorphism in their economically significant ampelographic characteristics. The presented grouping can be used in determining the level of stenospermocarpia in the individual varieties, for taxonomic purposes, as well as in the selection for the creation of new seedless vine varieties. By applying targeted agro-technical measures, the desired change of the indicators of the first and second factors in the separate groups of traits can be actively influenced.

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