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POLYMORPHISM OF AMYLASES FROM RYE ENDOSPERM II. INTRA- AND INTERCULTIVAR VARIABILITY OF THE ELECTROPHORETIC PATTERN OF AMYLASES[1]

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Summary. Using polyacrylamide gel electrophoresis the variability in the isoenzymatic composition of alfa- and beta-amylases from 10 population varieties and strains of rye were studied (Dańkowskie Złote, Animo, Halo, Otello, Petkus 1035, Ponsi, Donar, Kungs II, Sv 6970 and Wiatka 2). Totally, 64 electrophoretic phenotypes of alfa-amylases and 16 of beta-amylases were detected. The number of bands on the zymograms obtained from single endosperms was from 4 to 14. A sprouting resistant rye cultivar Otello distinguished by the lowest degree of the amylase polymorphism and by the smallest mean number of bands, and simultaneously showed the largest genetic distances from the remaining varieties. Cultivars with a higher sprouting resistance — Sv 6970, Donar, Kungs II, Petkus 1035, Ponsi — showed a higher degree of similarity with the cv. Otello than did sprouting ones — Dańkowskie Złote, Wiatka 2, Halo. Alfa-isoamylases of the cv. Kungs II and of derived from it cv. Otello exhibited a relatively low degree of similarity.

It is suggested that isoenzymatic composition of endosperm amylases is not a selectively neutral trait in breeding sprouting resistant rye varieties.

On the basis of the so-far results of the studies of amylase in rye endosperm (Wagenaar, Lugtenborg 1973; Alexandrescu et al. 1975; Michalczyk 1979; Buschbeck, Wilp 1982; Perez de La Vega et al. 1982; Masojć 1982; Łapiński, Masojć 1983) it may be inferred that both alfa- and beta-amylases occur in many molecular forms. However, the variability range of isoamylases in cultivated rye varieties has not been described. In view of a direct relation between the activity level of alfa-amylase and rye susceptibility to sprouting (Hagberg, Olered 1975) it seemed interesting to compare the composition of isoamylases in cultivars with different sprouting resistance. As suggested by Buschbeck and Wilp (1982), strongly sprouting varieties should have a larger number of alfa-amylases than sprouting resistant ones.

The purpose of the paper was to compare 10 rye cultivars of the European origin with respect to the composition of alfa- and beta-amylases from the endosperm of germinated seeds.

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MATERIALS AND METHODS

Material of the studies were seeds of the cultivars: Animo, Halo, Wiatka 2, Petkus 1035, Ponsi, Kungs II, Sv 6970, Donar, received from the collection of the Experimental Department of Plant Breeding and Acclimatization in Smolice; Dańkowskie Złote — from the Plant Breeding Station in Choryń and Otello — from the Plant Breeding Station in Dańków.

The analysis was carried out on semi-fluid starch endosperm forced out from seeds germinating for 5 days. A single endosperm was separately ground in 0.1 ml of 1 mM acetate buffer pH 5.0 added with 2 mM $CaCl_2$, the whole being thickened by 50 µl of 80% (w/v) sucrose. An electrophoretic analysis was performed on fresh crude amylase extracts.

Electrophoresis was carried out using vertical slab apparatus (15×28 cm) in 5% polyacrylamide gel with the addition of 0.25% soluble starch according to the methodics described in details in the previous paper (Łapiński, Masojć 1983). Each variety was represented by 200 or 300 zymograms of amylases obtained from single, randomly taken endosperms.

Localization of isoamylases was based on the comparison of their location with the bands of the model zymogram (amylases from 50 endosperms of the cv. Dańkowskie Złote) which was distributed each 10 places in each gel.

For estimation of intraspecific variability the index of phenotype polymorphism (Kahler et al. 1981), calculated according to the model

$$P_j=\sum_{i=1}^{n} p_i\,(1-p_i) \tag{1}$$

was used, where P_j is the index of phenotype polymorphism, p_i — frequency i of that phenotype, n — the number of phenotypes found in the variety.

Interspecific variability is presented in the form of indices of genetic similarity (Hedrick 1975) calculated according to the model:

$$I_H=\frac{\sum_{j=1}^{n} P_{jx}P_{jy}}{\frac{1}{2}\left(\sum_{j=1}^{n} P_{jx}^2+\sum_{j=1}^{n} P_{jy}^2\right)} \tag{2}$$

where I_H is the index of genetic similarity according to Hedrick, n — the number of phenotypes common for the variety x and y, P_{jx}, P_{jy} are frequencies j of that phenotype in the varieties x and y. The indices (1) and (2) were calculated separately for each of the analyzed zones of zymograms, and the means of these values were made. On the basis of the mean similarity indices the genetic distances between varieties were calculated using the formula:

$$D_{g(H)}=\sqrt{1-I_H} \tag{3}$$

where $D_{g(H)}$ is genetic distance according to Hedrick's I_H similarity index.

RESULTS

A combined zymogram of amylases from rye endosperm obtained as a result of the comparison of 2500 zymograms representing single endosperms consisted of 24 bands (Fig. 1). On the basis of earlier results (Łapiński, Masojć 1983), two zones of beta-amylases (I and II) and two zones occupied by alfa-amylases (III and IV) were distinguished in it.

The electrophoretic variability of phenotypes was analyzed within zone I covering 5 bands, zone III having 6 bands and zone IV consisting of 8 bands. Zone II was not analyzed because of enzymatic affiliation of part of the bands and for the significant variation of their intensity, which made impossible clear differentiation of phenotypes.

Totally, 64 electrophoretic phenotypes of alfa-amylases and 16 phenotypes of beta-amylases were distinguished (Table 1). The largest number of phenotypes —

Table 1. Electrophoretic phenotypes distinguished as a result of analysis alfa- and beta-amylases zymograms of 10 rye cultivars

Phenotype No.	Zone of a zymogram		
	I	III	IV
	amy:	amy:	amy:
1	null	12b, 13	16, 19
2	1	11 , 12b	17, 20
3	2	11 , 12a	18, 21
4	3	11 , 12a, 12b	17, 22
5	4	11 , 13	17, 18, 21, 22
6	5	11 , 12b, 13	17, 20, 22
7	1, 2	11 , 12a, 12b, 13	17, 18, 20, 21
8	1, 3	11 , 12a, 13	16, 18, 19, 21
9	1, 4	11 , 12b, 13 , 14, 15	16, 17, 19, 20
10	1, 5	11 , 13 , 15	16, 17, 19, 20, 22
11	2, 3	12b, 13, 15	17, 19, 20
12	2, 4	11 , 13 , 14 , 15	16, 19, 20
13	2, 5	11 , 12a, 12b, 13, 14, 15	16, 17, 19, 20, 21, 22
14	3, 4	11 , 12a, 13 , 14, 15	16, 17, 19, 21
15	3, 5	11 , 12a, 13 , 15	16, 18, 19, 20, 21, 23
16	4, 5	11 , 12b, 13 , 15	16, 18, 19, 20, 21, 22
17		12a, 13 , 14 , 15	17, 18, 20, 21, 22, 23
18		11 , 12b, 13 , 14	16, 17, 19, 20, 22, 23
19		12b, 14 , 15	17, 18, 20, 21, 22
20		12a, 14 , 15	17, 20, 21
21		11 , 12b, 15	16, 17, 18, 19, 20, 22
22		11 , 12a, 12b, 13 , 15	16, 17, 18, 19, 21, 22
23		14 , 15	16, 17, 18, 19, 20
24		12b, 13 , 14 , 15	18, 21, 22
25		11 , 12b, 14 , 15	17, 21, 22
26		12a, 12b, 13	17, 21
27		12b	18, 20, 21
28		12b, 15	16, 18, 19, 21, 22
29		11 , 13 , 14	16, 19, 21
30		12a, 12b, 13 , 14	16, 17, 18, 19, 20, 21, 22
31		11 , 12b, 14	17, 18, 20, 22
32			16, 17, 18, 19, 20, 21
33			17, 18, 20, 21, 23

Table 2. Frequences of electrophoretic phenotypes from zones III and IV of alfa-amylase zymograms in rye varieties

Phenotype No.	Zone III										Zone IV									
	Otello	Petkus 1035	Donar	Ponsi	Kungs II	Sv 6970	Dańkowskie Zł.	Animo	Halo	Wiatka 2	Otello	Petkus 1035	Donar	Ponsi	Kungs II	Sv 6970	Dańkowskie Zł.	Animo	Halo	Wiatka 2
1	0.680	0.205	0.260	0.195	0.060	0.130	0.050	0.097	0.033	–	0.580	0.140	0.045	0.090	0.080	0.110	0.007	0.217	0.013	–
2	–	0.010	0.050	0.015	0.005	–	0.040	–	0.007	0.007	–	0.065	0.285	0.205	0.100	0.085	0.257	0.197	0.137	0.496
3	–	–	–	–	–	0.005	–	0.009	0.127	–	0.017	0.095	0.060	0.055	0.055	0.105	0.083	0.013	0.130	0.013
4	–	–	–	–	0.005	–	–	–	0.007	–	–	–	–	–	0.045	–	0.010	–	0.003	0.047
5	0.163	0.065	0.095	0.06	0.025	0.125	0.310	0.090	0.417	0.133	–	0.025	0.005	0.010	0.125	0.010	0.017	–	0.007	0.010
6	0.143	0.575	0.505	0.615	0.355	0.560	0.407	0.333	0.210	0.120	–	0.015	0.005	0.025	0.040	–	0.047	0.007	0.023	0.240
7	–	0.010	0.045	0.010	0.045	0.085	–	0.287	0.110	0.133	0.023	0.090	0.270	0.200	0.120	0.145	0.323	0.047	0.347	0.107
8	–	0.020	0.010	0.015	0.035	0.055	–	0.167	0.013	0.267	0.263	0.110	0.060	0.080	0.095	0.285	0.063	0.053	0.103	–
9	–	0.025	–	0.015	0.165	0.02	0.073	–	0.017	0.040	0.093	0.375	0.230	0.275	0.150	0.230	0.057	0.453	0.167	0.02
10	0.003	0.010	–	0.01	0.015	–	0.060	–	0.010	0.050	–	0.040	0.025	0.035	0.130	0.025	0.017	0.01	0.013	0.007
11	0.010	–	–	–	–	–	0.010	–	0.007	–	–	–	–	–	–	–	0.007	0.003	–	–
12	–	0.010	–	–	0.005	–	0.013	–	0.017	0.01	0.017	–	–	–	–	–	–	–	–	–
13	–	–	–	–	0.015	–	–	0.017	0.003	0.047	–	–	–	–	–	–	0.003	–	0.007	–
14	–	–	–	–	0.005	–	–	–	–	0.030	0.003	–	–	–	–	–	0.003	–	0.007	–
15	–	–	–	–	0.015	–	–	–	0.013	0.077	–	–	–	–	–	–	0.003	–	–	–
16	–	0.035	0.020	0.020	0.155	0.020	0.027	–	0.003	0.033	0.003	–	–	–	0.015	–	0.003	–	–	–
17	–	–	–	–	–	–	–	–	0.003	–	–	–	–	–	–	–	0.020	–	–	–
18	–	0.005	–	–	0.020	–	0.010	–	0.003	0.003	–	–	–	–	–	–	0.007	–	–	–
19	–	–	0.005	–	0.010	–	–	–	–	–	–	0.010	–	–	–	–	0.023	–	0.007	0.047
20	–	–	–	–	–	–	–	–	–	0.003	–	–	–	–	–	–	0.010	–	0.017	0.003
21	–	–	–	–	–	–	–	–	–	0.003	–	–	–	–	–	–	0.003	–	–	–
22	–	–	0.005	–	0.010	–	–	–	–	0.040	–	–	–	–	–	–	0.007	–	–	–
23	–	–	–	–	–	–	–	–	–	0.003	–	–	–	–	–	–	0.003	–	–	–
24	–	0.025	0.005	0.020	0.010	–	–	–	–	–	–	–	–	–	0.005	–	0.007	–	0.007	–
25	–	0.005	–	–	0.010	–	–	–	–	–	–	–	–	–	–	–	0.003	–	–	–
26	–	–	–	0.020	0.005	–	–	–	–	–	–	–	–	–	0.005	–	0.003	–	–	–
27	–	–	–	0.005	–	–	–	–	–	–	–	–	–	–	–	–	0.010	–	0.003	–
28	–	–	–	–	0.015	–	–	–	–	–	–	–	–	–	–	–	0.003	–	–	–
29	–	–	–	–	0.005	–	–	–	–	–	–	–	–	–	–	–	–	–	0.003	–
30	–	–	–	–	0.005	–	–	–	–	–	–	0.035	–	0.010	0.015	0.005	–	–	0.010	–
31	–	–	–	–	0.005	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.010
32											–	–	0.015	0.015	0.010	–	–	–	–	–
33											–	–	–	–	0.010	–	–	–	–	–

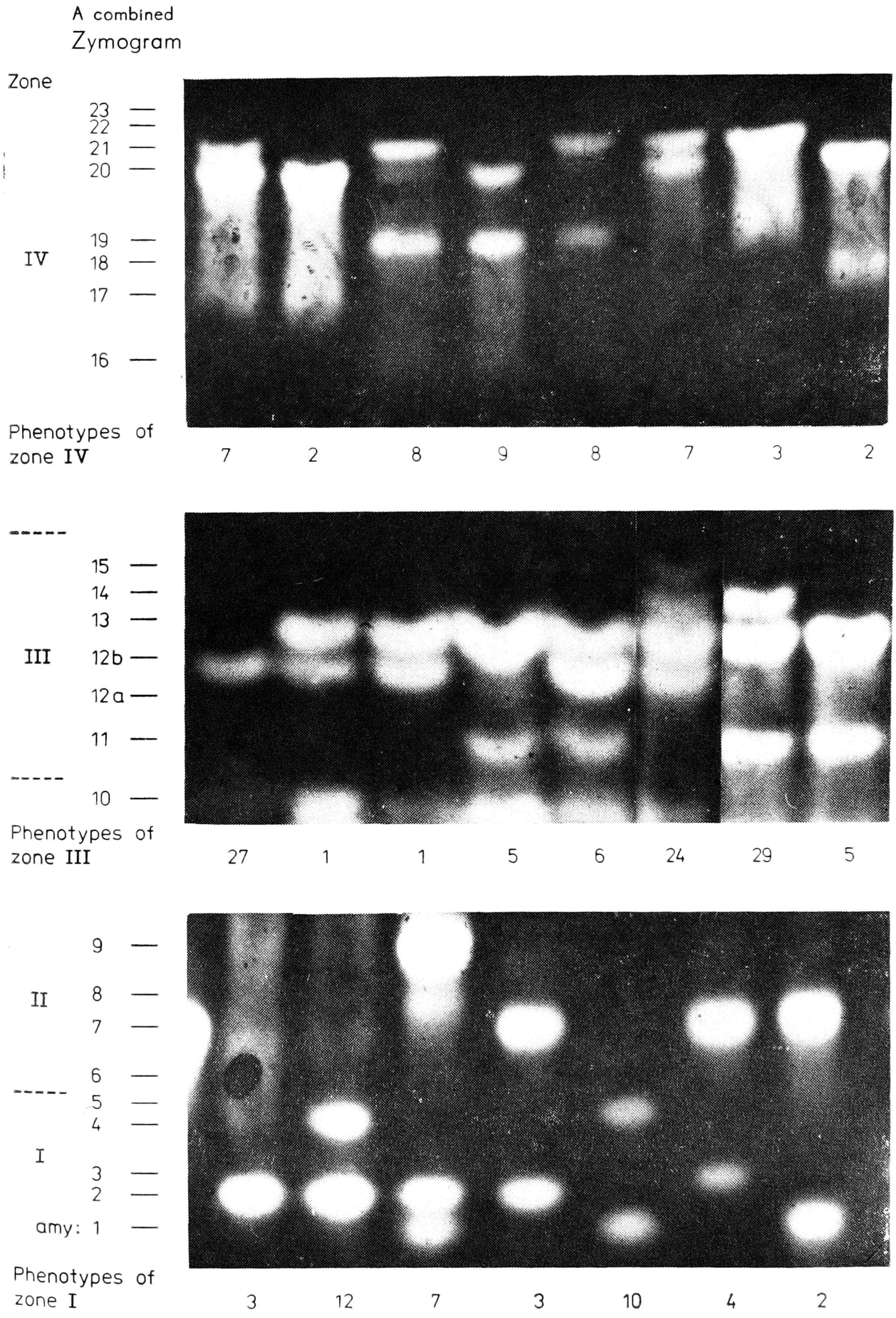

Fig. 1. Variability of isoamylases from rye endosperm (see also Table 1)

33 was found in zone IV. Phenotypes of zone I consisted of 0 - 2 bands, of zone III — from 1 to 6 bands and zone IV — from 2 to 7 bands. In most cases no relationship was found between phenotypes from different zones. An exception were phenotypes consisting of bands amy 14 or 15 from zone III and phenotypes having in the composition band amy 22, as they nearly always occurred simultaneously. In consequence, it was difficult to find two endosperms with the identical isoamylase composition in such cultivars as Dańkowskie Złote, Kungs II or Halo. Additional differentiation of phenotypes resulted from variable relative intensity of individual bands.

The studied varieties differed in both the number of phenotypes and the frequency of their occurrence (Table 2). The smallest numbers of electrophoretic phenotypes of alfa- and beta-amylases were found in the cv. Otello, 13 and 8, respectively, and also in Animo, 16 and 9, whereas the largest numbers were detected in the cv. Kungs II, 40 and 16, and in Dańkowskie Złote, 37 and 16. In general, most phenotypes of a given variety occur at a low frequency, and some were encountered only in single cases. The frequency limit equal to 0.1 was exceeded by hardly 2 - 5 phenotypes. The most frequently detected phenotypes in the varieties under study were phenotype No. 2 from zone I, phenotypes No. 6 and 5 from zone III and phenotypes 2 and 9 from zone IV. On the other hand, phenotypes No.

Table 3. Intravarietal variability of alfa- and beta-isoamylases

Cultivar	Mean number of bands	Number of detected phenotypes		Indices of phenotype polymorphism			
		alfa-amylase	beta-amylase	zone I	zone II	zone IV	mean of zones III and IV
Otello	6.0	13	8	0.58	0.49	0.59	0.54
Petkus 1035	7.4	24	12	0.81	0.62	0.80	0.71
Donar	7.2	20	14	0.86	0.66	0.78	0.72
Ponsi	7.3	23	14	0.85	0.58	0.82	0.70
Kungs II	8.2	40	16	0.79	0.81	0.90	0.86
Sv 6970	7.6	18	15	0.70	0.64	0.82	0.73
Dańkowskie Złote	7.5	37	16	0.87	0.72	0.81	0.77
Animo	7.7	16	9	0.68	0.76	0.71	0.74
Halo	7.8	35	10	0.70	0.75	0.80	0.78
Wiatka 2	7.3	28	13	0.81	0.86	0.69	0.78

Table 4. Similarity indices and genetic distances of varieties in relation to the cv. Otello

Cultivar	Similarity index I_H				Genetic distance $D_{\varphi(H)}$
	zone I	zone III	zone IV	mean	
Petkus	0.86	0.52	0.49	0.62	0.62
Donar	0.73	0.63	0.23	0.53	0.69
Ponsi	0.37	0.49	0.35	0.40	0.77
Kungs II	0.87	0.28	0.34	0.50	0.71
Sv 6970	0.96	0.44	0.55	0.65	0.59
Dańkowskie Zł.	0.27	0.40	0.12	0.26	0.86
Animo	0.14	0.34	0.52	0.33	0.82
Halo	0.21	0.27	0.20	0.23	0.88
Wiatka 2	0.20	0.12	0.01	0.11	0.94

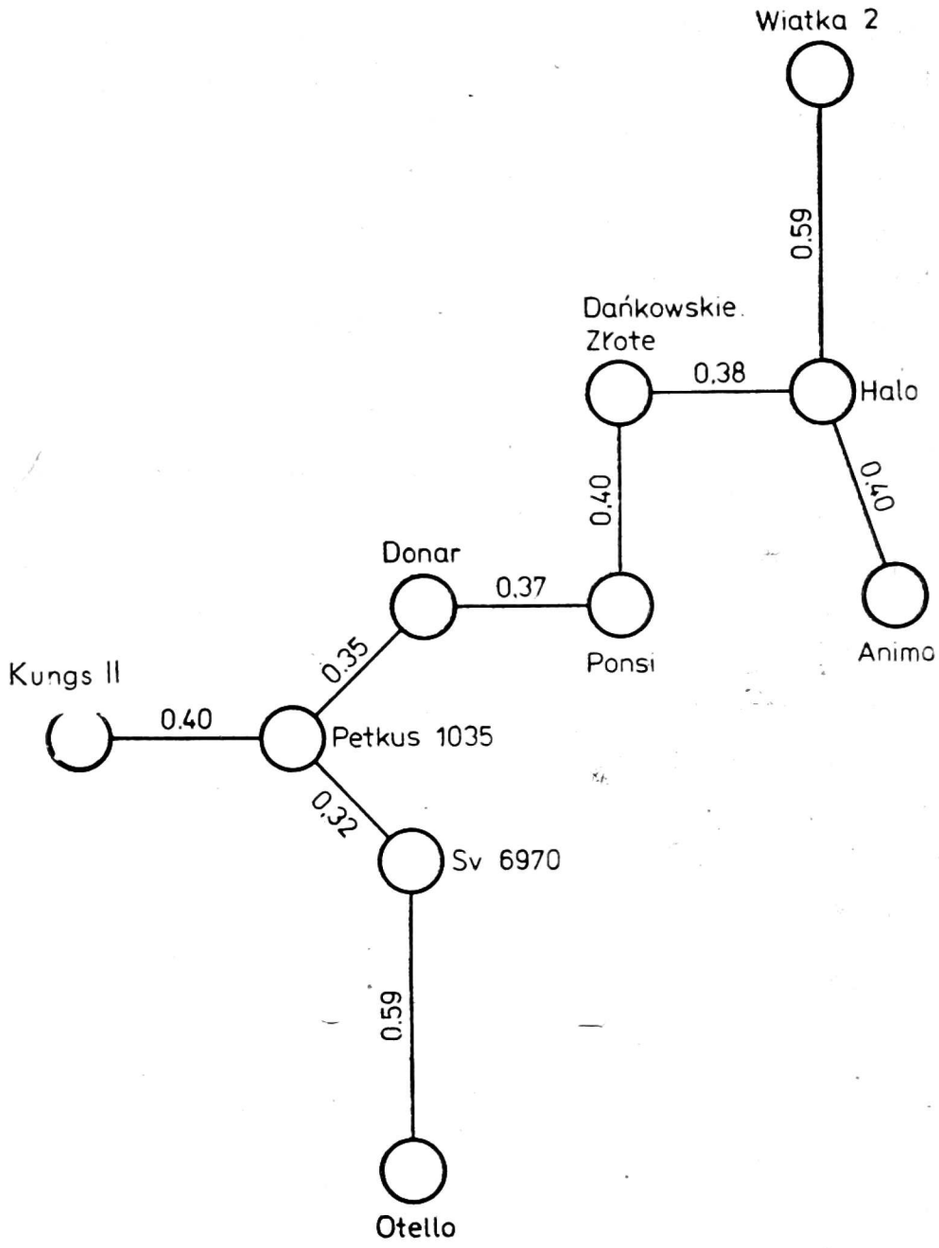

Fig. 2. A dendrite presenting intervarietal variability of 10 varieties of cultivated rye and genetic distances between them

20, 21, 23, 27 - 31 from zone III and 12, 15, 17, 18, 21, 23, 25, 28, 29, 31, 33 from zone IV were encountered very rarely and exclusively in one of the varieties.

It was found that there is a significant differentiation in the degree of polymorphism of the studied varieties (Table 3). A relatively smaller polymorphism was displayed by alfa-amylase of the cv. Otello (0.54), whereas the largest — by alfa-amylase of the cv. Kungs II (0.86). The remaining varieties could be divided into two groups. The varieties Petkus 1035, Ponsi, Donar, Sv 6970 and Animo were characterized by a lower degree of polymorphism than the cultivars Halo, Wiatka and Dańkowskie Złote.

Beside phenotypic differentiation, the zymograms of amylases displayed differences also in the number of bands. Individual endosperms were found to have from 4 to 14 isoamylases (not including bands from zone II). However, the mean number of bands in most cultivars was from 7.2 to 7.8. Only in the cv. Otello, a single individual exhibited the presence at average 6.0 bands, while in the cv. Kungs II this value was 8.2.

On the basis of indices of genetic similarity summarized in Table 4 it could be inferred that the strain Sv 6970 and then Petkus 1035, Donar, Ponsi, Kungs II and Animo had the isoamylase composition most similar to that of the cv. Otello. The phenotypes of the remaining cultivars, particularly Wiatka 2, showed no similarity to the phenotypes of the cv. Otello. Genetic similarity of the studied cultivars is presented in the form of a dendrite (Fig. 2). Petkus 1035, Sv 6970, Donar and Ponsi constituted a group of the most similar cultivars, whereas the cultivars Otello, Wiatka 2 and Kungs II were extremely distinct.

DISCUSSION

In the studies on interlinear variability of rye endosperm isoamylases (Łapiński, Masojć 1983), 29 homozygous phenotypes were found out within zones I, III and IV of the zymograms. They were distinguished by a relatively small number of bands. Thus, in zone I, 0-1-banded types were found, in zone III — 1-2-banded (with 0-3 trace bands) and in zone IV — two-banded types.

Population varieties of rye were characterized by a significantly higher diversity of electrophoretic phenotypes of amylases than inbred lines. Most of the previously distinguished homozygous phenotypes were also detected in particular individuals of the studied varieties, however, as a rule they were encountered comparatively rarely. More frequent were phenotypes with a larger number of bands i.e. 2 — in zone 1, 3-4 in zone III and 4-banded ones in zone IV. Each of them contained the sum of bands from definite combination of two homozygous phenotypes. Also phenotypes consisting of 5-6 bands were found in zone III and those of 5-7 bands — in zone IV, however the frequency of their occurrence was generally low. It may be considered that phenotypes consisting of a larger number of bands constitute examples of heterozygotes. Their considerable number indicates a high degree of heterozygosity of the studied varieties at genic loci of amylases.

On the basis of the falling number (Grochowski 1981; Klammann et al. 1982; Wolski 1982), the cultivars: Otello (commonly used as a standard), Sv 6970, Donar, Ponsi, Kungs II and Petkus 1035 may be recognized to have a high or increased resistance to sprouting. The remaining varieties, particularly Dańkowskie Złote, represent rye susceptible to sprouting. Among them the cv. Animo only in some years displayed increased values of the falling number. Besides that it is known that the cultivars Otello, Sv 6970 and Donar represent the final effect of the breeding process, the purpose of which was a decrease of the alfa-amylase activity. Their isoenzymatic amylase composition deviated to a considerable degree from the set found in sprouting varieties. It was especially clear in the standard cultivar Otello, which was characterized by the lowest degree of polymorphism, by the smallest number of electrophoretic phenotypes and the lowest mean number of bands. The most frequent phenotype in that variety was amy 12b, 13, 16, 19. From unpublished studies of the first of the authors it follows that the inbred

line Ot 1-3 with exactly such phenotype, derived from the cv. Otello, is characterized by a high sprouting resistance.

Isoamylase sets in varieties with increased sprouting resistance — Sv 6970, Donar as well as Petkus 1035 and Ponsi — display in relation to each other, as well as to isoamylases of the cv. Otello relatively the highest similarity. The central place in that group of varieties is occupied by Petkus 1035, which is understandable, since all the analysed varieties except the cultivar Wiatka 2 are related with the rye Petkus to a larger or smaller degree.

As known (Persson 1975), the cultivar Otello was selected from the variety Kungs II, the main criterion of selection being a low activity of alfa-amylase. From a comparison of isoamylases of both varieties it follows that they are very similar in the zone of beta-amylase, whereas they are significantly different in the zones of alfa-amylases. Regarding alfa-amylases the cv. Kungs II showed a much lower similarity to the cv. Otello than the cv. Animo not closely related with it (Table 4). Significant differences in the isoenzymatic composition of alfa-amylase of the varieties Otello and Kungs II could arise as a result of selection aimed at an increase of sprouting resistance. This hypothesis is supported by the fact that the cv. Otello is 27 alfa-amylase phenotypes poorer than the cv. Kungs II, principally all the phenotypes occurring in Otello being present also in Kungs II. In addition to that the endosperms of the cv. Kungs II averagely contain 3 isoamylases more than those of the cv. Otello. It cannot be also excluded that the revealed differences arose as a result of an accidental pollination with pollen of other varieties during seed reproduction of the cv. Kungs II. However, such a suggestion seems to be little probable, as the phenotypes detected in the cv. Kungs as significantly frequent, were rare in all the remaining varieties.

An increased sprouting resistance was not always related with a lower number of active alfa-amylases. Though the endosperm of the cv. Otello was characterized by the lowest number of alfa-amylases, that number, however, was the largest in the cv. Kungs II, recognized as little susceptible to sprouting. On the other hand, a large difference in sprouting resistance between the varieties Sv 6970 and Dańkowskie Złote was not reflected in the number of isoamylases. In the light of the obtained results it may be inferred that there are possibilities to decrease significantly the numbers of alfa- and beta-amylases in population varieties of rye by selection — in extreme case — to 4 alfa-isoamylases active in a single endosperm.

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POLIMORFIZM AMYLAZ W BIELMIE ŻYTA
II. WEWNĄTRZODMIANOWA I MIĘDZYODMIANOWA ZMIENNOŚĆ ELEKTROFORETYCZNEGO SPEKTRUM AMYLAZ

Streszczenie

Przy użyciu techniki elektroforezy w żelu poliakrylamidowym badano zmienność składu izoenzymatycznego alfa- i beta-amylazy z bielma 10 odmian populacyjnych i rodów żyta (Dańkowskie Złote, Animo, Halo, Otello, Petkus 1035, Ponsi, Donar, Kungs II, Sv 6970 i Wiatka 2). Ogółem wyróżniono 64 fenotypy elektroforetyczne alfa-amylazy oraz 16 — beta-amylazy. Liczba prążków na zymogramach uzyskanych z pojedynczych bielm wynosiła od 4 do 14. Odporna na porastanie odmiana Otello wyróżniała się najniższym stopniem polimorfizmu amylaz i najniższą średnią liczbą prążków, a w porównaniu z pozostałymi odmianami wykazywała równocześnie największe odległości genetyczne. Odmiany o podwyższonej odporności na porastanie: Sv 6970, Donar, Kungs II, Petkus 1035, Ponsi — wykazywały wyższy stopień podobieństwa do odmiany Otello niż odmiany skłonne do porastania: Dańkowskie Złote, Wiatka 2, Halo. Alfa-izoamylazy odmiany Kungs II i wywodzącej się z niej odmiany Otello wykazywały stosunkowo niski stopień podobieństwa.

Wyniki sugerują, że skład izoenzymatyczny amylaz bielma nie jest cechą selekcyjnie obojętną w hodowli odmian żyta odpornych na porastanie.

ПОЛИМОРФИЗМ АМИЛАЗ В ЭНДОСПЕРМЕ РЖИ ВНУТРИ- И МЕЖСОРТОВАЯ ИЗМЕНЧИВОСТЬ ЭЛЕКТРОФОРЕТИЧЕСКОГО СПЕКТРА АМИЛАЗ

Резюме

С помощью техники электрофореза в полиакриламидовом геле исследовалась изменчивость изоэнзиматического состава альфа- и бета-амилаз из эндоспермы 10 популяционных сортов и линий ржи (Dańkowskie Złote, Animo, Halo, Otello, Petkus 1035, Ponsi, Donar, Kungs II, Sv 6970, Wiatka 2). Всего выло выделено 64 электрофоретических фенотипов альфа-амилаз и 16 фенотипов бета-амилаз. Число полос на зимограммах, полученных из отдельных эндосперм, составляло от 4 до 14. Устойчивый к прорастанию сорт Otello отличался наинисшей степенью полиморфизма амилаз и наименьшим средним числом полос, а также имел наибольшие генетические расстояния по сравнению с остальными сортами. Сорта с подвышенной устойчивостью к прорастанию — Sv 6970, Donar, Kungs II Petkus 1035, Ponsi — имели высшую степень сходства с сортом Otello, чем прорастающие сорта — Dańkowskie Złote, Wiatka 2, Halo. Альфа-изоамилазы сорта Kungs II и выведенного из него сорта Otello обнаруживали относительно низкую степень сходства.

На основании полученных результатов можно предположить, что изоэнзиматический состав амилаз эндоспермы не есть селекционно нейтральным признаком в разведении сортов ржи, устойчивых к прорастанию.