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B Chromosome Frequency in Yugoslav Rye Populations

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Abstract. The cytological analysis of 25 Yugoslav rye populations, collected from Slovenia Serbia and Macedonia, showed the presence of B chromosomes in the all populations analysed (100%). The number of B chromosomes present was small, from 1 to 3, while the average number per plant ranged from 0·13 to 0·97. The frequency of rye plants with B chromosomes for Yugoslavia had an average of 27·10%. The frequency of plants with B chromosomes and the average number of that chromosome category per plant were appreciably greater in the arid region of Macedonia than in the humid region of Slovenia, the differences being significant and real biometrically.

Comparing the data of other authors for primitive Asian rye populations, it was established that the B chromosome frequency is lowest in the populations from regions designed as centres of the origin of this plant species (Near East, Asia Minor), with a considerable successive increase of their frequency further as well toward the East (Transbaikal, Korea), as toward the West (Balkan Peninsula, Yugoslavia). Possible causes of the B chromosome frequency increase in the populations out of the centres of rye origin were discussed, and it was pointed out to the importance of their study in primitive West European populations.

Studying B chromosomes of rye, MÜNTZING (1954, 1957, 1958, 1963) established that this category of chromosomes was rare or completely absent in European high-bred varieties. In primitive Asian rye populations, collected from possible centres of the origin of this species (Iran, Afghanistan, Turkey), B chromosome frequency is a high one. Going toward the eastern parts of Asia (Transbaikal, Korea), farther from the centres of the origin of rye, the frequency of this category of chromosomes considerably increases (OINUMA 1952, MÜNTZING 1957, LEE 1963).

With respect to the fact Müntzing's data on B chromosome frequency for Europe are related to high-bred rye varieties only and that there is no data about their frequency for the European population material, we attempted to study the frequency of that chromosome category in Yugoslav rye populations. We believed that such a study should be of interest, since no high-bred varieties are raised in Yugoslavia, where only primitive or semi-primitive populations exist. Besides this, rye is widely distributed in

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Yugoslavia, from the extreme NW (Slovenia) to the extreme SE (Macedonia).

Material and Methods

The investigated experimental material included 25 Yugoslav rye (*Secale cereale* L.) populations, i.e. 9 from Slovenia (north-western area), 7 from Serbia (eastern area), and 9 from Macedonia (south-eastern area).

For germination rye seed was put into Petri dishes on water-wet filter paper. The dishes were left in the thermostat at a constant temperature of 23° C. The germinated seeds, in which primary roots were approximately 1·5 cm long, were transferred to special dishes with 0·2% solution of BDH colchicine (BATTAGLIA 1957). The pretreatment lasted for 2 hours. The fixation and staining were performed as described by SNOW (1963).

The cytological data obtained was elaborated by standard biometrical methods.

Results and Discussion

The data on the number and frequency of B chromosomes for the all Yugoslav rye populations investigated is shown in Tab. 1.

B chromosomes were found in all the Yugoslav rye populations. Their number was small, ranging from 1 to 3. Three B chromosomes were found in 6 populations only, viz. in the populations of Lesce, Kranj and Podbrežje (Slovenia), Šipačina (Serbia), and Karbinci and Pehčevo (Macedonia).

The B chromosome frequency was lowest in the Lesce population from Slovenia (10·00%), and highest in the Pehčevo population from Macedonia (54·84%). Arranged by regions, B chromosome frequencies were from 10·00% (Lesce population) to 32·35% (Podbrežje population) for Slovenia; from 15·78% (Lisina population) to 48·57% (Inovo population) for Serbia; and from 19·35% (Bogoslovac population) to 54·84% (Pehčevo population) for Macedonia.

The average number of B chromosomes per plant was smallest in the Lesce population from Slovenia (0·13 $\pm$ 0·060), and greatest in the Pehčevo population from Macedonia (0·97 $\pm$ 0·185).

It is evident from Tab. 1 that the B chromosome number in the investigated rye populations of Yugoslavia was relatively small — up to 3; the small number of B chromosomes (not exceeding 4) in primitive rye populations was also found by OINUMA (1952) and MÜNTZING (1954, 1957).

The average number of B chromosomes per plant in the investigated rye populations of Yugoslavia did not exceed 1 (Tab. 1). In the rye populations from Korea MÜNTZING (1957) found that the average number of B chromosomes per plant ranged from 0·36 to 2·32, i.e. it was considerably larger than the one found in rye populations from Yugoslavia (between 0·13 and 0·97 — see Tab. 1).

Table 1
Number and frequency of B chromosomes in Yugoslav rye populations

Population	Number of plants analysed	Number of plants with B chromosomes				Average number of B chromosomes per plant $\bar{x} \pm s_{\bar{x}}$	% of plants with B chromosomes
		0	1	2	3		
Slovenia							
Pivka	55	45	8	2	—	0·22 ± 0·067	18·19
Lesce	60	54	5	—	1	0·13 ± 0·060	10·00
Kranj	34	28	4	1	1	0·27 ± 0·114	17·64
Podbrežje	34	23	8	2	1	0·44 ± 0·128	32·35
Zvirce	48	40	4	4	—	0·25 ± 0·086	16·66
Kovor	38	27	9	2	—	0·34 ± 0·095	28·95
Postojna	41	29	11	1	—	0·31 ± 0·082	29·27
Tržič	45	36	9	—	—	0·20 ± 0·060	20·00
Begunje	38	31	7	—	—	0·18 ± 0·064	18·52
Serbia							
Šipačina	42	27	12	2	1	0·45 ± 0·109	35·71
Gradac	35	27	7	1	—	0·25 ± 0·086	22·86
Lisina	38	32	3	3	—	0·23 ± 0·095	15·78
Gornja Kamenica	32	25	5	2	—	0·25 ± 0·105	21·87
Inovo	35	18	11	6	—	0·66 ± 0·192	48·57
Šesti Gabar	38	29	4	5	—	0·37 ± 0·116	23·79
Gornji Branetić	30	21	4	5	—	0·46 ± 0·143	30·00
Macedonia							
Bogoslovac	31	25	4	2	—	0·26 ± 0·103	19·35
Karbinci	31	16	3	10	2	0·94 ± 0·192	48·39
Kiselica	35	26	6	3	—	0·34 ± 0·108	25·71
Trabotovište	34	21	8	5	—	0·52 ± 0·127	38·22
Kočilari	37	26	3	8	—	0·51 ± 0·139	29·73
Jastrebnik	31	24	5	2	—	0·29 ± 0·106	22·58
Leški	32	22	4	6	—	0·50 ± 0·142	31·25
Pehčevo	31	14	6	9	2	0·97 ± 0·185	54·84
Vladimirovo	37	25	9	3	—	0·40 ± 0·106	32·43

It is characteristic that we found B chromosomes in all our rye populations studied (100% — Tab. 1). The presence of B chromosomes in all studied Korean rye populations was also observed by OINUMA (1952), MÜNTZING (1957), and LEE (1963). On the contrary, using the material from the centres of rye origin, MÜNTZING (1954, 1957) found B chromosomes present in some populations only (Afghanistan, Turkey). The same author found B chromosomes in about two-thirds of rye populations collected from Iran.

The average frequency of rye plants with B chromosomes present for all Yugoslav populations studied is relatively high — 27·10% (Tab. 2). The value obtained for Yugoslavia is double as compared with the value found by MÜNTZING (1954, 1957) for some rye populations from Turkey and Afghanistan (13·3% and 14·1% respectively), and with the values calculated from his data for Iranian populations (11·9%). The average value for Yugoslav rye populations is rather close to the value reported by MÜNTZING (1958a,

Table 2

Average frequency of plants with B chromosomes for the all Yugoslav rye populations studied

Category	5—10	10—15	15—20	20—25	25—30	30—35	35—40	40—45	45—50	50—55	Total number of populations analysed	Average percentage of plants with B chromosomes $\bar{x} \pm s_{\bar{x}}$
Number of populations	1	0	7	4	5	3	2	0	2	1	25	27·10 ± 0·43

1958b, 1963) for a population from Transbaikal (28·2%). On the other hand, the average frequency of plants containing B chromosomes is half of the value calculated from MÜNTZING's data (1957) for Korean rye populations (about 54% with frequencies ranging from 19·4% to 91·5%) and also considerably lower than the value obtained by LEE (1963) for Korean populations (between 39% and 53%, with the average value above 40%).

Table 3

Number and frequency of B chromosomes in rye populations in individual regions, with *d* values

Region	Number of plants analysed	Number of plants with B chromosomes				Average number of B chromosomes per plant $\bar{x} \pm s_{\bar{x}}$	% of plants with B chromosomes
		0	1	2	3		
Slovenia	393	313	65	12	3	0·24 ± 0·027	20·36
Serbia	250	179	46	24	1	0·39 ± 0·042	28·40
Macedonia	299	199	48	48	4	0·53 ± 0·046	33·45
Entire Yugoslavia	942	691	159	84	8	0·38 ± 0·022	26·64

d values for the ratios:
(minimal satisfactory value) Slovenia—Serbia 3·01
Slovenia—Macedonia 5·47
Serbia—Macedonia 2·26

In Tab. 3, where the data for Slovenian, Serbian and Macedonian areas according to the population groups are shown, one observes clearly the increase both in the average percentage of plants with B chromosomes and the average number of that chromosome category per plant from Slovenia through Serbia to Macedonia. The data indicates that the B chromosome frequency and its average number per plant is lower in the populations from Slovenia, a typical forest region with more than 50% of conifers and with humid Atlantic (Central European) climate, than in the populations from Macedonia, a region of unstable forests with continental and arid climate. At the same time, these results clearly indicate the importance of climatic-ecological factors for frequency, adaptability and maintenance of this chromosome category in the genotypes formed under the existing environmental conditions. Besides this, it is necessary to emphasize that the differences in the average number of B chromosomes were biometrically real and significant for the ratios: Slovenia — Serbia and Slovenia — Macedonia. The reduction of B chromosome frequency under the influence of humid climate, as its increase in arid climate was reported by FRÖST (1958) for *Centaurea scabiosa* and LEWIS (1953) for *Clarkia*.

The existing data concerning the primitive rye populations studied up to now indicates that the frequencies of populations and plants with the presence of B chromosomes are the lowest in the regions designated as centres of the origin of this plant species (Near East und Asia Minor). These frequencies increase largely and successively toward the East (Transbaikal, Korea) and appreciably toward the West (East Europe — Yugoslavia). It seems that farther from the centres of the rye origin both toward the East and the West, B chromosome frequency in primitive populations also increases, viz. there appear genotypes tolerant to an increased number of that category of chromosomes. This fact has been obviously confirmed by data obtained for primitive Asian rye populations. The data for Europe is not yet sufficient, since it is related to Yugoslav populations only. It would be interesting, therefore, to study B chromosome frequencies in West European rye populations where, theoretically, one could expect an increase of frequency of supernumerary chromosomes taking into account the data obtained for Yugoslav populations.

It is difficult to establish precisely the causes of such high concentrations of B chromosomes in primitive rye populations outside the region of origin centres of this plant species. It is also difficult to explain the causes of their successive increase from the centres of origin both toward the East (Far East in Asia) and toward the West (Balkan Peninsula in Europe). One could, perhaps, partly accept MÜNTZING's opinion (1957) that the B chromosome concentration is "only a consequence of historic factors during the distribution of the species *Secale cereale*" (p. 684).

The B chromosome concentration in primitive rye populations is obviously controlled by a complex of conditions, the most important among them being climatic, edaphic and ecological ones in the areas concerned. MÜNTZING (1963) thinks, therefore, that the ecological and climatic conditions in Korea are more favourable for the adaptation and maintenance of B chromosomes in rye populations as compared with the conditions in other regions. Besides this, a high adaptability of B chromosomes and the tolerance of genotypes formed toward the increase of B chromosome frequency are important for their high concentration and maintenance (LEWIS 1953, RICK and NOTANI 1961, MÜNTZING 1963). GRUN (1959), however, presented a view that any population must be regarded as a balanced environmental-genetic system. Hence, B chromosomes are present and their genes benefit only when they appear with specific A-chromosome genotypes and under specific environmental conditions. FRÖST (1958) thinks that the differences in average ecological conditions could be accepted as an indication that the variation in B chromosome frequency among populations of various regions is a result of unequal selective values of plants with and without B chromosomes under various environmental conditions, i.e. a result of the interaction between environmental (ecological) conditions and genotype constitution of the plants. He is of the opinion, therefore, that under determined ecological conditions one must adopt the existence of natural selection in favour of plants with B chromosomes (e.g. in the continental climate with a low humidity, as in populations of Macedonia) and, under other conditions, the existence of a natural selection in favour of plants with a smaller number or absent of B chromosomes (more Atlantic climate and high humidity, as in the populations of Slovenia). Similar views on the role of natural selection are presented by BOSEMARK (1956).

Finally, MÜNTZING (1963) holds that, due to the rigid breeding work, the European rye varieties either have a low frequency of B chromosomes or none at all. He regards, therefore, that a rigid selection of high fertility is an important factor in the reduction or complete absence of B chromosomes.

In any case, it could be concluded that for the conservation and the high frequency of B chromosomes, as well as for their distribution in primitive rye populations, a complex of factors is responsible, the degree of their expression being dependent on their interactions. Such a complex includes ecological, edaphic and climatic conditions, the B chromosome adaptability, the tolerance of formed genotypes to B chromosomes, the interaction between genotypes and the environment, and the influence of natural selection.

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References

BATTAGLIA, E.: Filogenesi del cariotipo nel genere *Urginea*. I—III. *U. maritima* (L.) BAKER, *U. fugax* (MORIS) STEINH. ed *U. undulata* (DESF.) STEINH. — Caryologia **9** : 234—272, 1957.

BOSEMARK, N. O.: On accessory chromosomes in *Festuca pratensis*. III. Frequency and geographical distribution of plants with accessory chromosomes. — Hereditas **42** : 198—210, 1967

FRÖST, S.: The geographical distribution of accessory chromosomes in *Centaurea scabiosa*. — Hereditas **44** : 75—111, 1958.

GRUN, P.: Variability of accessory chromosomes in native populations of *Allium cernuum*. — Amer. J. Bot. **46** : 218—224, 1959.

LEE, W. J.: Frequency and geographical distribution of rye (*Secale cereale*) with accessory chromosomes in Korea. — Genetics Today, Proc. XI Intern. Congr. Genet. Hague, Vol. 1 : 119 (Abstr.), 1963.

LEWIS, H.: Quantitative variation in wild genotypes of *Clarkia*. — Symposium on Genetic of Population Structure, Pavia (Italy): 114—125, 1953.

MÜNTZING, A.: Cyto-genetics of accessory chromosomes (B-chromosomes). — Proc. IX Intern. Congr. Genet., Caryologia (Suppl.) **6** : 282—301, 1954.

MÜNTZING, A.: Frequency of accessory chromosomes in rye strains from Iran and Korea. — Hereditas **43** : 682—685, 1957.

MÜNTZING, A.: Accessory chromosomes. — Trans. Bose Res. Inst. (Calcutta, India) **22** : 1—15, 1958a.

MÜNTZING, A.: A new category of chromosomes. — Proc. X Intern. Congr. Genet., Montreal (Canada) Vol. I : 453—467, 1958b.

MÜNTZING, A.: Effects of accessory chromosomes in diploid and tetraploid rye. — Hereditas **49** : 370—426, 1963.

OINUMA, T.: Karyomorphology of cereals. — Biol. J. Okayama Univ. **1** : 12—71, 1952.

RICK, C. M., NOTANI, N. K.: The tolerance of extra chromosomes by primitive tomatoes. — Genetics 46 : 1231—1235, 1961.

SNOW, R.: Alcoholic „hydrochloric acid-carmine as a stain for chromosomes in squash preparations. — Stain Techn. **36** : 9—13, 1963.

L. Zečevič, Dobrila Paunovič, Genetické oddělení Ústavu pro biologický výzkum, Bělehrad, Jugoslavie: **Frekvence B chromosomů v jugoslávských populacích žita.** — Biol. Plant. **9** : 205—211, 1967.

Cytologická analysa 25 populací žita z Jugoslavie, které byly vybrány ve Slovinsku, Srbsku a Makedonii, ukázala, že ve všech analysovaných populacích (100 %) se vyskytovaly B-chromosomy. Počet přítomných B-chromosomů byl nízký, od 1 do 3, při čemž průměrný počet na jednu rostlinu se pohyboval v rozmezí od 0,13 do 0,97. Průměrná četnost žitných rostlin s B-chromosomy byla pro Jugoslavii 27, 10%. Četnost rostlin s B-chromosomy a průměrný počet chromosomů této kategorie, vztažený na jednu rostlinu, byly značně větší v aridní oblasti Makedonie než v humidní oblasti Slovinska. Rozdíly byly reálné a významné, jak to bylo prokázáno biometricky.

Při hodnocení údajů jiných autorů o populacích primitivních asijských žit bylo zjištěno, že frekvence B-chromosomů je nižší v populacích z oblastí, označovaných jako centra původu tohoto rostlinného druhu (Blízký Východ, Malá Asie) a postupně se jejich frekvence značně zvyšuje s postupem ve směru na východ (Zabajkalí, Korea) i ve směru na západ (Balkánský poloostrov, Jugoslavie). Diskutují se možné příčiny zvyšování četnosti B-chromosomů v populacích vně center původu žita a je zdůrazněn význam jejich studia v západoevropských populacích primitivních forem žita.

Л. Зечевич, Добрила Паунович, Генетическое отделение Института биологических исследований, Белград, Югославия: **Частота Б-хромозома в югославских популяциях ржи.** — Biol. Plant. 9 : 205—211, 1967.

Цитологический анализ 25 югославских популяций ржи из Словении, Сербии и Македонии показал наличие Б-хромосом во всех анализированных популяциях. Число Б-хромосом было небольшое, от 1 до 3, в то время как среднее число на одно растение колебалось от 0,13 до 0,97. Частота встречаемости ржаных растений с Б-хромосомами в Югославии достигала в среднем 27,10%. Встречаемость растений с Б-хромосомами и среднее количество хромосом данной категории в расчете на одно растение было с очевидностью более высоким в сухой зоне Македонии, чем во влажной области Словении, причем различия были достоверны и биометрически определимы.

При сравнении данных других авторов, относящихся к примитивным азиатским ржаным популяциям, было установлено, что частота встречиваемости Б-хромосом наиболее низка в популяциях из областей, которые считаются центрами происхождения этого вида растений (Близкий Восток, Малая Азия), и постепенно значительно возрастает как к востоку (Забайкалье, Корея), так и к западу (Балканский полуостров, Югославия). Обсуждаются возможные причины этого явления и высказываются мнения о важности изучения примитивных западноевропейских популяций.