GENETIC VARIABILITY IN WINTER RYE (*SECALE CEREALE* L.) ACCESSIONS AT EARLY STAGE OF SELF-POLLINATION MANIFESTED THROUGH FERTILITY, PLANT HEIGHT AND SECALINS

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*Selection of winter self-pollinated plants with short to medium stem height was initiated in 15 cultivated rye populations. About 8.8 % seed set per selfed spike was registered in the first two years. In inbred S_2 families, self-fertility varied between 0 − 73 seeds per isolated ear and plant height ranged from 76 to 115 cm. Response to selection and genetic advance in percent of the mean characterized the S_3 families for one cycle of selection. SDS-PAGE gel patterns showed two major protein bands for the rye HMW secalins − one slowly moving x-subunit expressed as 2r, 5.2*r and 5.3r, and the second quickly moving y-subunit, expressed as 6r, 6.5r, 7r and 9r. Regarding alleles in Glu-R1 and Gli-R2 loci, nine progenies appeared to show genetic homogeneity in proteins, supporting by low coefficients of variation for plant height. The HMW compositions 2r (alone band) and 5.3r+7r, were defined as new secalin subunits. 75K γ-secalins, encoded at Gli-R2, were composed by alleles a, b, c, for subunits d1, d2 and t1, respectively. The results showed that among all, four selfed rye progenies were considered as homogeneous genotypes and could be used as inbred lines in further genetic and breeding experiments.*

***Key words**: rye, inbred lines, plant height, heading date, self-fertility, secalins, Glu-R1, Gli-R2.*

ГЕНЕТИЧНА МІНЛИВІСТЬ ІЗОЛЯТІВ ОЗИМОГО ЖИТА (*SECALE CEREALE* L.) НА РАННЬОМУ ЕТАПІ САМОЗАПИЛЕННЯ ЗА ПОКАЗНИКАМИ ЗАПИЛЕНОСТІ, ВИСОТИ РОСЛИН ТА СЕКАЛІНУ

Селекцію озимих самозапильних рослин з невеликою або середньою висотою стебла ініціювали у 15 популяціях культурного жита. Впродовж перших двох років було зафіксовано близько 8,8 % насіння на одному самозапиленому колоску. У інбредних сімействах S_2 спостерігали самозапилення у діапазоні від 0 до 73 зернин на окремий колос, і висота рослин складала від 76 до 115 см. Реакція на селекцію та генетичне удосконалення у процентному вираженні середнього числа характеризувало сімейства S_3 щодо одного циклу селекції. Зразки ДНС-ПААГ продемонстрували дві основні смуги протеїну для високомолекулярних секалінів жита − одна x-субодиниця з повільним рухом, виражена як 2r, 5,2*r і 5,3r, і друга y-субодиниця з швидким рухом, виражена як 6r, 6,5r, 7r і 9r. Що стосується алелів у локусах *Glu-R1* та *Gli-R2*, 9 нащадків продемонстрували генетичну гомогенність у білках, що супроводжувалося низькими коефіцієнтами зміни висоти рослини. Високомолекулярні комбінації 2r (окрема смуга) і 5,3r+7r були визначені як нові субодиниці секаліну. 75K γ-секаліни, кодовані у *Gli-R2*, складалися з алелів *a*, *b*, *c* для субодиниць d1, d2 і t1, відповідно. Результати продемонстрували, що чотири, з-поміж усіх, нащадки самозапиленого жита є гомогенними генотипами, і їх можна використовувати як інбредні лінії у подальших генетичних та селекційних експериментах.

Ключові слова: жито, інбредні лінії, висота рослин, дата колосіння, самозапилення, секаліни, *Glu-R1*, *Gli-R2*.

REFERENCES

Amiour N, Dardevet M, Khelifi D, Bouguennec A, Branlard G. (2002a) Allelic variation of HMW and LMW glutenin subunits, HMW secalin subunits and 75K gamma-secalins of hexaploid triticale. Euphytica **123**:179−86.

Amiour N, Bouguennec A, Marcoz C, Sourdille P, Bourgoin M, Khelifi D, Branlard. (2002b) Diversity of seven glutenin and secalin loci within triticale cultivars grown in Europe. Euphytica. **123**:295−305.

APHA, 2019. United Kingdom national list trials: Trial procedures for official examination of value for cultivation and use (VCU) harvest 2019, March 2019, https://assets.publishing.service.gov.uk/vcu-procedure-winter-oilseed19.pdf.

Arias Aquirre A, Studer B, Do Santo J, Frei U, Lьbberstedt T. (2013) Mapping a new source of self-fertility in perennial ryegrass (*Lolium perenne* L.). Plant Breed. Biotech. **1**:385−95. doi: 10.9787/PBB.2013.1.4.385.

Bellil I, Bouguennec A, Khelifi D. (2010) Diversity of seven glutenin and secalin loci within triticale cultivars grown in France. Not. Bot. Hort. Agrobot. Cluj. **38**:48−55.

Crespo-Herrera LA, Garkava-Gustavsson L, Ehman I. (2017) A systematic review of rye (*Secale cereale* L.) as a source of resistance to pathogens and pests in wheat (*Triticum aestivum* L.). Hereditas. **154**:1−9. doi: 10.1186/s41065-017-0033-5.

Czyczylo-Mysza I, Myśkyw B. (2017) Amalysis of the impact of drought on selected morphological, biochemical and physiological traits of rye inbred lines. Acta Physiol. Plant. **39**:87. doi: 10.1007/s11738-017-2385-x.

Daskalova N, Spetsov P. (2020) Taxonomic relationships and genetic variability of wild *Secale* L. species as a source for valued traits in rye, wheat and triticale breeding. Cytol. Genet. **54**:71–81. doi: 10.3103/S0095452720010041.

Dennett AL, Cooper KV, Trethowan RM. (2013) The genotypic and phenotypic interaction of wheat and rye storage proteins in primary triticale. Euphytica. **194**:235–42. doi: 10.1007/s10681-013-0950-y.

Doneva S, Daskalova N, Spetsov P. (2018) Transfer of novel storage proteins from a synthetic hexaploid line into bread wheat, Zemdirbyste-Agriculture. **10**5:113–22. doi: 10.13080/z-a.2018.105.015.

Egorova IA, Peneva TI, Baranova OA, Voylokov AV. (2000) Analysis of linkage between biochemical and morphological markers of rye chromosomes 1R, 2R, and 5R and mutations of self-fertility at the main incompatibility loci. Russ. J. Genet. **36**:1423–30.

Goncharenko AA, Makarov AV, Ermakov SA, Semenova TV, Tochilin VN. (2015) Evaluation of ecological stability and plasticity of inbred lines of winter rye. Russ. Agric. Sci. **41**:87–94. doi: 10.3103/S106836741502010X.

Goncharenko AA, Makarov AV, Ermakov SA, Semenova TV, Tochilin VN, Tsygankova NV, Krahmaleva OA. (2019) Selection of winter rye (*Secale cereale* L.) inbred lines for general and specific combining ability and its relationship with valuable traits, Agric. Biol. **54**:38–46. doi: 10.15389/agrobiology.2019.1.38eng.

Hansen HB, Mшller B, Andersen SB, Jшrgensen JR, Hansen E. (2004) Grain characteristics, chemical composition, and functional properties of rye (*Secale cereale* L.) as influenced by genotype and harvest year. J. Agric. Food. Chem. **52**:2282–91. doi: 10.1021/jf0307191.

Igrejas G, Guedes-Pinto H, Carnide V, Branlard G. (1999) Seed storage protein diversity in triticale varieties commonly grown in Portugal. Plant Breed. **118**:303–6. doi: 10.1046/j.1439-0523.1999.00379.x

Johnson HW, Robinson HF, Comstock RE. (1955) Estimation of genetic and environmental variability in soybeans. Agron. J. **47**:314–8.

Jurkowski A, Bujak H, Nowosad K. (2014) Estimation of the level of infection by the powdery mildew *Blumeria graminis* f. sp. *secalis* of winter rye *Secale cereale* L. breeding material, JцKULL. J. **64**:332.

Kozub NA, Motsnyi II, Sozinov IA, Blume YaB, Sozinov AA. (2014) Mapping a new secalin locus on the rye 1RS arm. Cytol. Genet. **48**:203–7. doi: 10.3103/S0095452714040021.

Kubicka H, Carrillo JM, Benito C. (2005) Zmiennosc morfologiczna i polimorfizm bialek zapasowych w liniach wsobnych zyta ozimego (*Secale cereale* L.) (Morphological variability and storage proteins polymorphism in inbred lines of winter rye *Secale cereale* L.). Zeszyty Naukowe Politechniki Bialostockiej. **10**:257–65.

Kuneva V, Valchinova E, Stoyanova A. (2018) Evaluation of rye speciments in maturity stage on the basis of mathematical-statistical analysis. Agric. Sci. Technol. **10**:21–4. doi: 10.15547/ast.2018.01.005.

Kussovska V. (2011) Agronomic characteristics of the newly synthesized primary alloplasmic octoploid forms of triticale. Bulg. J. Agric. Sci. **17**:145–9.

Laemmli UK. (1970) Clavage of structural proteins during the assembly of the head of bacteriofage T4. Nature. **227**:680–5.

McIntosh RA, Hart GE, Devos KM, Morris CF, Rogers WJ. (2003) V. Catalogue of gene symbols for wheat: 2003 Supplement. Ann. Wheat Newsl. **4**9:246–82.

Miedaner T, Müller BU, Piepho H-P, Falke KC. (2011) Genetic architecture of plant height in winter rye introgression libraries. Plant Breed. **130**:209–16. doi: 10.1111/j.1439-0523.2010.01823.x.

Miedaner T, Schwegler DD, Wilde P, Reif JC. (2014) Association between line per se and testcross performance for eight agronomic and quality traits in winter rye. Theor. Appl. Genet. **127**:33–41. doi: 10.1007/s00122-013-2198-2.

Prášilová P, Prášil I. (2001) Winter-hardiness scale for wheat cultivars of different geographical origin. Icel. Agr. Sci. **14**:35–9.

Rakoczy-Trojanowska M, Orczyk W, Krajewski P, Bocianowski J, Stochmal A, Kowalczyk M. (2017) ScBx gene based association analysis of hydroxamate content in rye (*Secale cereale* L.). J. Appl. Genet. **58**:1–9. doi: 10.1007/s13353-016-0356-3.

Ribeiro M, Seabra L, Ramos A, Santos S, Pinto-Carnide O, Carvalho C, Igrejas G. (2012) Polymorphism of the storage proteins in Portuguese rye (*Secale cereale* L.) populations. Hereditas. **149**:72–84. doi: 10.1111/j.1601-5223.2012.02239.x.

Salmanowicz BP, Langner M, Kubicka-Matusiewicz H. (2014) Variation of high-molecular-weight secalin subunit composition in rye (*Secale cereale* L.) inbred lines. J. Agric. Food. Chem. **62**:10535–41. doi: 10.1021/jf502926q.

Schlegel R. (2014) Current list of wheats with rye and alien introgression. Version 02-14. http://www.rye-gene-map.de/rye-introgression.

Sesay S, Ojo D, Ariyo OJ, Meseka S. (2016) Genetic variability, heritability and genetic advance studies in top-cross and three-way cross maize (*Zea mays* L.) hybrids. Maydica. **61**:1–7.

Shewry PR, Parmar S, Miflin BJ. (1983) Extraction, se-

paration and polymorphism of the prolamin storage proteins (secalins) of rye. Cereal. Chem. **60**:1–6.
Simmonds NW. (1979) Principles of crop improvement. Published in the USA by Longman Inc., New York.
Singh RK, Chaudhary BD. (2004) Biometrical methods in quantitative genetic analysis. Kalyani Publishers. New Delhi, India.
Singh NK, Shepherd KW, Cornish GB. (1991) A simplified SDS-PAGE procedure for separating LMW subunits of glutenin. J. Cereal. Sci. **14**:203–8.
Snedecor GW, Cochran WG. (1980) Statistical methods, seventh edition. The Iowa State University Press.
Tikhenko N, Rutten T, Voylokov A, Houben A. (2008) Analysis of hybrid lethality in F_1 wheat-rye hybrid embryos. Euphytica. **159**:367–75. doi: 10.1007/s10681-007-9528-x.
Tikhenko ND, Tsvetkova NV, Lyholay AN, Voylokov AV. (2017) Identification of complementary genes of hybrid lethality in crosses of bread wheat and rye. Results and prospects. Russ. J. Genet. Appl. Res. **7**:153–8. doi: 10.1134/S2079059717020149.
Voylokov AV. (2007) Prospects of using self-fertility in breeding rye populations varieties. Russ. J. Genet. **43**:1173–80. doi: 10.1134/S1022795407100122.

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