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SELECTION OF WINTER RYE *(SECALE CEREALE* L.) FOR ALUMINUM– AND ACID RESISTANCE

ABSTRACT

Estimation of initial materials and selection of resistant biotypes were carried out in stress conditions of field, greenhouse and laboratory experiments. Classical and biotechnological methods (callus and cell selection) were used in creation of initial materials. Some cultivars had high level of aluminum resistance (RRL 80–100%). Activity of root acid phosphatases indicated high level of resistance of these cultivars. Root oxidizing activity allows distinguish these cultivars between each other, but not correlated with field data on their productivity. Aluminium stress leaded to reduction of number of productive caulis, reduction of autumn tillering, significant decrease of number of caulis in winter–spring period, decrease of regenerative ability after snow mould. Cultivar "Kirovskaja 89" was referred as relative acid– and aluminium resistant. The population "Cyprez" was obtained from cultivar "Kirovskaja 89" by periodical selection and had higher thickness of productive caulis and exceeded initial form by productivity. Cultivars "Falenskaja 4" and "Snezhana" were created by using classical methods of breeding. Short–stem cultivar "Regina" was formed from best regenerant plants, obtained by methods of cell selection. This cultivar exceeded standard "Vjatka 2" under aluminium field condition on 0.76 t/ha. Investigations confirm the opportunity of creation of winter rye cultivars, which combine acid and aluminium resistance with high stable productivity, high winter hardness and resistance to logging.

Key words: aluminium, breeding, regenerants, resistance, rye

INTRODUCTION

Podzol and turf–podzol soils with a low level of natural fertility, high acidity and high content of exchangeable $Al^{3\sim}$ ions are predominant on North–East of European part of Russia. The breeding and usage of edaphic tolerant cultivars of rye is most ecological pure and energy–saving way to lower the toxicity of acid soils for plants. Scientific researches and practical breeding of winter rye for this purpose on North–East of Russia was initiated at the end of 80s.

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MATERIALS AND METHODS

The researches were carried out in provocative conditions (H^+ and Al^{3+}) of field, greenhouse and laboratory experiments. Unique crop rotation at Falenki breeding station of North–East Agricultural Research Institute was used as provocative field background. It allows obtain statistically significant estimations of initial materials and breed biotypes by complex of parameters (productivity, winter hardiness, resistance to snow mould). Soils of provocative and control backgrounds had following parameters:

— control background: pH 5.4, content of P_2O_5 is 31.6 and K_2O 15.4 mg/100 g of soil;

— provocative background: pH 4.0; content of P_2O_5 is 14.0 and K_2O 10.0 mg/100 g of soil with 11... 16 mg of exchangeable Al^{3+} ions per 100 g of soil.

Estimation of initial material by reaction of its root systems on aluminium stress was conducted in Department of Plant Edaphic Resistance by using the method of paper–solution culture (Lisitsyn, 2000).

Alongside with the classical methods of breeding the biotechnological methods were used in creation of initial materials. Perspective samples of our own breeding were the subjects of studies. Aluminium and acid–resistant plant regenerants were created by selection on acid selective medium (pH 3.8...4.0) in culture of callus (Laboratory of Biotechnology). Further estimation and selection of them by complex of parameters under field condition was stipulated by the breeding program. After that, the recurrent selection was used on medium and hard provocative field backgrounds.

RESULTS AND DISCUSSION

Six winter rye cultivars were analyzed for resistance against heightened acidity, stipulated by high content of exchangeable aluminium, in paper–solution culture. The results are presented in Table 1.

Table 1

Relative acid resistance of winterrye cultivars (paper–solution culture, 5 days)

Cultivar	Root length		Coefficient of variation in aluminium treatment	Relative root length (RRL)
	Control treatment (distilled water)	Aluminium treatment (1mM Al3+)		
Vjatka 2	79.9±0.9	83.3±0.6	25.0	104.2
Dymka	72.1±2.6	53.6±1.6	28.0	74.3
Kirovskaja 89	77.3±1.7	63.1±2.4	30.0	81.6
Alfa	101.1±0.8	71.2±2.6	18.6	71.1
Falenskaja 4	96.2±3.0	64.8±2.3	18.8	67.4
Snezhana	91.0±1.6	74.1±2.2	27.4	81.4

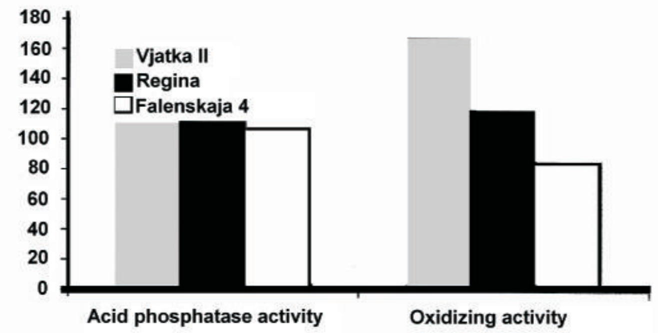

Fig.1 External mechanism of aluminium tolerace of 3 winter rye cultivars ($^{+}$Al/$^{-}$Al [%])

As it is visible from Table 1, some rye cultivars had high level of aluminium resistance (RRL 80–100%), but some of them had medium and low level of the parameter (with RRL *75%* and lower). It is interesting to point out that plants of cultivar "Vjatka 2" under aluminium treatment had longer roots then under control treatment. This may indicates stimuli action of aluminium as it was sometimes scored in the literature. Thus, Klimov (1985) reported stimuli effect of low aluminium concentrations (4–8 mg per L) on root growth of winter and summer wheat, winter rye, oat, and barley. Rodina and Solodjankina (1999) also reported the same action of 10 mg/L Al on growth of root system of "Dma" barley. One can also refers articles of Andrew *et al.* (1973), Mullette *(1975),* Matsumoto *et al.* (1976), Bennet *et al.* (1987), Taylor (1988), and some other.

On diagram (Fig. 1), we present the data about biochemical activity of roots of some winter rye cultivars.

The action of external resistance mechanism, which can be estimated by relative activity of acid phosphates, indicates high level of resistance of these cultivars. At the same time, relative root oxidizing activity allows distinguish these cultivars between each other, but not correlates with field data on relative productivity of the given cultivars.

Perennial field investigations of genotype x environment interaction on different soil backgrounds indicated significant genotypic and biotypic variation of acid soil tolerance of different winter rye cultivars. Aluminium stress leaded to decrease of productivity because of reduction of number of productive caulis, reduction of autumn tillering, sig–

nificant decrease of number of caulis in winter–spring period, decrease of regenerative ability after snow mould (Table 2).

Table 2

Main biological parameters of winter rye grown on different soil backgrounds (1992–1994)

Parameter	Vjatka 2			Kirovskaja 89		
	1*	2*	3*	1*	2*	3*
Productivity [t × ha–1]	4.2	1.7	40	4.3	1.4	31
Winter hardness [%]	44	38	86	37	25	68
Spring regrowth [%]	75	57	76	67	51	76
Productive tillers	5.6	2.7	48	5.4	2.6	48
Thickness of productive cauli	382	170	44	423	170	40

1* neutral background
2*aluminium background
3*resistance [%]

Table 3

Effect of selection on biological properties of winter rye (Al provocative background, 1989–2000)

Cultivar	Productivity [t × ha^{-1}]		Winter hardness [%]		Productive caulis [plants × m^{-2}]		Productivity index	
	1*	2*	1*	2*	1*	2*	1*	2*
Kirovskaja 89 [(a)]	4.70	2.66	76	42	357	258	38	41
Cyprez	5.54	3.42	84	48	366	318	41	44
$LSD_{0.05}$	0.52	0.47	8.2	8.1	46.8	52.6	2.4	2.7

1* neutral background
2*aluminium background
[(a)] – initial form

Lesion by *Fusarium nivale* was heightened under acid soil condition up to 36%. Even under similar levels of snow mould infectious on both soil backgrounds, spring regrowth under acid condition was lowered for 13%. High of plants was decreased up to 23 cm.

Studies under edaphic stress condition shown that even high winter hardness and resistant cultivar “Vj atka 2” decreased its productivity up to 60% in comparison with neutral background. Cultivar “Kirovskaja 89” was referred as relative acid– and aluminium resistant. Other cultivar with less level of adaptation to local conditions had more signif–icant depression of productivity.

Natural provocative background allows select high aluminium toler–ant biotypes for forming perspective populations by complex of desirable parameters. The population “Cyprez” was obtained from cultivar “Kirovskaja 89” by using periodical selection by different parameters (including index of productivity). Because of more winter hardness, “Cyprez” had higher thickness of productive caulis (parameter of plas–ticity b_1 0.68) and exceeded initial form by productivity (Table 3).

Winter rye cultivars "Falenskaja 4" and "Snezhana", which ensured higher harvest under stress condition then standard cultivar "Vjatka2", were created by using classical methods of breeding. Short–stem cultivar "Regina" was formed from best regenerant plants, obtained by methods of cell selection. This cultivar exceeded standard "Vjatka 2" under provocative aluminium field condition on 0.76 t/ha (Table 4, Fig. 2).

Table 4

Estimation of winter rye cultivars on Al^{3+} provocative background (1989–2000)

Cultivar	Productivity [$t \times ha^{-1}$]	Winter hardness [%]	Productive caulis [plants × m^{-2}]	Productivity index
Vjatka 2 [(a)]	2.96	45	248	37
Falenskaja 4	3.62	48	332	43
Cyprez	3.42	48	318	44
$LSD_{0.05}$	0.47	8.1	52.6	2.7

[(a)] – standard

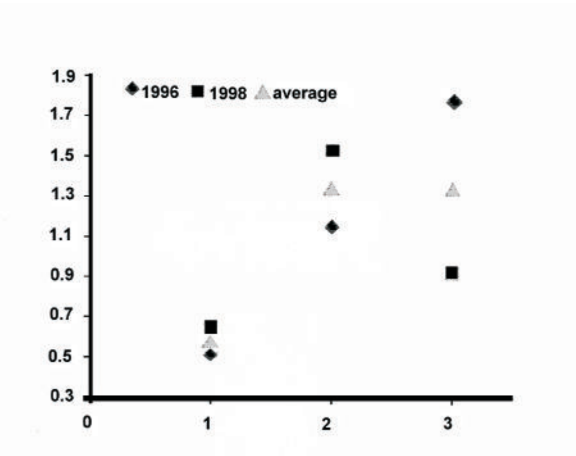

Fig. 2 Productivity of perspective winter rye cultivars under edaphic stress (Al^{3+}) [t/ha].
1 – Vjatka 2 (standard), 2 – Snezhana, 3 – Regina

Thus, the given investigations confirm the opportunity of creation of winter rye cultivars, which combine acid and aluminium resistance with high stable productivity, high winter hardness and resistance to log–ging.

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