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Winter-hardiness scale for wheat cultivars of different geographical origin

PAVLA PRÁŠILOVÁ
and
ILJA PRÁŠIL
Research Institute of Crop Production, Drnovská 507, CZ-16106 Prague 6, Czech Republic
E-mail: Prasilova@vurv.cz

SUMMARY

A provocation pot-culture method under natural conditions was used in 1975–1995 to assess winter-hardiness of a set of 820 winter wheat cultivars at a site of RICP in Prague. Data on pot winter survival in the treatments of the experiment were processed by a cultivar classification method. Winter survival indices (WSI) calculated for each cultivar were translated to a uniform 9-point winter-hardiness scale (WHS) describing the cultivar winter-hardiness potential. Significant agreement was found between field winter survival of 13 cultivars tested in Nordic countries and their WSI determined in RICP in Prague. The average degree of WHS of winter wheat cultivars of common geographical origin sets the requirements for wheat winter-hardiness in a given area or region.

Key words: cultivars, degree of winter-hardiness, potential winter-hardiness, wheat.

YFIRLIT

Skali til mats á vetrarþoli hveitis af mismunandi uppruna

Álagsaukandi pottatilraun við náttúrulegar aðstæður var gerð árin 1975–1995 til að kanna vetrarþol 820 stofna af vetrarhveiti á Plönturannsóknadeildinni í Prag. Niðurstöður lifunar í tilraununum voru reiknaðar með aðstoð stofnaflokkunaraðferðarinnar. Vetrarlifun (WSI) fyrir hvern stofn var breytt í 9 stiga vetrarþolsskala (WHS) sem lýsir mögulegu vetrarþoli hvers stofns. Raunhæft samband fannst á milli lifunar 13 stofna á akri á Norðurlöndum og vetrarlifunar sem mæld var í Prag. Meðaltal mögulegs vetrarþols (WHS) stofna af vetrarhveiti af sama landfræðilega uppruna setur kröfur um vetrarþol hveitisins á ákveðnu svæði.

INTRODUCTION

Tolerance to freezing and other winter stress factors is one of the important characteristics of winter wheat. Winter-hardiness of wheat varies in the course of the winter season as a result of many external and internal factors (Fowler and Gusta, 1979; Prášil and Zámecník, 1991). Potential winter-hardiness of wheat cultivars is often overshadowed by environmental conditions and human interventions, so that overwintering of cultivars differs between years and localities. It is of importance if overwintering is stable such that overwintering of cultivars with higher potential hardiness is always more successful than of cultivars with lower hardiness, provided that no specific interventions have been made (e.g. wrong cultural practices, local disease infections). It is then possible for different workplaces to establish a similar order of winter-hardiness and freezing tolerance of cultivars if some standard conditions are observed (e.g. plant hardening) even though different tests are used. Results of experiments carried out in the seventies on an identical set of 16 wheat cultivars in the countries of Central and Eastern Europe (Koch, 1979), cultivar trials in Canada and USA (Fowler and Gusta, 1979) and many-year trials in the countries of northern Europe (Pulli *et al.*, 1996) have demonstrated this possibility.

Mutual comparisons of many-year results of wheat tests can be used to create a winter-hardiness scale that describes the potential tolerance of cultivars but would be applicable to an extensive area comprising a number of countries. On the basis of experiments conducted in Central and Eastern Europe, 8 wheat cultivars were proposed as standards representing 8 different classes of freezing tolerance (Koch, 1979). Field Survival Indices of cultivars (Fowler and Gusta, 1979; Fowler, 1992) are successfully used in Canada and USA for classification of cultivar winter-hardiness. The need to evaluate winter-hardiness of genetic resources of grain crops for gene banks resulted in a 5-point scale devised in Russia and Ukraine (Baraskova *et al.*, 1983) and a nine-point winter-hardiness scale constructed at our workplace in the Research Institute of Crop Production in Prague (Prášil *et al.*, 1994).

The Czech Republic is situated in Central Europe, on the boundary between maritime and continental climate. Snow thawing and topsoil flooding are typical of mild winters. Wheat plants are little hardened, so they are sensitive to sudden variations in temperature below the freezing point. In harsh winters, plants in the field are mostly under snow cover for a long time. They can become exhausted and consequently be attacked by pathogens (winter diseases). Recent years were characterised by mild winters. Typical are winters when thaws and cold periods with frosts of different intensity alternate. The main factor causing damage to grain crops in the Czech Republic is frost, the action of other winter stresses (flooding, ice-encasement, soil heaving, winter drought, snow cover) is shorter and on limited areas. The resulting overwintering of wheat in the field differs substantially between year, winter killing usually afflicts a certain group of cultivars only. That is the reason why a provocation pot-culture method under natural conditions was developed at the Institute's Prague workplace that enables the determination of differences in the overwintering of grain cultivars in winters of different harshness (Prášil and Rogalewicz, 1989). Variable conditions are achieved by a suitable combination of pot-culture covering and placing at various heights above the ground. This paper is based on the results obtained by a provocation pot-culture method in the past 20 years. The objective was to compare winter-hardiness of an extensive set of wheat cultivars of different origin that were tested in different years, and to describe the degree of their winter-hardiness by a uniform 9-point scale.

MATERIAL AND METHODS

Seed of wheat (*Triticum aestivum* L.) cultivars was received every year from the Central Institute for Supervising and Testing in Agriculture, the Gene Bank of our Institute and other partner breeding and research institutions in the CR and in other countries.

Winter-hardiness of wheat cultivars was assessed by a provocation pot-culture method under natural conditions that was described in detail in the paper by Prášil and Rogalewicz (1989). Plants were grown in wooden boxes (40×30×15 cm) filled with earth and placed at two heights above the ground (0 and 50 cm), partly protected with a roof against snow, so the treatments of experiment provided for the action of diverse winter stresses (frost, winter drought, flooding, soil heaving, ice-encasement, etc.). At least a half of the cultivars was replaced every year and the cultivars were sown on two or three dates. An automatic station was used to register temperatures and moisture contents of soil, and, in particular treatments, snow cover and frost heaval during the winter. In spring, plant survival and the degree of plant damage were assessed according to Prášil and Rogalewicz (1989) in each experimental treatment.

Data on overwintering of cultivars in the provocation trial in 1975–1995 were used to calculate Winter Survival Index of each cultivar. So-called cultivar classification method, continually developed at our workplace, was applied (Prášil *et al.*, 1989; Palovský *et al.*, 1992). The acquired winter survival data were processed after inverse logistic transformation by weighted two-way analysis of variance for unbalanced series of trials. Winter survival index (WSI), representing a cultivar's survival under average conditions, was estimated on a percentage scale for each cultivar, regardless of the year when it was tested. The cultivars were sorted according to the WSI values into nine degrees of the winter-hardiness scale (WHS) [1= the most sensitive (WSI<15) to 9= the hardiest (WSI>85)].

RESULTS AND DISCUSSION

A total of 820 wheat cultivars originating from 19 countries of Europe and America were assessed. Examples of calculated WSI and WHS for selected cultivars are presented in Table 1. Table 2 compares the order of cultivars according to WSI and field winter survival determined in tests carried out in 1990–1992 in the Nordic countries (Pulli *et al.*, 1996). The similar order (highly significant correlation, k=0.75) shows agreement of results obtained by both methods. Similar agreement of our results was found (results not shown) with other published data (e.g. Koch, 1979; Fowler, 1992).

Frost is the dominating factor in the provocation pot-culture method used in our trials. Other stress factors involve topsoil heaving, winter drought, ice-encasement or flooding which occur in some treatments of this method in limited periods. These other stress factors can be more important in some other areas of Europe and America. They contribute to a reduction in freezing tolerance of grain crops even when they do not cause plant killing. This explains the generally good agreement between freezing tolerance tests and field winter survival (Fowler, 1992; Pulli *et al.*, 1996).

The average WHS degrees for wheat cultivars from different countries of Europe is for example 2.8 for cultivars for Italy, 4.7 for Austria, 5.7 for Czech Republic, 5.7 for Poland, 5.8 for Denmark, 5.9 for Sweden, 7.0 for Finland. The effect of geographical origin of cultivars on the degree of winter-hardiness is evident as the average increases from south to north. It is also possible to deduce that a certain degree of winter-hardiness is typical of certain areas, e.g. WHS=6.2 and WHS=3.4 on the average for the Nordic countries and the countries of Western Europe, respectively.

A significant effect of the geographical origin of cultivars on its potential winter-hardiness was also reported in other studies (Koch, 1979; Pulli *et al.*, 1996). On the basis of WHS degrees given in this paper it is possible to make a comparison of winter-hardiness of wheat from different countries using a uniform scale. Average WHS degrees can serve as a breeding goal or an optimum degree of winter-hardiness necessary for winter wheat growing in different countries or areas within a country, e.g. WHS=3 is sufficient for cultivars grown in Italy, but WHS around 7 is required for cultivars grown in Finland. Cultivars with a lower WHS degree than indicated for the respective country or area can be at risk to suffer complete winter killing in harsh winters.

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Table 1. WSI and WHS of selected winter wheat cultivars in a provocation test conducted in RICP in Prague.
1. tafla. Vetrarlifun (WSI) og mögulegt vetrarþol (WHS) valinna stofna af vetrarhveiti í álagsaukandi tilraun sem gerð var á Plönturannsóknadeildinni í Prag.

Cultivar	Country origin	WSI %	WHS 1 to 9	Cultivar	Country origin	WSI %	WHS 1 to 9
Lgovskaja	UKR	87	9	Vlsevnica	BGR	49	5
Tarasovskaja 29	RUS	86	9	Estica	NLD	49	5
Pavlovka	RUS	84	8	Malwa	POL	49	5
Saljut	UKR	80	8	Kraka	DNK	48	5
Kosack	SWE	79	8	Maris Huntsman	GBR	48	5
Vlada	CZE	78	8	Zlatna Dolina	YUG	47	5
Bezostaja 2	RUS	78	8	Elpa	DEU	46	5
Mironovskaja 808	UKR	77	8	Istra	SVK	46	5
Samanta	CZE	76	8	Rexia	SVK	45	5
Blava	SVK	75	8	Genessis	FRA	45	5
Ebi	DEU	73	7	Florida	DEU	44	4
Amika	SVK	73	7	Versailles	NLD	43	4
Bezostaja 1	RUS	72	7	Sleipner	SWE	40	4
Leopold	AUT	69	7	Colombo	BEL	40	4
Sparta	CZE	69	7	Nova Zlatna	YUG	39	4
Aurora	UKR	67	7	Ferdinand	AUT	38	4
Solid	SWE	66	7	Bovictus	DEU	38	4
Lovrin 34	ROM	66	7	Gawain	GBR	38	4
Perlo	AUT	66	7	Gaspard	FRA	37	4
Iris	SVK	65	7	Konsul	SWE	36	4
Walde	SWE	64	6	Torysa	SVK	36	4
Kavkaz	RUS	64	6	Ritmo	NLD	36	4
Bruta	CZE	63	6	San Pastore	ITA	35	4
Turda 81	ROM	62	6	Pony	BEL	35	4
Hana	CZE	62	6	Carmen	ROM	35	4
Linna	FIN	62	6	Granta	GBR	34	3
Folke	SWE	61	6	Georg	AUT	34	3
Compact	AUT	60	6	Zagra	BGR	33	3
Viginta	SVK	60	6	Zdar	CZE	33	3
Sofia	CZE	60	6	Moisson	FRA	31	3
Ricardo	NLD	60	6	Advokat	DEU	30	3
Gama	POL	60	6	Cordial	FRA	30	3
Brigantina	UKR	59	6	Famulus	AUT	30	3
Moldava	ROM	58	6	Zwezda	YUG	30	3
Iulia	ROM	57	6	Requiem	BGR	29	3
Maris Beacon	GBR	56	6	Sava	YUG	29	3
Jana	POL	56	6	Copromar 6	ITA	28	3
Livia	SVK	56	6	Granit	AUT	26	3
Holme	SWE	55	6	Rialto	GBR	23	2
Urban	SWE	55	6	Barouder	FRA	22	2
Alana	CZE	55	6	Acion	FRA	19	2
Partizanka	YUG	54	5	Brimstone	GBR	19	2
Senta	CZE	53	5	Maris Hustler	GBR	17	2
Anja	DNK	53	5	Elysee	FRA	16	2
Bezostaja Rannaja	RUS	53	5	Colorben 4	ITA	15	2
Hadmerslebener Qual.	DEU	53	5	Rendor	FRA	13	1
Martin	AUT	52	5	Capta	FRA	12	1
Louvre	NLD	52	5	Brock	GBR	12	1

Table 2. Comparison of field winter survival (%) of wheat cultivars in Nordic countries (according to Pulli *et al.*, 1996) with WSI determined in RICP in Prague.
2. tafla. Samanburður á vetrarlifun (%) vetrarhveitisstofna á Norðurlöndum (sbr. Pulli et al.*, 1996) og WSI mælt á Plönturannsóknadeildinni í Prag.*

Cultivar	Field tests in the Nordic countries: Locations without snow	Locations with snow	Average %	Provocation pot-culture method in RICP-Prague WSI
Linna	77.6	82.1	80.1	62
Kosack	64.6	73.5	69.5	79
Walde	62.1	74.7	69.0	64
Folke	64.8	70.0	67.7	61
Norstar	64.2	70.4	67.6	75
Holme	54.0	68.8	62.1	55
Kraka	56.0	63.7	60.2	48
Solid	47.8	61.2	55.2	66
Sleipner	47.0	60.1	54.2	40
Urban	43.5	59.3	52.2	55
Gawain	41.9	47.4	44.9	38
Apollo	38.2	45.3	42.1	44
Longbow	40.4	43.4	42.0	34

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