COLD TOLERANCE IN EUROPEAN OAT GENETIC RESOURCES

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Abstract: *Oat is a crop with an important European history and tradition. The high value of oat in human nutrition, which is unique among cereals, is widely recognized and confirmed by health claims issued in various countries. It is based on a high content and quality of proteins, considerable content of fat with high proportion of polyunsaturated fatty acids, high contents of dietary fiber, especially the soluble, highly viscous mixed linked (1->3)(1->4)-ß-D-glucans, which hypo-cholesterolemic effects, minerals and antioxidants, especially tocopherols, tocotrienols and avenanthramides. Oat is considered moderately susceptible to Fusarium spp. infection and mycotoxin contamination. Nevertheless T2/HT-2 toxins raise considerable concerns in the European health administration (European Commission, 2006).*
Among winter cereals, oat is the most frost sensitive and its insufficient level of winterhardiness is the most important factor limiting the sowing of winter oat in Northern and Central Europe (Cattivelli et al., 1998).
Resistance to low temperatures, which limited yield potential and sustainable oat growing in many major oat growing regions in Europe, was the main aspect which have been evaluated in this paper.
The results of the evaluation of frost tolerance at first leaf stage, accomplished in the laboratory of Experimental Institute for Cereal Research, Fiorenzuola d'Arda, Italy were compared with the data of winter hardiness obtained in the field experiments carried out by Suceava Genebank in environments more frequently subjected to severe frost events, as compared to the Italian site

Keywords: *cold tolerance, winter hardiness, genotypes*

1. Introduction

In order to improve the utilisation of the oat germplasm collection in breeding programs, apart from biochemical and molecular characterisation, an extensive evaluation of important agronomic traits is also required. Resistance to abiotic stress is a crucial aspect for cultivar adaptation to agriculture environments. Among winter cereals, oat is the most frost sensitive and its insufficient level of winterhardiness is the most important factor limiting the sowing of winter oat in Northern and Central Europe [1].

Winter hardiness can be defined as the ability to survive throughout the winter. By the virtue of the wide range of stressful conditions that a plant may experience during the cold season, winter hardiness is a complex trait. Freezing temperature is the most relevant stress factor, although other stress situations, such as anoxia due to excess water or to ice encasement and photoinhibition due to the combination of light and low temperature, may also occur. In temperate areas, winter cultivars are preferred, whenever possible, as winter varieties are higher-yielding than spring ones, and the identification of new gene sources for frost tolerance is still an important task for oat improvement [2].

Despite the fact that genetic diversity has also been observed for freezing tolerance of non-acclimated barley plants, the ability of overwintering plants to withstand cold is mainly based on an adaptive response, known as cold acclimation or hardening, activated during growth at low non-freezing temperatures. Frost resistance can be assessed through field evaluation methods, a strategy depending of the occurrence of natural conditions which satisfactorily differentiated genotypes, or through artificial freezing tests such as percentage of post-stress survival, LT50 (temperature at which 50% of the population is killed), integrity of cell membranes after freezing [3], evaluation of the Fv/Fm ratio the maximum quantum yield of the PSII photochemistry after freezing [4].

A number of physiological traits such as proline accumulation, ABA and crown fructan content have been associated with the development of frost tolerance. Generally, the amount of these metabolites increases during acclimation, being higher in frost-tolerant genotypes versus frost-susceptible ones [5]. A comparison of a number of frost resistance evaluation methods in different crop species was carried out by [6]. The value of the laboratory tests appears to vary with the plant species, although for cereals frost resistance evaluation methods based on freezing assays provide the highest correlation with field survival.

2. Materials and methods

Winter hardiness was assessed in a field experiment at Suceava for 104 oat accessions (including 9 standards - Mures, Ivory, Jaak, Argentina, Mina, Belinda, Saul, Genziana, Auteuil).

The seeds were sown manually into one row of 1m length (50 seeds per row) in two replications with a distance between accessions of 25 cm. Time of sowing was October 1st 2009.

The following data were recorded:

- Number of emerged seeds.
- Number of survived plants after winter
- The field injury have been visually estimated on a 0-9 scale according to Rizza et al. (1994), where: 0: no damage; 1: slightly yellowed leaf tips; 2: half yellowed basal leaves; 3: fully yellowed basal leaves; 4: whole plants slightly yellowed; 5: whole plants yellowed and some plants withered; 6: whole plants yellowed and 10% plant mortality; 7: whole plants yellowed and 20% plant mortality; 8: whole plants yellowed and 50% plant mortality; 9: all plants killed.
- The environmental conditions were registered in the target period (October 2009 – March 2010).

All obtained results in the field were compared with obtained results in the laboratory of the Experimental Institute for Cereal Research, Fiorenzuola d'Arda, Italy The used method for frost tolerance was the chlorophyll fluorescence evaluation (Fv/Fm) on a set of 104 oat cultivars, at the temperature on -10°C and -12°C.

3. Results and discussion

A minimum air temperature of -24.7°C (-31°C soil temperature) was measured in January and severe freezing conditions persisted from December 2009 to March 2010 (Table1).

Table 1
The decadal temperatures registered at Suceava Meterological Centre, Romania, during period October 2009- March 2010

Decades	Aer temperatures			Soil temepratures				RH (%)	Sun light (h)	P
	Average	Max	Min	7 h. a.m	avera ge	Max	Min			mm
October, 2009										
Decade 1	12.4	19.3	7.3	8.7	12.2	23.4	5.9	79	39.0	12.4
Decade 2	6.0	10.3	2.5	4.4	5.9	12.3	2.1	83	27.7	35.2
Decade 3	7.8	11.8	5.0	5.1	7.6	14.6	4.0	86	40.4	15.0
Monthly average	8.7	13.7	4.9	6.0	8.5	16.7	4.0	83	107.1	62.6
November 2009										
Decade 1	3.3	5.5	1.4	2.7	3.6	6.4	1.8	93	4.4	7.9
Decade 2	6.8	10.5	3.7	4.2	6.0	10.8	3.0	87	22.3	4.4
Decade 3	6.5	12.8	2.2	1.0	4.3	12.3	0.1	80	50.2	6.3
Monthly average	5.5	9.6	2.4	2.6	4.7	9.8	1.6	87	76.9	18.6
December 2009										
Decade 1	2.4	4.7	0.6	1.4	2.5	5.2	0.9	97	9.2	0.2
Decade 2	-8.0	-6.1	-9.8	-1.2	-0.9	-0.2	-1.3	93	6.0	20.9
Decade 3	-1.3	2.4	-5.3	-4.1	-2.8	1.4	-5.9	87	22.7	16.0
Monthly average	-2.3	0.4	-4.8	-1.4	-0.5	2.1	-2.2	92	37.9	37.1
January 2010										
Decade 1	-2.4	0.0	-4.6	-3.8	-2.8	-0.6	-5.2	96	3.8	8.7
Decade 2	-5.1	-3.7	-5.8	-5.0	-4.4	-2.3	-6.0	97	0.0	19.0
Decade 3	-13.1	-9.2	-16.9	-17.5	-13.5	-6.0	-20.3	86	30.3	3.7
Monthly average	-7.0	-4.4	-9.4	-9.1	-7.1	-3.1	-10.8	93	34.1	31.4
February 2010										
Decade 1	-7.9	-4.3	-11.4	-12.3	-8.9	-2.6	-14.6	87	36.5	1.4
Decade 2	-2.1	0.8	-5.3	-4.6	-2.6	1.6	-6.6	98	15.4	30.0
Decade 3	0.3	4.4	-2.0	-2.3	-0.6	3.4	-3.4	93	18.6	3.8
Monthly average	-3.5	0.0	-6.5	-6.7	-4.3	0.6	-8.5	92	70.5	35.2
March 2010										
Decade 1	-2.9	1.3	-5.8	-5.9	-3.2	2.7	-8.4	86		27.4
Decade 2	0.6	5.8	-4.2	-3.9	-0.9	6.0	-7.0	73	49.6	2.2
Decade 3	9.2	15.5	4.3	5.6	8.7	18.1	2.6	69	81.9	16.8
Monthly average	2.6	7.8	-1.7	-1.2	1.8	9.2	-4.0	76	158.9	28.6

High damage occurred for most accessions. For 91 out of 104 accessions all plants were killed showing a visual score of 9 (Table 2): For 8 accessions a score of 8 (whole plants yellowed and 50% plant mortality) was recorded. Only five accessions were identified as superior for winter hardiness capacity showing a value of 6 (plants yellowed and up to 10% plant mortality) for 83/200-CR (coming from Bulgaria) and Local 7 (coming from Russia) and value of 7 (whole plants yellowed and between 10 to 20% plant mortality) for Millennium (coming from Great Britain), Ava and Donata (coming from Italy).

Table 2
The winter hardiness capacity of oat analysed genotypes

Status of sample	Genotype	No. of emerged seeds	No. of survival plants after winter	Score according Rizza, 1994, immediately after winter	Status of sample	Genotype	No. of emerged seeds	No. of survival plants after winter	Score according Rizza, 1994, immediately after winter
modern	Cavallo	14.5	0	9	modern	Raven	19.5	0	9
modern	Monarch	14.5	0	9	modern	Flaming	30	0	9
modern	Efesos	18.5	0	9	modern	Flamingsg	21	0	9
modern	Effektiv	21.5	0	9	modern	Nelson	27	0	9
modern	Ehostar	21	0	9	Standard	Ivory	34	0.5	9
Standard	Mina	19.5	0	9	modern	Tyfhon	20.5	0	9
cultivated	***83/200-C***	11.5	8.5	6	modern	Pergamon	18	0	9
cultivated	BGR 250	17.5	0	9	cultivated	Konradin	14.5	0	9
cultivated	Sofia 121	14	0	9	cultivated	Nuernberg	25.5	0	9
cultivated	BGR 7982	22	3.5	8	cultivated	Mayer A	22.5	0	9
modern	Veli	11	0	9	cultivated	Lueneburg	31.5	0	9
cultivated	Brnensky	20.5	1	8	modern	Sandokan	32.5	0	9
modern	Abel	21	0	9	modern	Kaplan	25.5	0	9
modern	Auron	22	0	9	modern	Leo	22	0	9
modern	Neklan	16.5	0	9	cultivated	Alo	29.5	0	9
modern	Istra	14.5	0.5	9	modern	Nelson	27	0	9
modern	Izak	21.5	0	9	cultivated	Platek	18.5	0	9
cultivated	Dalimil	19.5	0	9	Modern	Breton	15	0	9
Standard	Saul	17	0	9	Modern	Cwal	9.5	0	9
cultivated	Konradin	14.5	0	9	Modern	Hetman	3	0	9
cultivated	Nuernberg	25.5	0	9	Modern	Sam	11.5	0	9
cultivated	Mayer A	22.5	0	9	cultivated	Acmariu 3	29.5	0	9
cultivated	Lueneburg	31.5	0	9	Standard	MURES	30.5	0	9
Modern	Sandokan	32.5	0	9	cultivated	Sacel	25	0	9
Modern	Kaplan	25.5	0	9	cultivated	Lunca Il	9.5	0	9
Modern	Leo	22	0	9	cultivated	Baisoara 1	24.5	0	9
cultivated	Alo	29.5	0	9	cultivated	Local 1	21	0	9
Standard	JAAK	37	0	9	cultivated	Winterhaf	17	0	9
cultivated	Jogeva	33	0	9	cultivated	Local 2	16.5	0	9
Modern	Miku	26	0	9	cultivated	Local 3	10.5	0	9
Modern	Villu	24.5	0	9	cultivated	Local 4	19.5	0.5	9
cultivated	Noire	31	0.5	9	cultivated	Mulyat	22.5	0	9
cultivated	Noire Ri.	15	0	9	cultivated	Jari Oves	28.5	0	9
cultivated	Neu Gro	14	2	8	cultivated	Beltckii 1	23.5	0	9
cultivated	Grise	31.5	0	9	cultivated	Kinelskjj	29	1.5	8
cultivated	Jaune	16	0	9	cultivated	Local 5	20	0.5	9

cultivated	Joanette	26.5	0	9	cultivated	Local 6	33.5	0	9
Modern	Chantilly	23.5	0	9	cultivated	***Local 7***	19	12.5	6
Standard	Auteuil	32	0	9	cultivated	Signal	26.5	0	9
Modern	Aintree	0	0	9	cultivated	Anchar	10	0	9
Modern	Lennon	11	0	9	cultivated	Vendelin	22.5	0	9
Modern	***Millenium***	10.5	5.5	7	cultivated	Gagybator	21	3	8
Modern	***Ava***	10.5	4	7	modern	Detvan	8.5	0	9
Modern	***Donata***	12.5	4.5	7	cultivated	Zvolen	14.5	0	9
Modern	Primula	9.5	0	9	cultivated	SVKPOL	16.5	0.5	9
Modern	Bionda	9.5	2	8	cultivated	UKRKAR	25.5	0	9
Modern	Teo BD40	16.5	0	9	cultivated	Sisko	26	0	9
Standard	Gentiana	13	2.5	8	cultivated	Fyris	16.5	0	9
Modern	Novella	6.5	0	9	cultivated	Seger li	13	0	9
Standard	ARG	14.5	2	8	cultivated	Purhavre	12	0	9
cultivated	1404-11	15	0	9	cultivated	Nidar li	24.5	0	9
Modern	Jaugila	17.5	0	9	modern	Cilla	27	0	9
cultivated	Stendes	21.5	0	9	Standard	Belinda	26	0	9
cultivated	Pulawski	28	0	9	modern	SW Betw	12	0	9
cultivated	Gorski	25.5	0	9	modern	Kentucky	22	0	9
cultivated	Persidskij	13.5	0	9	modern	SW Iborg	20.5	0	9
cultivated	Platek	18.5	0	9	cultivated	OMSKIJ	27.5	0	9

The results of the evaluation of frost tolerance at first leaf stage, accomplished in the laboratory of Experimental Institute for Cereal Research, Fiorenzuola d'Arda, Italy were compared with the data of winter hardiness obtained in the field experiments carried out by Suceava Genebank in environments more frequently subjected to severe frost events, as compared to the Italian site.

Correlation coefficients (r) are reported in Table 3 between the frost tolerance data obtained in two independent experiments under controlled conditions at stress temperature of -10 and -12°C and the winter hardiness evaluated during 2009-2010 in Suceava, Romania, (by visual score and number of plants that survived) The correlations between the different evaluations of winter hardiness are also reported to compare the results obtained in the different fields and with different methods.

Table 3

Correlations of frost tolerance results on the oat accessions analyzed in the laboratory conditions (Experimental Institute for Cereal Research, Fiorenzuola d'Arda, Italy) and in field conditions (Suceava Genebank) (2009 – 2010)

	WINTERHARDINESS Suceava Genebank field 2009-10 Visual score (0-9 Rizza et al.)	**WINTERHARDINESS Suceava Genebank field 2009-10) number survived plant**
FROST TOLERANCE F_v/F_m means two experiments (-10 and -12°C)	-0.447***	0.432***
WINTERHARDINESS Suceava Genebank field 2009-10 Visual score (0-9 Rizza et al.)		-0.951***

,**, significant at the 0.05, 0.01 and 0.001 probability level, respectively; ns non significant (0.05 level)**

4. Conclusion

1. The high severity of the conditions recorded in the site of Suceava Genebank did not allow to record high variability among the accessions (visual score 9 for 87.5% of the accessions) but it was very useful in showing few genotypes with plant survival (6, 7) that were identified as superior for frost tolerance also in the laboratory tests recorded in the Experimental Institute for Cereal Research, Fiorenzuola d'Arda, Italy.
2. Results obtained from laboratory tests on frost tolerance of 104 accessions were highly correlated with data for winter hardiness obtained in Romania for the same group of accessions.

5. References

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