Winter Hardiness of Cocksfoot Cultivars in Hokkaido

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Winter hardiness is one of the most important characteristics determining the distribution of temperate grasses in Hokkaido, the northernmost part of Japan. Actually, timothy (*Phleum pratensis*), one of the hardiest grasses[3], is mainly grown in the eastern Hokkaido where low temperature and snow mold diseases prevent tender grasses from surviving cold winters. On the other hand, cocksfoot (*Dactylis glomerata*) that is less hardy but more productive than timothy is the dominant species in the other parts of Hokkaido with less severe winters. Thus, winter hardiness is of very importance and its improvement is one of the main objects for grass breeding.

In this study, we introduced natural populations of cocksfoot from Turkey and observed the relation of their winter hardiness to the climatic conditions in the original habitat. Then attempts were made to develop the laboratory techniques for screening seedlings. Lastly, we showed the practical significance of winter hardiness in herbage and seed production.

Winter hardiness in Turkish population of cocksfoot in relation to the climate in their original habitat[1,2]

Turkey is not only considered to be one of the original centers for domestication of cocksfoot, but also is known to have a great diversity of climate and altitude in the country. Therefore, the natural populations must be valuable for evolutionary studies and breeding materials.

Over a six-year period, 99 populations of cocksfoot from Turkey were investigated as to winter hardiness in the field in Sapporo (Fig. 1). After the first winter, only populations from the mild Marmara (map ref. 1–4), Aegean (map ref. 5–8) and Mediterranean regions (map ref. 9, 10) were badly damaged. As the differential plant survival among geographical groups widened with a lapse of years, we are able to rank the groups in descending order of relative hardiness from Eastern Anatolia (map ref. 23–28), through the Black Sea (map ref. 20–22), Central Plateau (map ref. 11–19), Marmara and Aegean regions and Mediterranean regions (Fig. 2). This could indicate that winter temperature prevailing in the locality of origin was the most important determinant.

As to the Black Sea group showing more hardiness than the expectations from winter climate, there exists another factor, i.e., different distribution of subspecies. *Dactylis glomerata* subsp. *hispanica* with poor winter hardiness that have grown in the maritime regions from Marmara, Aegean to Mediterranean coasts was considered to affect hardiness in the maritime populations by means of introgression. On the other hand, the continental type of cocksfoot with more winter hardiness is likely to improve hardiness in the populations of Black Sea region.

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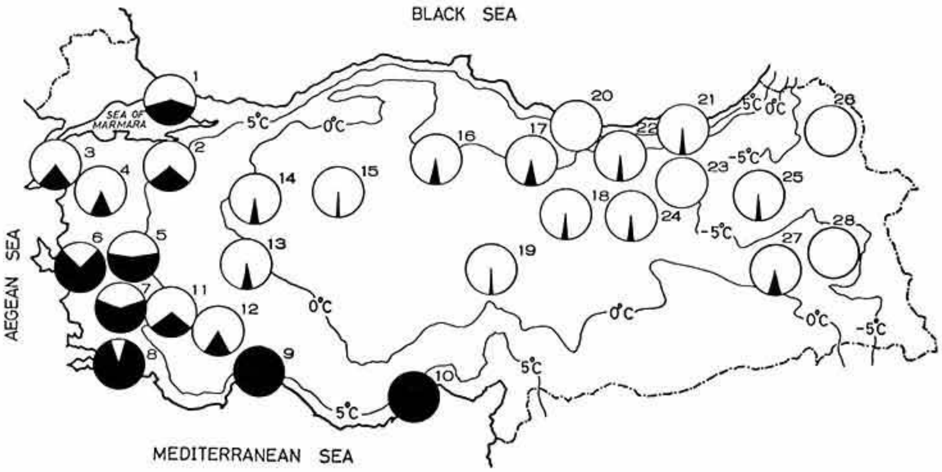

Fig. 1. Percentage survival of plants after the first overwintering period in Sapporo in relation to geographical origin
Lines on the map are January isotherms.
White section: Surviving plants, Black section: Dead plants.

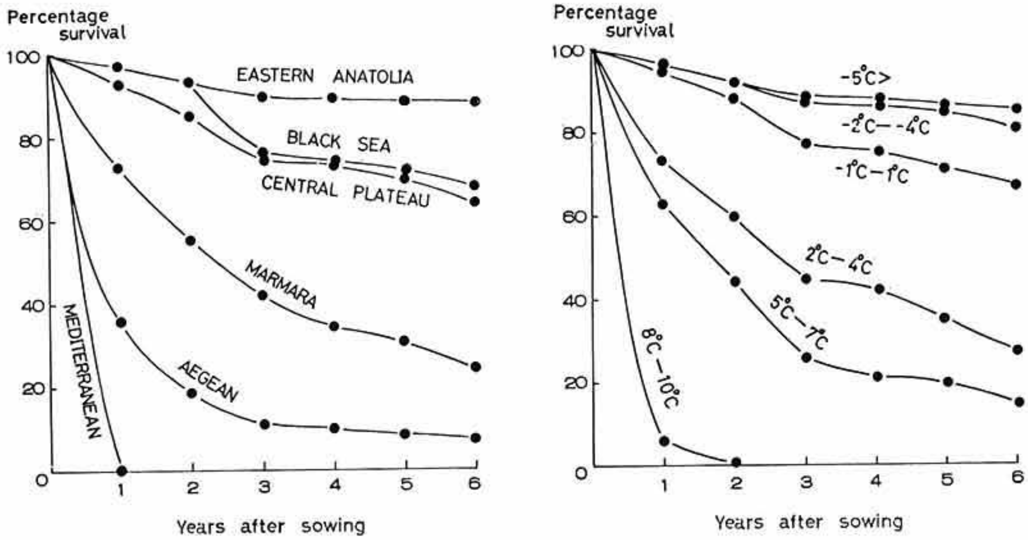

Fig. 2. Changes in percentage survival of geographical groups (left) and climatic groups based on the mean January temperature in the original habitat (right)

Lastly, the results of the present study also indicate the necessity of a fairly long period of plant mortality assessment, even for moderately hardy populations in the field.

Development of screening techniques for the factors related to winter hardiness

As there are several factors responsible for winter survival of temperate grasses, plant breeders should test each factor separately.

We aimed to develop screening techniques for seedling materials as to freezing tolerance and resistance to snow mold caused by *Typhula* spp. in addition to seedling survival test in the field.

1) Wintering ability of cocksfoot cultivars[4]

Wintering ability, which is based on plant survival, seedling vigor, number of panicles and heading plant rate, in seedlings of 24 cultivars sown in autumn were investigated (Fig. 3).

Wintering ability of the cultivars (Fig. 3 ref. 16–18) developed in Sapporo was almost similar to that of Leikund (Fig. 3 ref. 1), Tammisto (Fig. 3 ref. 2) and Kay (Fig. 3 ref. 10) from northern Europe and Canada where winter temperatures are far lower than those in Sapporo. Excluding these northern cultivars, wintering ability was highly correlated with the mean January temperature in the place of origin. In conclusion, the field test is a valuable means for evaluating potential ability of the plants from warmer regions than the experimental site, but it is very difficult for the plants from colder regions.

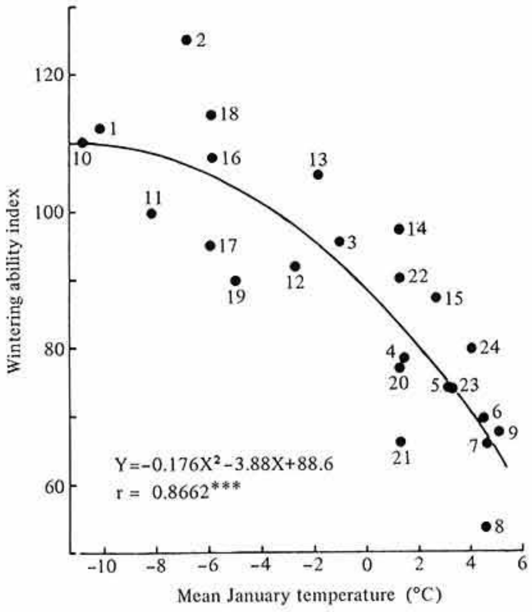

Fig. 3. Relation between mean January temperature at the place of origin and wintering ability in 24 cultivars[4]

2) Freezing tolerance in cocksfoot cultivars[5]

The modified freezing method developed by Lorenzetti et al.[8] was used in testing freezing tolerance of 24 cocksfoot cultivars. Plant survival was compared under three levels of temperature (−14, −12 and −10°C) at a set duration of 16 hr following a hardening regime with a temperature of 3°C for 2 weeks.

None of plants survived after −14°C freezing. About half of the plants of Scandinavian and Canadian cultivars survived at −12°C treatment, whereas less than 30% of the plants of Japanese cultivars survived. With −10°C treatment varietal difference in plant survival increased and the Hokkaido cultivars showed the values between 30 and 50%. As a result, −12°C freezing is recommended in selecting hardier plants for severe winter regions. And −10°C treatment should be suitable for discriminating varietal differences in freezing tolerance together with eliminating tender plants.

As to the varietal differences the varieties from Finland, Norway and Canada showed significantly greater survival than the others including Japanese cultivars.

3) Resistance to snow mold diseases in cocksfoot cultivars[6]

Experiments were carried out to develop techniques for testing the resistance to *T. ishikariensis* and *T. incarnata* and to study the relation between wintering ability and the resistance.

The following method was suitable to determine the resistance in cocksfoot; seedlings were grown in a greenhouse for 10 weeks followed by hardening for 2 weeks at 3°C. Then the plants that had been artificially inoculated were incubated under a snow cover of more than 50 cm in thickness for 65 days to test the resistance to *T. ishikariensis* and for 80 days in the case of *T. incarnata*. After

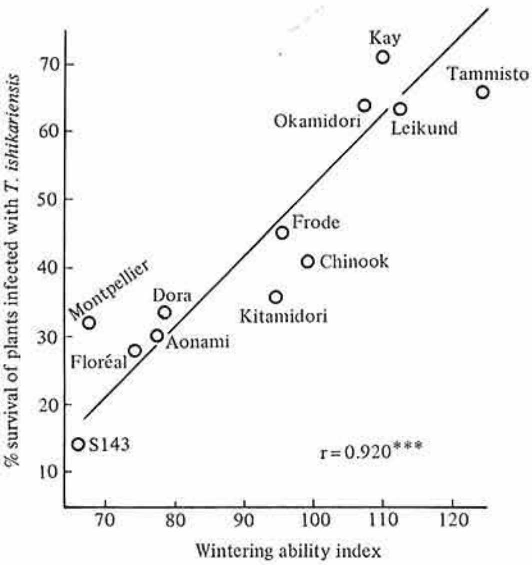

Fig. 4. Relation between wintering ability and resistance to *T. ishikariensis*, based on angularly transformed percentage survival of plants

recovery of a month in a greenhouse plant survival was measured.

The varieties from colder regions were resistant to *T. ishikariensis* except for a few cases. Though the resistance to *T. incarnata* did not always agree with that to *T. ishikariensis*, the resistance to *T. ishikariensis* was closely related to wintering ability assessed in Sapporo (Fig. 4). This suggests that the primary factor responsible for the wintering of cocksfoot in Sapporo be the resistance to snow mold diseases.

Relation of winter hardiness with seed and herbage production

We aimed to know the practical level of winter hardiness in cocksfoot varieties that meets winter conditions of Hokkaido. Two sets of field trials as to seed and herbage production were carried out using the leading cultivars in Hokkaido and foreign cultivars of contrasting origins.

1) Varietal difference in seed production[7]

The experiment consisted of 16 cocksfoot cultivars and two levels of fertilization. Increase in fertilizer application increased seed yields by about 10% each year (Table 1). Year to year variation in seed yield was

Table 1. Effect of fertilizer application on seed production (kg/a) in relation to winter hardiness

Cultivar	Origin	1st harvest yr			2nd harvest yr			W. I.[1]	Cold tol.[2]
		Med.	High	Mean	Med.	High	Mean		
Tammisto	Finland	8.3	9.5	8.9	4.0	4.3	4.1	124	60.1
Frode	Sweden	6.5	7.8	7.1	3.8	3.0	3.4	95	30.0
Floréal	France	3.9	5.5	4.7	2.8	3.2	3.0	74	23.0
S 143	U.K.	3.9	3.5	3.7	0.5	0.7	0.6	66	0.0
Kay	Canada	7.6	8.5	8.1	3.1	4.0	3.6	110	57.1
Chinook	Canada	7.6	9.7	8.6	5.4	5.3	5.3	99	61.7
Pennlate	U.S.A.	8.1	9.0	8.6	3.2	3.6	3.4	92	35.8
Latar	U.S.A.	6.6	7.9	7.3	2.2	2.5	2.4	105	42.1
Boone	U.S.A.	6.5	7.0	6.7	3.5	4.2	3.8	97	39.4
Potomac	U.S.A.	6.9	7.6	7.3	3.9	4.1	4.0	87	24.1
Kitamidori	Japan	8.7	8.9	8.8	4.2	4.6	4.4	95	40.8
Hokkai 1	Japan	8.5	8.1	8.3	3.6	3.9	3.8	114	45.0
Aonami	Japan	4.2	5.5	4.9	2.7	2.6	2.7	77	30.0
Akimidori	Japan	4.4	5.2	4.8	2.0	2.1	2.1	66	10.1
Nakei 18	Japan	4.2	5.1	4.6	2.1	2.5	2.3	90	31.7
Kyushu 2	Japan	3.2	3.7	3.4	2.7	3.2	3.0	79	19.4
l.s.d. (p=0.05)				1.5			0.8		15.0

1) : W. I. : Wintering ability index (Abe, 1980)[4].
2) : Cold tolerance : Percentage of plant survival at −10°C for 16 hr (Abe, 1980)[5].

so great that the yield of the second production year reduced to 3.2 kg/a, half of the preceding year yields. Seed quality such as 1000-seed weight and purity rate was significantly lowered in the second year largely because of higher air temperatures during the period of seed formation and maturation.

Less hardy cultivars than the Hokkaido ones decreased the number of panicles due to winter injury. Kitamidori, together with such hardy varieties as Tammisto and Chinook, had the greatest number of panicles, resulting in best seed yields each year. The level of winter hardiness in the Hokkaido cultivars appears to be enough for seed production.

2) *Relation of winter hardiness with herbage production*[7]

Fifteen cocksfoot cultivars from Japan, Europe and North America were used in field trials to assess herbage productivity in Sapporo. There appeared varietal differences in seasonal distribution of herbage production in relation to their level of winter hardiness. The yields at heading stage correlated positively with winter hardiness, whereas the yields in autumn negatively correlated with wintering ability and freezing tolerance (Fig. 5). Kitamidori and Frode which were less hardy than the Finnish and Canadian cultivars, gave the best annual total yield. On the other hand, the cultivars from warm regions such as S.143, Saborto and Montpellier were the poorest in the annual total yields in spite of the best in autumn herbage production. The northern cultivars gave poor herbage production in early autumn. Thus winter hardiness influences directly the seasonal productivity. Moderate hardy cultivars appear to be best in total yields as well as good both in spring and autumn.

We should improve the winter hardiness further, since it is of necessity to grow in severer regions or to tolerate unusual weather winters. Breeders in cooperation with plant physiologists and pathologists should study hardening behavior in relation to snow mold resistance and cold tolerance, together with collecting breeding materials suitable for autumn and winter conditions in Hokkaido.

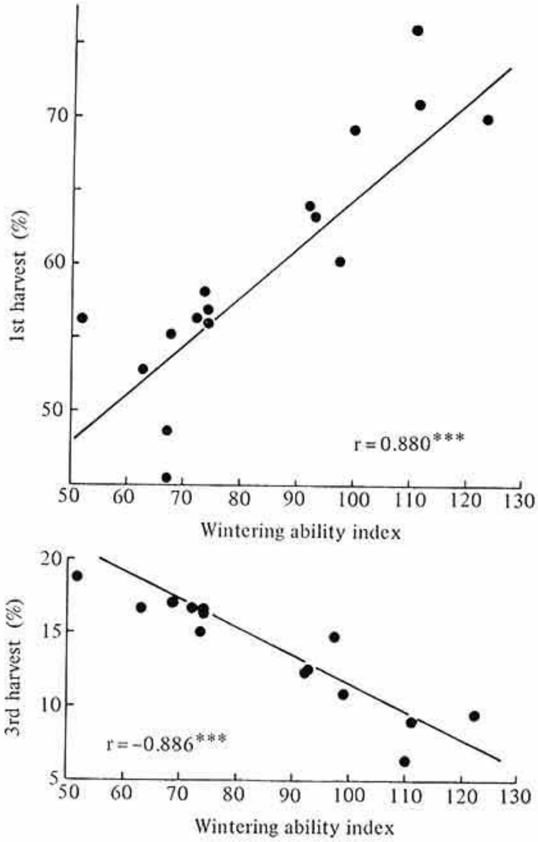

Fig. 5. Influence of wintering ability on seasonal herbage production in the first harvest year at the hay stage and the last harvest (on Oct. 20)

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(Received for publication, Jan. 9, 1989)