STRESSES AFFECTING BARLEY GROWTH IN CANADA[1]

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Abstract

Stresses affecting barley growth and quality in Canada and cultivar resistance and susceptibility to these stresses are summarized. Information was obtained by questionnaire from barley pathologists, breeders, soil scientists, and extension personnel in industry, universities, and provincial and federal governments. Considerable information is known on cultivar reactions to diseases but inadequacies exist concerning the response of cultivars to edaphic and climatic effects, particularly those of nitrogen and of heat and moisture during flowering and filling of the grains. A list of indicator-standard cultivars susceptible or resistant to particular stresses is presented for use with field trials and for investigating crop failures.

Résumé

On trouvera au present rapport un résumé des agressions qui influent sur la croissance et la qualité de l'orge au Canada, de même que de la resistance et de la sensibilité de ses cultivars à ces agressions. Cette information provient de questionnaires adressés à des pathologistes et des sélectionneurs de l'orge, des pedologues et des vulgarisateurs du secteur privé, des universités et des gouvernements federal et provinciaux. On sait beaucoup de choses sur les reactions des cultivars aux maladies, mais il existe encore des lacunes concernant leurs reactions aux effets Bdaphiques et climatiques, en particulier ceux de l'azote, de la chaleur et de l'humidité durant la floraison et le remplissage du grain. On trouvera une liste des cultivars servant d'indicateurs, sensibles et resistants aux agressions particulières, et qui doivent servir aux essais en plein champ et aux enquêtes sur les mauvaises récoltes.

A biologic stress may be defined as any environmental factor capable of inducing a potentially injurious strain in living organisms (4). Barley is subject to many climatic, edaphic, biotic, and other stresses which adversely affect its growth, yield, and quality. This is particularly so in Canada because of the wide variation in climate and soils in the areas in which it is grown. Barley workers across Canada are familiar with particular stresses affecting the crop in their own areas and with yarietal response to these stresses, but some of this information has not been published or widely circulated. Because of the importance of stresses in breeding, pathology, and quality, information on stresses was collected by means of a postal survey of barley workers across Canada in industry, universities, and federal and provincial governments. The 55 respondents included barley breeders, pathologists, soil scientists, brewers and maltsters, field extension personnel, and administrators. The information received is summarized in four sections: nature of the stresses and their geographical occurrence, varietal response to stresses, use of stress data to maximize barley production and quality, and suggestions for further work.

Results and discussion

1. The main stresses affecting barley growth in Canada

Stresses affecting barley growth for the purposes of this study were placed in five main categories: climatic, edaphic and atmospheric, biotic, physiologic, and those caused by applied chemicals. Lists of stresses in each of the five main categories were given on the survey forms, and respondents were asked to indicate which were the most important stresses affecting barley growth and yield in their area in most years. Replies received are summarized in Table 1.

On a regional basis, tendencies to certain types of stress are apparent. These include soil acidity in northern Alberta and

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Table 1. Stresses that affect barley growth in Canada, their present regional importance end cultivar susceptibility and resistance

Growth stress	Region affected				Cultivars**	
	Park Belt	Prairies	Central	Maritimes	Susceptible	Resistant
Climatic						
1 Spring frost	A,B,F		I	N,O		
2 Fall frost	A,B,C,F	G	I	Θ		
3 Heat at emergence						
4 Heat at heading	H	E,H			Olli	Conquest, Palliser
5 Drought	A,H	D,E,G,H			Husky	Galt, Palliser
6 Excess moisture	H	G,H	I,J,M	N	Galt	Centennial
7 Hail	C					
Edaphic & atmospheric						
8 High alkalinity						Pallidum, California Mariout
9 High acidity (low pH)	A		J,M	N	Herta, Husky	Volla, Gateway
10 Aluminum toxicity	A		J		Herta	Volla, Trebi
11 Sulphur dioxide						
12 Ozone						
13 Nitrogen deficiency	A,B,H	H			Fergus	UM 6451
14 Nitrogen excess						
15 Phosphorus deficiency						
16 Potassium deficiency						
17 Minor element deficiency						
Biotic						
A) Diseases						
18 Stem rust					Betzes	Bonanza
19 Leaf rust					Bonanza	Wisc H379-2
20 Covered smut					Odessa	Galt
21 False loose smut					Odessa	Galt
22 Loose smut			J		Regal	Bonanza, Trebi
23 Common root rot	A,B,C,H	D,E,H		O	Galt, Olli	Bonanza
24 Spot blotch	A,H	H	J	O	Galt	Br X6D-33
25 Net blotch	A,B,C,H	H		O	Betzes	CI 5791
26 Speckled leaf blotch					Bonanza	65-593
27 Scald	A,B,C				Bonanza	BT 609, Keystone
28 Powdery mildew			J		Bonanza	Trent
29 Bacterial blight						
30 Stripe mosaic					Black Hulless (CI 666)	Moreval
31 Yellow dwarf	H	H	M	Θ	Herta	CI 5791
32 Aster yellows					Herta	none
33 Oat blue dwarf					62-528	none
34 Ergot					Herta	none
35 Neck break		E	K	N	OAC 21	Centennial
36 Seedling blight				N		
B) Fauna						
37 Thrips						Herta
38 Aphids	H	H				OAC 21
39 Mites					OAC 21	Gem
40 Cereal leaf beetle						
41 Grasshoppers	H	H				
42 Nematodes			L		Herta	Sabarlis
C) Weeds						
43 Weeds	A,B	E,G				
Physiologic'						
44 Lodging	B,H	E,H	I,J,M	N	Betzes, OAC 21	Centennial
45 Shattering		E		N	Montcalm	Centennial
46 Discoloration					Bonanza	Conquest
Chemical						
A) Herbicide						
47 Carbyne					Herta	
48 2,4-D					Unitan	
49 Bromoxynil					Charlottetown 80	Olli
50 Atrazine residues from previous corn crop						
B) Insecticide						
51 Insecticide						
C) Fungicide						
52 Fungicide						
Other						
53 Late seeding					Herta, Olli	Trent, Conquest

* A = Beaverlodge, Alta.; B = Edmonton, Alta.; C = Lacombe, Alta.; D = Lethbridge, Alta.; E = Saskatoon, Sask.; F = Melfort, Sask.; G = Regina, Sask.; H = Winnipeg and Brandon, Man.; I = Kapuskasing, Ont.; J = Ottawa, Ont.; K = Guelph, Ont.; L = Vineland, Ont.; M = Ste. Foy, P.Q.; N = Truro, N.S.; Θ = Charlottetown, P.E.I. Blanks indicate that a particular stress is either not present in a region, is not recognized, or is only a potential threat due to successful breeding programs or improved management practices.

** selected either because of multiple listings by respondents or because of the expertise of a respondent working with a particular stressing agent. Blanks indicate a lack of information on cultivar response to the particular stress.

+ Items 44-46 are actually the visible effects of physiologic stresses.

Table 2. Barley growth stress symptoms and their probable causes

Plant part and symptoms	Cause
Young leaves	
horizontal bands of damaged tissues	heat, spring frost
Young plants	
pale yellow	spring frost
brown streaks on leaves	seedling blight
dwarfed, few tillers, leaves pale-yellow green	nitrogen deficiency
dwarfed, few tillers, leaves dark-blue green	phosphorus deficiency
dwarfed, excessive tillering, leaf scorch	potassium deficiency
Leaves	
brown spots	net or spot blotches
scalded appearance	scald, some herbicides
V-, inverted V-, W-shaped brown streaks	barley stripe mosaic
white, powdery areas	mildew
white, chlorotic areas	sulphur dioxide (3), roadside salt
water-soaked areas, bacterial ooze	bacterial blight
darkening, yellowing, wilting from tip	mites
Leaves and stems	
pale brown areas with black spots	speckled leaf blotch
purplish tints	phosphorus deficiency
red-orange or black raised areas	rusts
Sub-crown internode, crown	
brown areas or brown spots	common root rot
Whole plant	
yellowing	barley yellow dwarf, asteryellows, oat blue dwarf, excess moisture, nitrogen deficiency, drought, mites
yellow, red and purple tinting	wireworms, cutworms, drought
thin, wiry stems	salinity
fallen	lodging, excess moisture, hail
defoliation	grasshoppers, armyworms
Stems	
broken	lodging, neck or stem break
Heads	
black spores filling or on heads	loose, false loose, covered smuts
black projecting bodies	ergot
distortion	aster yellows, hail, 2,4-D
disintegration	shattering
tips of awns white, banded	sulphur dioxide
unfilled individual grains	thrips
kernels black, brown	staining, weathering, black point
kernels shrunken	fall frost, lack of moisture
heads small	nitrogen, phosphorus deficiencies
grain formation poor	potassium deficiency

* For more detailed descriptions of disease symptoms see (1) and of nutritional deficiencies, which are much less clearly seen and complicated by other stresses in older plants, see (8).

eastern Canada; length of growing season in northern Alberta, northern Saskatchewan, and northern Ontario; moisture, wild oats, and common root rot in the Prairie Provinces; neck break in southern Ontario: and cold wet springs, soil acidity, and seedling blight in Quebec and the Maritimes. These tendencies reflect regional differences and similarities in soil type, rainfall, and number of frost free days (2). Common root rot, neck break, and seedling blight are diseases caused by the fungus Cochliobolus sativus (Ito & Xurib.) Drechsl. ex Dastur. The soil-borne phase of the disease is favored by conditions in western Canada and the aerial phases by the wetter conditions of eastern Canada.

In local regions growth can be adversely affected by a large number of stresses (Table 1). The stresses listed reflect those that axe Important in most years because resistant varieties are not yet available, because of difficult management practices, or because of

climatic factors beyond human control. Some stresses, e.g. stem rust, are at present only potential threats due to successful ongoing breeding programs and thus probably have not been emphasised by respondents (Table 1).

When emerging from the soil young plants can be damaged by heat or by spring frost. Seedling blight and herbicide damage can reduce the photosynthetic area of the young leaves, and excessively moist or saline conditions severely restrict growth. Barley leaves are affected by many diseases, including spot blotch, net blotch, scald, powdery mildew, rusts, stripe mosaic, and yellow dwarf. Aphids, grasshoppers, root rot, and lodging can all seriously reduce yields of older plants. Loss of grain or reduction in grain size and quality can occur through the action of hail, smut, aster yellows, thrips, shattering, staining, weathering, and late frosts.

A simplified outline of stress symptoms is given in Table 2. Symptoms of some stresses are not documented, e.g. heat and moisture stress at flowering and filling of the grain. Also some symptoms, e.g. yellowing, are common to several stresses and may mask or modify others.

Apart from the five main types, stresses also occur through poor management practices. To obtain good barley yields the crop should be sown early in moist, well drained soil with optimal fertilization. Rapid early nitrogen uptake is essential for good yields *(6)* and any interference through bad management practices, e.g. by deep or delayed seeding, poor fertilization, poor drainage or poor weed control, will reduce growth and yields. Furthermore, late-seeded crops are more likely to be affected by aphids, barley yellow dwarf, ergot, staining, weathering, and fall frost, which will result in either a further loss in yield or of quality. Poor management practice, particularly inadequate fertilization, is probably the single most important factor adversely affecting barley yields in Canada today.

2. Varietal response to barley stresses

Each respondent was asked to submit the name of a cultivar known to be highly resistant or susceptible to a particular stress. Since a major proportion of the questionnaires were sent to agricultural scientists, it is probable that most selections were based on experimental results. These replies are also summarized in Table 1. Some indicators for particular stresses were well defined as they were chosen by several workers; others were mentioned once. For Some stresses no information on indicator cultivars was received, showing that either these stresses are not important or are not recognized.

From the data in Table 1, a list of 10 susceptible indicator cultivars (Table 3) was chosen to delimit selected growth stresses in Canada. The usefulness of such a series of indicator cultivars is described below in Sections 3B and C.

3. use and importance of stress data to maximize barley production and quality

The survey data obtained are useful in:

A) Assisting barley workers in recognizing the symptoms and the relative importance of stresses and in giving them an overall awareness of the important factors affecting barley quality and yield.

B) Choosing susceptible cultivars to determine the occurrence of stresses in field trials and in areas of frequent crop failures. These susceptible cultivars could also be used as standards against which the reactions of test cultivars could be compared on a year-to-year basis. Preliminary trials with such indicator-standards have already shown promise in Manitoba (J. T. Mills and A. Tekauz, unpublished data).

C) Investigating the effects of specific stresses on yields, e.g. common root rot. By using indicator cultivars to determine the presence or absence of other stress factors, the effects of a single factor such as root rot, when other stresses ate found to be absent, can be obtained more precisely. This could enable a more accurate assessment of the individual causes behind crop losses.

D) Maximizing quality. Some information was obtained on differences in susceptibility of cultivars to staining and weathering but none to fall frosts. cultivars should be evaluated for these factors as they are important in determining quality.

E) Determining gaps in *our* knowledge of stresses. Considerable information exists on response to many diseases, but more information is needed on cultivar response to N, P, and K levels, to alkalinity, air pollutants, spring and fall frosts, to heat and drought at flowering and filling of the grain, to staining and weathering, and to thrips, aphids, and grasshoppers. In some instances the symptoms of these stresses, e.g. drought at flowering, are not adequately described.

4. Suggestions for further work

A) Cultivar response to nitrogen - This could be determined by sowing selected cultivars in soils containing different known levels of nitrogen and comparing the resulting yields. Nitrogen determinations for developing leaves, stems, heads, and kernels should be made, and experiments on the rate of nitrogen transfer from leaves to heads should also be carried out.

Table 3. Susceptible indicator cultivars for delimiting some growth stresses occurring in Canada

Susceptible cultivar	Biotic stresses	Climatic, edaphic, and physiologic stresses
1 Betzes	Stem rust, net blotch	Lodging
2 Bonanza	Leaf rust, speckled leaf blotch, scald, powdery mildew	
3 Odessa	Covered smut*, false loose smut*	
4 Regal	Loose smut*	
5 Galt	Common root rot, spot blotch	Excess moisture
6 Herta	Aster yellows, barley yellow dwarf, ergot, nematodes	High acidity, aluminum toxicity
7 Husky		Drought, high acidity
8 Fergus		Nitrogen deficiency
9 OAC 21		Lodging, neck break
10 Montcalm		Shattering

* Presence of smut can only be determined by sowing harvested seed and examining resulting heads.

B) cultivar response to heat and moisture at flowering and filling of the grain - selected cultivars could be subjected to different soil moisture levels and temperatures during flowering and filling of the grain. Kernel weights and other quality parameters, e.g. starch enzymes, could then be determined during growth and maturation *(5)*.

Two recent reports support the importance and need for working on environmental stresses:

1. The recommendations of the Committee on Genetic Vulnerability of Major Crops, Washington, D. C. (7), state that a) non-specific characteristics of wheat (barley) that render the crop less subject to damage from biotic and environmental hazards should be investigated; and b) preoccupation with diseases and insects may have led to lack of concern for vulnerabilities to environmental stresses and other hazards of wheat (barley) production.

2. Environmental stresses were observed by farmers in 815 fields in Manitoba during 1972 as reported in a postal survey conducted by the Provincial Soils Testing Laboratory, Manitoba Department of Agriculture. Nitrogen and drought stresses were severe, while damage from excess moisture, visible diseases, hail, and frost were less frequently reported (Table 4).

In conclusion results of the survey indicate that there is a lack of information on cultivar response to many environmental stresses. It is considered that additional information in this area may be helpful because of the importance of these stresses to growth, quality, and yield.

Table 4. Stresses reported by farmers in 815 fields in Manitoba, 1972

Stress	No. of fields with stress			
	None	Light	Moderate	Severe
Nitrogen*	177	305	199	134
Drought	316	211	246	42
Excess water	735	38	37	5
Disease	732	56	22	5
Frost	757	27	24	7
Hail	786	14	9	6
Other**	644	53	108	10

* Nitrogen stress computed in laboratory; based on results from soil tests to determine NO_3-N levels plus amount of fertilizer added by farmer.

** Includes weeds.

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