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Trait Association with Earliness and Winter Hardiness Within a Collection Korean Land Race Barleys

W. L. McProud, Seong-Ho Bae, Eun-Sup Lee,
Tae-Young Chung and Kyung-Soo Min

Wheat and Barley Research Institute, ORD, Swweon, Korea

韓國의 보리 蒐集種에서 熟期와 耐寒性과의 關聯性

農村振興廳 麥類研究所

W.L. McProud · 배성호 · 이은섭 · 정태영 · 민경수

ABSTRACT

528 Korean land races of barley were examined for 15 agronomic traits to determine if any preferential trait associations with early heading and winter hardiness existed in this collection.

Eight traits were non-randomly associated with the 1977~'78 cold damage levels, and seven traits were non-randomly associated with heading date. No early heading, least-cold-damaged land race lines were found. However the least-cold-damaged class preferentially associated with mid-early heading land race lines. Ten traits were preferentially associated with the mid-early heading, least-cold-damaged class. The utilization of these associations should increase the probability that genes for winter hardiness will be preserved in the mid-early heading selections from this collection.

Introduction

A major goal of the Korean barley development program is to breed earlier maturing barley varieties with increased leavels of cold tolerance.

The inheritance of heading date in barley ranges from rather simple to very complex. Various researchers have resported 3:1 segregation ratios for earliness, with both early and late phenotypes being dominant. Other researchers have concluded that earliness in barley is controlled by additive alleles, possibly at two loci, altered by modifying factors (Nilan, 1964).

Takahashi and Yasuda(1957) concluded that the heading date of barley depends on 1) spring and winter growth habit(vernalization response), 2) response to short-day(photogeriod response) and, 3) response to long-day(earliness in a narrow sense). The genetic control for conditions 2 and 3 are polygenic while condition 1 is controled by the spring habit genes. These authors also observed that spring and winter habit is of little consequence to the earliness of fall sown barley.

Winter hardiness is the plants ability to escape, to modify or to withstand many types of stress, thus allowing the plant to survive the winter(Olien 1968, 1974). Wiebe and Reid(1961) have noted that the winter killing of barley can result from low temperature, heaving, alternating temperatures, smothering, disease, high winds or unfavorable moisture conditions.

In cereals the most critical region for winter hardiness is the crown(Olien 1968, 1974, Grafius 1974). Hardening is a physiological change that permits the barley's protoplast to withstand freezing. Severe stress before this physiological change has

occurred or after a mid-winter thaw is more frequently the cause of winter injury(Olien 1974).

Hardened barley with a low crown moisture content can survive lower temperatures than it can at higher crown moisture contents. Repeated freezing and thawing can cause winter damage by sectioning the crown and encouraging diseases(Olien 1974). Diseases such as mildew can greatly disrupt the rate at which winter hardiness is achieved(Grafius 1974). Varietal differences to heaving tolerance seemed based on the root systems ability to anchor the plant and the ease with which different plant parts are mechanically broken. Flooding in early spring can cause severe winter damage(Olien 1974).

Observations of above ground tissue can be used to evaluate the crown's condition. The new leaves on hardened plants are darker and more appressed. The number of active growing points indicates the amount of non-destroyed crown tissue. Chlorotic leaves that die back during spring regrowth indicate injury to the crown's base(Olien 1968, 1974). Spring leaf condition can be misleading since some of the more tender varieties have hardy leaves.

Ramage(1977) has noted that each character or combination of characters has a background genotype that is most favorable for the expression of that character or combination of characters. Strong negative linear relationships between early maturation dates and high winter hardiness levels have been observed for both covered and naked barley in Korea(Anonymous, 1978). Olien(1974) states that breeders seem to inadvertently select against winter hardiness components when developing other needed characteristics.

Barley has been cultivated on the Korean peninsula for thousands of years(McProud, et. al., 1979). Over this time Korean barley land races have developed various characters or combinations of characters, and the corresponding most favorable background genotypes, adapted to the Korean environment. The purpose of this study is to determine for a collection of Korean barley land races the extent to which the characters of early heading and high levels of winter hardiness have become associated and to identify trait combinations allowing for the rapid exploitation of any early, cold tolerant associations within this collection.

Materials and Methods

A collection of 528 Korean land races of barley was examined for fifteen characters during the 1977∿78 growing season in Suweon. These barleys were obtained from Dr. R. Takahashi, Ohara Institute in Japan, who had made this collection during the early 1930's.

The traits examined are as follows:

1) Fall growth type – Lines were visually classified as being prostrate, semi-prostrate or erect.
2) Fall leaf width – Lines were visually classified as having wide, mid-wide or narrow leaves.
3) Fall leaf color – Lines were visually classified as having dark green, green or light green leaves.
4) Cold damage – The three visual classifications were least-cold-damaged, mid-cold-damaged and most-cold damaged.
5) Heading date – A line was considered headed when the top floret of 40% of the spikes cleared the leaf sheath. Lines were classified as heading early, mid-early, late or extremely late.
6) Flag leaf length – Lines were visually classified as having long, mid-long or short flag leaves.
7) Flag leaf width – Lines were visually classified as having wide, mid-wide or narrow flag leaves.
8) Leaf position – The three visual classifications for leaf position were drooping, semi-drooping and erect.
9) Culm length – An average of 20 dandom measurements per line taken from ground level to the collar was used to determine plant height. Lines were classified as tall, mid-tall or short.
10) Peduncle length – An average of 20 random measurements per line taken from the

flag leaf's blade and sheath junction to the collar was used to determine peduncle length. Lines were classified as having long, mid-long or short peduncles.

11) Head position – Lines were visually classified as having nodding, semi-nodding or erect heads.

12) Spike length – The average of 20 random spikes per line, measured from the collar to the top of the last seed producing floret, was used to determine spike length. Lines were classified as having long, mid-long or short spikes.

13) Awn length – Lines were visually classified as having long, mid-long or short awns.

14) Kernel length – Lines were visually classified as having long, mid-long or short kernels.

15) 1,000 grain weight-The average of two 500 kernel samples was used to determine 1000 grain weight.

Chi-quare procedures were used to determine if associations among traits were random or preferential.

Results and Discussion

Within a collection of 528 Korean land races of barley, very strong associations between the cold damage levels of 1977-78 and heading date were observed. The number of early heading, most-cold-damaged lines was 376.6% of expected. Early heading, mid-cold-damaged lines and early heading, least-cold-damaged lines were 49.8% and 0.0% of the expected number, respectively. Chi-square values for these three relationships were highly significant, suggesting their non-random assortment. The number of late heading lines in the most-cold-damaged class was 57.3% of expected, giving a significant chi-square value. Early heading Korean land races are strongly disassociated with the least-cold-damaged and mid-cold-damaged classes. The least-cold-damaged land race lines show a significant association with mid-early heading(Table 1).

Table 1. Associations between cold damage and heading date

Association		Observed	Expected	Observed – Expected	Chi square
Least-cold-damaged	-Early heading	0	7.0	-7.0	7.00**
〃	-Mid-early heading	64	48.7	15.3	4.81*
〃	-Late heading	21	28.4	-7.4	1.93
〃	-Extremely late heading	1	2.0	-1.0	0.50
Mid-cold-damaged	-Early heading	14	28.1	-14.1	7.08**
〃	-Mid-early heading	190	196.3	-6.3	0.20
〃	-Late heading	135	114.5	20.5	3.67
〃	-Extremely late heading	8	8.0	0.0	0.00
Most-cold-damaged	-Early heading	29	7.7	21.3	58.92**
〃	-Mid-early heading	45	53.8	-8.8	1.44
〃	-Late heading	18	31.4	-13.4	5.72*
〃	-Extremely late heading	3	2.2	0.8	0.29
					$\chi^2 = 91.56$ **

* significance at 0.05 level ** significance at 0.01 level

Cold damage level

Six of fourteen examined associations were found to randomly combine with the 1977∿78 cold damage levels. These six characters were flag leaf width, kernel length, 1000 grain weight, awn length, flag leaf width and leaf position. Seven characters gave highly significant chi-square values and one character gave a significant chi-square value suggesting their non-random association with the recorded levels of 1977∿78 cold damage(Table 2).

Head position and spike length were strongly associated with the 1977∿78 cold damage levels. This significance resulted from a smaller than expected number of nodding, long heads and a larger

Table 2. Characters associated with the 1977-1978 cold damage levels within 528 Korean land races of barley

Characters having random associations with all cold damage classes	Chi square	Characters having non-random associations within only one cold damage class	Chi square	Characters having non-random associations within two or more cold damage classes	Chi square
		Most-cold-damaged class			
Flag leaf length	2.15	Head position	31.43**	Fall leaf width	101.39**
Kernel length	3.50	Spike length	24.66**	Fall leaf color	98.42**
1000 grain weight	5.36	Peduncle length	16.93*	Fall growth type	120.29**
Awn length	6.11	Least-cold-damaged class		Heading date	91.56**
Flag leaf width	6.51	Culm length	21.52**		
Leaf position	11.90				

* significance at 0.05% level
** significance at 0.01% level

than expected number of erect, short heads within the most-cold-damaged class. Random associations with the least-cold and mid-cold-damaged classes for these two spike characters were observed.

Within the least-cold-damaged class, the number of short culmed lines was 29.2% of expected while the number of long culmed lines was 173.9% of expected. Both of these associations gave highly significant chi-square values. Most-cold-damaged, short peduncle association, which was 162.6% of the number expected, gave a highly significant chi-square value. The above data indicates that the collected Korean land race barleys in the most-cold-damaged class tended to have short, erect heads on short peduncles. This is consistent with the observation that most of the uzu phenotypes have lower winter hardiness levels.

Those characters having the strongest associations with the 1977∿78 cold damage levels were the fall growth traits. The most-cold-damaged class had 262.0% more lines than expected with wide fall leaves. The numbers of lines with mid-wide and narrow fall leaves within the most-cold-damaged class were 56.9% and 8.1% of expected, respectively. All the above associations gave highly significant chi-square values suggesting preferential associations.

The occurences of lines with wide fall within the mid-cold and least-cold-damaged classes were 65.8% and 58.0% of expected, respectively. The number of mid-cold-damaged lines with wide fall leaves gave a highly significant chi-squared value. The most-cold-damaged land race lines are associated with wide fall leaves and disassociated with mid-wide or narrow fall leaves. Those land races showing the least-cold-damage in 1977∿78 tended to have narrow or mid-wide fall leaves.

The number of most-cold-damaged lines with light green fall leaves was 227.3% of expected. The numbers of mid-cold-damaged and least-cold-damaged lines with light green fall leaves were 80.1% and 39.4% of expected, respectively. All three relationships gave a significant or highly significant chi-square values. Within the most-cold-damaged class, lines with green fall leaf color and dark green fall leaf color were 51.5% and 13.9% of expected, respectively. Both of these relationships gave highly significant chi-square values. These Korean land races show a strong association between fall leaf color and the level of cold damage. Those lines showing the least-cold-damage tend to have green or dark green fall leaf color.

There were strong associations between fall growth habit and the level of 1977∿78 cold damage. The number of erect, most-cold-damaged lines was 285.0% of expected while the numbers of erect, least-cold-damaged and erect, mid-cold-damaged lines were 30.9% and 66.5% of expected, respectively. The association of prostrate and semi-prostrate fall growth

habit with the most-cold-damaged class gave 28.7% and 56.9% of the number of expected lines, respectively. All these relationships gave highly significant chi-square values. Within this collection there is a strong tendency for erect fall growth lines to be highly cold-damaged. The least-cold-damaged lines tend to have prostrate or semiprostrate fall growth characteristics.

Heading date

Within this collection flag leaf length, flag leaf width, leaf position, culm length, kernel length, awn length and spike length showed random association with heading date. Six characters had highly significant and one character had significant chi-square values suggesting their preferential associations with 1977~78 heading date(Table 3).

Table 3. Characters associated with the date of heading within 528 Korean land races of barley

Characters having random associations with all heading date classes	Chi square	Characters having non-random associations within only one heading date class	Chi square	Characters having non-random associations within two or more heading date classes	Chi square
Flag leaf length	2.46	Early-heading-class		1000 kernel weight	31.39**
Flag leaf width	5.42	Fall leaf color	34.76**	Fall growth type	37.39**
Leaf positon	7.57	Peduncle length	21.60*	Fall leaf width	43.78**
Culm length	8.73			Head position	54.35**
Kernel length	14.29			Cold damage level	91.56**
Awn length	15.59				
Spike length	16.51				

* significance at 0.05 level
** significance at 0.01 level

Highly significant chi-square values indicate that early heading lines preferentially associate with, short peduncles, and erect spike, giving 193.9% and 212.8% of the number of expected lines, respectively. The number of early heading lines with nodding spikes and late heading lines with erect spikes were 124.1% and 50.3% of expected, respectively. All of the above associations gave significant or highly significant chi-squared values. These data additionally support the observation that most uzu land race lines, which are typified by short culms, awns and peduncles with erect leaves and heads, tend to be early and have lower winter hardiness levels.

The number of late heading lines with light 100 kernel weights was 60.2% of expected while the number of late heading lines with heavy 1000 kernel weights was 141.6% of expected. Significant or highly significant chi-square values were calculated for both relationships. A significant chi-square value for the number of early heading lines with light 1000 kernel weights, 170.5% of expected, was observed. These data suggest that early heading Korean land race lines tend to have light seed.

The number of early heading lines with wide fall leaves, was 188.7% of expected. This highly significant association suggested non-random assortment. Late heading lines with wide fall leaves were 61.6% of expected while the class of early heading lines with narrow fall leaves was completely missing. Both of these relationships gave significant chi-square values. There is a strong tendency in this collection for early heading lines to have wide fall leaves.

The number of early heading lines with light green fall leaves was 216.8% of expected while the number of early heading lines with dark green fall leaves was 10.0% of expected. Both of these associations gave highly significant chi-square values, suggesting the preferential association of early heading with light green fall leaf color.

The number of early heading, erect fall growth lines was 252.5% of expected and gave a highly significant chi-square value. Within this collection

early heading lines preferentially associate with erect fall growth.

Least-cold-damaged, mid-early heading class

As shown in Table 1, there are no early heading land race collections in the least-cold-damaged class. However there is a perferential association for mid-early heading lines within the least-cold-damaged class. To help identify least-cold-damaged, mid-early heading lines, trait associations with this combination were calculated(Table 4). Significant or highly significant chi-squared values indicate that ten traits preferentially associate with the mid-early heading, least-cold-damaged land race lines. These ten traits are long spikes, long awns, long kernels, long culms, drooping leaves, mid-wide flag leaves, mid-long flag leaves, mid-long peduncles, semi-prostrate fall growth and mid-wide fall leaves. Selection for these characteristics within the mid-early heading class of this collection will improve the probability that winter hardiness genes are also being selected.

Table 4. Traits associated with mid-early heading lines within the least-cold-damaged and most-cold-damaged classes of Korean land race barleys.

Trait associations that gave significant or highly significant chi-squared values	Observed	Expected	Observed / Expected × 100	Chi square
Mid-early heading, least-cold-damaged, long spikes	27	15.5	174.2 %	8.49**
〃 , 〃 , long awn	43	28.9	148.8 %	6.82**
〃 , 〃 , long kernel	28	19.1	146.6 %	4.14*
〃 , 〃 , long culms	18	9.6	187.5 %	7.47**
〃 , 〃 , drooping leaves	23	13.4	171.6 %	6.85**
〃 , 〃 , mid-wide flag leaves	45	30.2	149.0 %	7.22**
〃 , 〃 , mid-long flag leaves	49	32.2	152.2 %	8.71**
〃 , 〃 , mid-long peduncles	55	33.6	163.7 %	13.60**
〃 , 〃 , semi-prostrate fall growth	38	23.5	161.7 %	8.91**
〃 , 〃 , mid-wide fall leaves	44	30.7	143.3 %	5.79*
Mid-early heading, most-cold-damaged, wide flag leaves	24	15.8	151.9 %	4.21*
〃 , 〃 , erect fall growth	29	11.9	243.7 %	24.69**
〃 , 〃 , light green fall leaves	35	17.2	203.5 %	18.27**
〃 , 〃 , wide fall leaves	31	12.8	242.2 %	25.96**
〃 , 〃 , long spikes	6	17.1	35.1 %	7.25**
〃 , 〃 , erect leaves	8	17.2	46.5 %	4.88*
〃 , 〃 , mid-wide flag leaves	12	33.4	35.9 %	13.71**
〃 , 〃 , nodding spikes	9	20.4	44.1 %	6.36*
〃 , 〃 , semi-prostrate fall growth	13	26.0	50.0 %	6.49*
〃 , 〃 , prostrate fall growth	2	15.8	12.6 %	12.09**
〃 , 〃 , mid-wide fall leaves	12	33.9	35.4 %	14.14**
〃 , 〃 , narrow fall leaves	1	7.1	14.1 %	5.24*

* significance at 0.05 level
** significance at 0.01 level

An equally valuable tool is knowing what significant trait associations exist within the mid-early heading, most-cold-damaged class, so their selection can be avoided. Four characteristics gave significant or highly significant chi-squared values indicating their preferential association with mid-early heading, most-cold-damaged lines. These four traits were wide flag leaves, erect fall growth, light green fall growth and wide fall leaves.

Additionally eight traits show a preferential disassociation with the mid-early heading, most-cold-damaged class. These eight traits are long spikes, erect leaves, mid-wide flag leaves, nodding spikes, semi-prostrate fall growth, prostrate fall growth, mid-wide fall leaves, narrow fall leaves. Selection for these characteristics within the mid-early heading class of land race barleys will reduce the probability of selecting for plants that will be easily winter.

damaged.

Conclusions

A typical early heading Korean land variety has wide, erect fall leaves that are light green in color. The adult plant has short peduncles, and erect spikes. It produces light weight kernels.

A typical most-cold-damaged Korean land variety has erect, wide fall leaves that are light green in color. The adult plant has erect spikes and short peduncles. Because there is a strong association within this land race collection between early heading and poor winter-hardiness, the profile similarities between early heading and most-cold-damaged land race selections are not surprising.

Trait associations with the higher levels of winter hardiness are not so numerous. A least-cold-damaged Korean land race line tends to have prostrate or semi-prostrate fall growth, green or dark green fall leaf color and a tendency toward narrow fall leaves. Adult plants tend to have long culms and to be mid-early heading.

Conscientious efforts must be made to establish high levels of cold tolerance in early heading populations. As it is difficult to screen for winter hardiness levels every year, the knowledge of trait associations can increase the probability that selected mid-early heading land race lines have maintained higher levels of cold tolerance. Traits that are shown to be preferentially associated with mid-early heading, least-cold-damaged land race lines include long spikes, long awns, long kernels, long culms, drooping leaves, mid-long peduncles, semi-prostrate fall growth and mid-wide fall laves. Traits that are shown to be preferentially associated with mid-early heading, most-cold-damaged land race lines include wide flag leaves, erect fall growth, light green fall leaves and wide fall leaves.

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摘　　要

1. 典型的인 早熟性 在來種의 特性은 越冬前에는 잎이 淡綠色 廣葉, 直立이며 成熟時에는 花梗이 짧고 直穗이며 粒重이 가볍다. 또한 耐寒性이 弱한 在來種도 上記 早熟性 品種과 같은 特性을 지니고 있다. 이는 早熟性과 弱한 耐寒性間에는 密接한 關係가 있기 때문에 當然한 것으로 생각된다.
2. 強한 耐寒性과 關聯된 特性은 많지 않으나 대체로 越冬前에 匍匐型이거나 半匍匐型이며 葉色은 綠色 또는 暗綠色을 띠며 狹葉, 長稈, 中熟인 傾向이 있다.

早熟性 集團에서 耐寒性이 強한 品種의 選拔은 대단히 어렵고, 또한 每年 合理的인 耐寒性 檢定을 실시하기란 極히 困難하나, 本 耐寒性과 關聯된 形質硏究에서 中生인 在來種을 利用하므로서 耐寒性이 強한 品種의 選拔可能性을 보여주고 있다.

4. 中生이며 耐寒性이 強한 品種과 關聯이 있는 것으로 여겨지는 特性은 長芒, 長穗, 長粒, 長稈, 늘어진잎, 中間止葉幅 및 長, 中間花梗長, 越冬前의 半匍匐型 및 中間葉幅 등이며, 中性이며 耐寒性이 弱한 品種은 止葉이 넓고, 越冬前에 잎이 直立, 淡綠色, 廣葉 등의 特性이 있다.