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9. ABSTRACT

This is the second annual report for a three-year project designed to increase the nutritive value of barleys consumed in less developed countries, increase barley yields, and decrease losses caused by barley diseases. During the first year of work, several LDC's were visited to establish contacts and collect isolates of the major disease organisms. The work with diseases has progressed to the point where a significant outreach program can be initiated. In work on nutritive value, the microbiological assay technique for determining lysine has been perfected to the point where it is a reliable screening tool. No significant differences were found in the feed value of waxy and normal Compana isogenic pairs due to starch type or amino acid composition of the protein. Preliminary results indicate that peoples who consume primarily rice would much prefer and probably consume more of a waxy endosperm barley than the normal endosperm barley. The High Amylose Glacier variety was slightly lower in energy value than normal Glacier, but the former has a higher quality protein due to an increase in the protein of several amino acids. Animal performance data (Growth, PER, and BV) support the chemical analyses for protein and amino acid composition of Hiproly and Hiproly Normal barleys. Lysine content of the protein has been found to be environmentally influenced differentially, dependent on the gene present, and is reflected in animal performance. Animal performance is highly correlated to the essential amino acid content of the barleys. Lysine usually accounts for over 50% of the animal variation in growth and PER and 60% of the variation in biological value. A double translocation has been located that should be effective in transferring the Hiproly gene to a population as well as disease resistance genes (scald, net-blotch, barley yellow dwarf) on chromosome 3. Fertile, plump, high-lysine lines from Hiproly crosses have been developed to serve as parents in further variety development work with this gene.

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ANNUAL REPORT on Improvement of the Nutritive Quality and Productivity of Barley for Semiarid Regions

March 25, 1975—March 24, 1976
Report No. 2
Contract ta-C-1094
Agency for International Development
Department of State
Washington, D.C.

ANNUAL REPORT SUMMARY SHEET

Project Title and Contract Number: "Improvement of the Nutritive Quality and Productivity of Barley for Semi Arid Regions." AID/ta-C-1094

Principal Investigators and Contractor: R. F. Eslick & L. P. Carter
Address: College of Agriculture, Montana State University, Bozeman, Montana 59715

Contract Period: March 25, 1974 to March 24, 1977.

Reporting Period: March 25, 1975 to March 24, 1976

Expenditures and Obligations Through Previous Contract Year	$146,551.00
Expenditures and Obligations for Current Contract Year	$192,058.00

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NARRATIVE SUMMARY

The first two years work under this project has emphasized nutritive value. During this two years we have formulated some working hypotheses relative to evaluating drouth resistance, and have verified some aspects. The work with diseases has progressed very rapidly. We believe we have advanced to the point where a significant outreach program can be initiated.

The microbiological assay technique for determining lysine has been perfected to the point where it is a reliable screening tool.

There were no significant differences in the feed value of waxy and normal Compana isogenic pairs due to starch type or amino acid composition of the protein. Preliminary results indicate that primarily rice consuming peoples would much prefer and probably consume more of a waxy endosperm barley than normal endosperm barley.

High Amylose Glacier was slightly lower in energy value than normal Glacier but the former barley has a higher quality protein due to an increase in the protein of several essential amino acids.

Animal performance data (Growth, PER, and BV) support the chemical analysis for protein and amino acid composition of Hiproly and Hiproly Normal barleys.

The Riso high lysine mutants are significantly higher in lysine than their parental varieties and some are superior to Hiproly. Animal performance data indicates that Riso 1508 would be considerably higher in biological value for feed or foods. Work is progressing to assign the Riso mutant genes to chromosomes.

Lysine content of the protein has been found to be environmentally influenced differentially, dependent on the gene present, and is reflected in animal performance.

Animal performance is highly correlated to the essential amino acid content of the barleys. Lysine usually accounts for over 50% of the animal variation in growth and PER and 60% of the variation in biological value (BV).

A double translocation has been located that should be effective in transferring the Hiproly gene to a population as well as disease resistance genes (scald, net-blotch, barley yellow dwarf) on chromosome 3.

Fertile, plump, high lysine lines from Hiproly crosses have been developed to serve as parents in further variety development work with this gene.

Four additional high-lysine non-allelic loci have been added to the high lysine collection, seg1 in Betzes, seg3 and sex1 in Compana, and seg6 in Ingrid. The first three are on chromosomes 1, 3, and 6 respectively. All have shrunken endosperm.

Addition of fertilizers containing N, P, K or combinations have had little effect on the percent lysine in the protein of the high lysine mutants Hiproly and High Amylose Glacier.

Five high lysine mutants, Riso 13, 29, 86 and 1508 and Compana sex1 have been shown to express xenia in 1st crosses. Recurrent selection populations for seed size and agronomic characters can be readily established using xenia to select for the gene.

A rapid technique for gibberellin assay has been developed.

Altering barley leaf width affects yield, yield components, stomatal density, aperature length, leaf area duration, cummulative water use and water use efficiency.

Growing points initiated a floral primordia by the time four leaves were visible over a wide range of maturity types in barley.

The scald resistant gene of Kitchin has been assigned to chromosome 4. Jet was shown to contain two resistant genes, one on chromosome 3 and the other on chromosome 4.

Tifang contains a single net blotch resistant gene on chromosome 3, C.I. 7584, a single gene on chromosome 2 and C.I. 9819 two genes, one on chromosome 3 and the other on chromosome 5.

A backcross derived Betzes barley that is resistant to seed passage of barley stripe mosaic virus is available.

Initial first releases of a scald resistant population and a high lysine (Hiproly source) population can be made this fall.

B. PROJECT OBJECTIVES

Two interim sub-objectives are common to the three major objectives of this project:

1. In cooperation with appropriate International Centers to survey representative target countries to evaluate present cultivars for general agronomic desirability, barley utilization and significance of disease and other pests.
2. To develop workshops or seminars in cooperation with appropriate International Centers to report on progress of the project and to exchange information and experiences.

The following are specific objectives under the three major areas of this research project.

Objective I - To increase the nutritive value of barleys consumed by peoples throughout the world, particularly in LDC's.

Interim sub-objectives

a. Compare methods for screening for lysine content including the development of a half-seed method.
b. Continue with the task of screening the world collection of barleys for high lysine lines.
c. Investigate protein fractionation and characterization of fractions as a means of allele identifications.
d. Determine a translocation breakpoint that is suitable for transferring the hi-lysine gene of Hiproly into a population without lysine analysis.
e. Determine if amylose:amylopectin ratio of the endosperm has nutritional significance.
f. Develop some fertile, plump-seeded, hi-lysine lines for use as donor parents.
g. Assign the Glacier hi-lysine gene to a chromosome.
h. Initiate evaluations of the biological value of proteins in lines determined to be high in lysine.
i. Initiate studies on protein inheritance, including maternal inheritance.
j. Determine the effect of environment, including soil fertility, on lysine stability across environments.
k. Initiate the development of homozygous hi-lysine composites in heterogeneous populations.

Objective II - To increase the yield of barley grown in semi-arid regions of the world, particularly in LDC's.

Interim sub-objectives

a. In cooperation with CIMMYT, survey representative target countries to evaluate those agronomic characters that may be of most value.
b. Screen barley varieties by use of the "elastic modulus" technique for drouth resistance.
c. Determine the effect of plant color on reducing heat loads, including conditions of extreme heat loads.
d. Determine the influence of leaf area on water use efficiency and the relationship of leaf area to "photosynthetic sink".

e. Determine the influence of moisture stress on the function of the awn.
f. Identify and determine the inheritance of day length insensitive gene (or genes) in barley.
g. Grow isogenes for some of the desirable traits as determined in "a" above, to verify conclusions.
h. Initiate the production of homozygous day-length insensitive composites segregating for other characters.

Objective III - To decrease losses caused by barley diseases, particularly in LDC's.

Interim sub-objectives

a. In cooperation with other interested agencies, survey representative target countries for prevalence of plant diseases, collect samples, and identify races.
b. Establish contacts for field evaluations of specific diseases.
c. Initiate work on homozygous combined stem rust, smut resistant composites segregating for the other characteristics.
d. Distribute disease resistant-susceptible isogenes for evaluation of economic importance of certain diseases.
e. Initiate work on at least one more disease based on survey in target countries.

C. ACCOMPLISHMENTS TO DATE

In April 1974, a survey was made of several LDC's by R. F. Eslick and E. L. Sharp (see 1974-75 Annual Report Appendix A for details) to view the situation first hand, establish contacts and collect isolates of the major disease organisms. In March of 1975, R. F. Eslick and L. P. Carter attended the Crop Production Division Contractors Meeting at Mississippi State University. This meeting was sponsored by the Bureau of Technical Assistance AID, Washington. In March of 1975 R. F. Eslick visited Obregon, Mexico and reviewed the barley program of CIMMYT. In July of 1975 R. F. Eslick, E. L. Sharp, and E. A. Hockett attended the Third International Barley Symposium in Munich, Germany and visited a number of barley research programs in conjunction with this trip. In November-December 1975 R. F. Eslick served as a consultant on the development of the barley research program in Korea. On a secondary mission barley supply, sources, usages, preferences, and marketing problems in Japan, Taiwan, Hong Kong, and the Philippine Islands were investigated by consultations with appropriate personnel in each country. While in the Philippine Islands IRRI headquarters was also visited. In March of 1976 A. H. Ferguson and Jarvis Brown visited Obregon to become familiar with the CIMMYT barley improvement programs.

OBJECTIVE I - To increase the nutritive value of barleys consumed by people throughout the world, particularly in LDC's.

During the past year we analyzed over 6000 culture tubes for lysine. This represents duplicate analysis on duplicate hydrolysates and all checks and standards.

The microbiological assay requires hydrolysis of ground barley samples in 6N HCl. This step was carried out on a total of three laboratory hot plates with the temperature adjusted to the boiling point of HCl. An occasional reflux vessel would boil dry during the reflux period. We found differences in the temperature of the hot plates and the temperature of various positions on each hot plate. We found significant variations in the lysine values of check samples refluxed on each of the three hot plates as well as differences in lysine among samples refluxed on different positions on each hot plate. By adding a ½ inch thick aluminum plate to each hot plate the differences in lysine among sub-samples of a check variety were not significantly different.

Standard curves - Initially, our standard curve for translating pH values into percent lysine was obtained by assaying ten samples containing 10 micrograms to 100 micrograms of L-lysine. The calculations required to relate the pH of unknown samples to this curve often resulted in a gross over estimation of high lysine samples. We obtained a series of barley samples containing lysine that covers the range of lysine from .31% to .79% lysine as a percentage of the grain. The lysine content of these samples was determined by using an amino acid analyzer. These samples are used as our standard curve and are assayed with each set of unknowns. PH values of unknowns can thus be compared directly with lysine values taken from the standards.

When our standard curve is plotted it is curvilinear. The high lysine end (low pH values) show relatively small changes in pH per unit of lysine compared to lower lysine areas of the curve. We suspected the growth of bacteria was being slowed by the concentration of lactic acid building up in the media. To study this we made up ten lots of media and adjusted the pH to cover the range pH 6.0 to pH 5.0. When our standard samples were assayed at each pH level we found essentially no growth of bacteria at or below pH 5.3. Only a slight reduction in pH occurred in the pH 5.4 media. The most nearly typical standard curves came from samples assayed at pH 5.9 and 6.0. This series is being repeated using lactic acid rather than HCl to change the starting pH levels.

Variations in the media pH as it was made up caused some discrepencies in the standard curve from one run to the next. We found that the starting pH must be kept constant. Reasons for the variation are unclear. However, we found the degree of heating when dissolving the media to be a factor. Samples of media boiled 1, 2, and 5 min. and media not heated at all produced standard curves that were essentially alike. Media heated but not boiled produced a standard curve significantly different from the other 4 curves. During the past year our method of media preparation has been standardized to boiling for 1 to 2 minutes.

One screening test for lysine is the dye binding capacity (DBC) of protein. When we applied this test to 26 pairs of Hiproly and its normal isogene (Appendix Table 1), significant differences between these genotypes were obtained. When we bioassayed the 26 pairs and computed correlation coefficients between DBC and lysine from the bioassay we found: r = .585** for DBC vs lysine as a % of grain and r = .768** for DBC vs lysine as a % of protein.

F_3 progeny from Hiproly crosses

A total of 213 entries were planted in 1973 including Hiproly. These selections were the F_3 progeny from 4 parental types crossed with Hiproly. Thirty-four selections (Appendix Table 2) had lysine levels in the same range as Hiproly. Six of the entries were as high or higher in lysine percentage in the protein than the highest sample of Hiproly.

The F_5, F_6, F_7 pedigree selections listed (Appendix Table 3) tested higher than the lowest Hiproly used in our standard curve. The nursery from which these were taken included 396 entries including parents. The microbiological assay identifies those entries having high lysine as a percent of the protein but these contain less total lysine than some high protein high lysine selections. The total lysine level has some advantage as a potential food or feed source.

Nutritional Evaluation of 2-Rowed Barleys Selected for High-Lysine

Nineteen 2-rowed barleys selected from the world collection for high-lysine potential and four commercial varieties were chemically analyzed and each fed to ten weanling rats in isonitrogenous, 10% protein diets. Rate of gain, feed consumption and feed efficiency were measured in a 21 day growth trial. Protein efficiency ratios (PER) were determined and adjusted with the PER of rats fed a standard 10% protein cornstarch-casein diet. Biological value (BV) and true protein digestibility (TPD) were determined on the five barleys having the highest PER and on the five barleys having the lowest PER. Proximate composition, calcium and

phosphorus, and amino acid composition of barleys were determined (Appendix Tables 4 and 5).

Performance of rats in a growth trial was determined (Appendix Table 6). Rats fed the cornstarch-casein diet tended to gain faster and more efficiently and had a significantly higher ($P < .05$) PER than rats fed any of the barleys. Five of the barleys produced rat gains that were not significantly different from those on the casein control diet. These were Hiproly (CI 3947), Hanna (CI 906), CI 10375, CI 12099, and Balder CI 7131. These diets also produced the highest PER and lowest feed/gain ratios of the barleys in the test.

The Hiproly diet was the best of the barleys in terms of gain, feed efficiency and PER, but all differences were not statistically significant. The casein diet was more efficiently utilized ($P < .05$) when compared to 22 of the barleys but was not significantly different in this regard from the Hiproly diet. There were numerical differences in feed consumption but the large variation in this parameter between rats within diets made these differences nonsignificant.

The commercial variety, Compana (CI 5438), produced the slowest rate of gain. Rats fed Compana also tended to be the least efficient and had the lowest PER. Waxy endosperm Compana (Mt 294318), an isoline of Compana, was similar in all parameters to the latter barley. The other commercial varieties, Unitan (CI 10421) and Shabet (CI 13827), appeared to be intermediate in comparison to the other barleys. Barleys producing low gains comparable to Compana and waxy Compana were CI 12171, CI 8192 and Bonus (CI 11308). With two exceptions, these three barleys and the Compana isolines also produced the lowest PER and the highest feed/gain ratio. Rats fed the variety Imperial (CI 12147), gained somewhat more than the five low PER barleys, but produced a low PER. Shabet (CI 13827) produced a gain of 48.0 g with a PER and feed/gain ratio of 1.71 and 5.85, respectively.

The percentage of lysine in the barley proteins was highly correlated to gain, the feed/gain ratio and PER ($r = .73$, $-.82$ and $.84$, respectively) ($P < .01$), but was less correlated with feed consumption ($r = .46$). The PER value appeared to be the best indicator in the growth trial of the percentage of lysine in the barley protein since the latter was responsible for 71% of the variation in PER.

Biological value and TPD of the five high and five low PER barleys were determined (Appendix Table 7). Hiproly had the highest BV but was only significantly greater ($P < .05$) than two other varieties in this respect, Imperial and waxy endosperm Compana. The barleys with the high PER values tended to be higher in BV but lowest in TPD. The TPD of Hiproly barley was lowest of the barleys compared and was significantly less ($P < .05$) than the TPD of Compana. The latter barley had the highest TPD of the ten barleys compared.

The BV and TPD of the combined high and combined low PER barleys (Appendix Table 8) were significantly different($P < .01$). The high PER barleys had the greater BV when compared to the five low PER barleys as a group, however they were the lowest in TPD.

Protein efficiency ratios obtained in growth trials were positively correlated ($P < .01$) with BV ($r = .81$) but were negatively correlated ($P < .01$) with TPD ($r = -.73$).

Correlation coefficients of amino acid composition of barley protein with BV and TPD were determined (Appendix Table 9). The percentage of

lysine was positively correlated ($r = .71 (P < .05)$ with BV but was negatively correlated ($r = -.60$) ($P < .05$) with TPD. Tyrosine showed the highest correlation with TPD ($r = .77$) ($P < .01$) and was negatively correlated to BV ($r = -.60$) ($P < .05$). Each amino acid tested exhibited the opposite relationship with BV and TPD, as with lysine and tyrosine, although most r values were not statistically significant.

Nutritional Evaluation of Nuclear Induced Riso Barley Mutants and the Spontaneous Mutants Hiproly and Betzes seg 1 seg 1

Five mutants of Bomi and two mutants of Carlsberg II and Hiproly, Hiproly Normal, Betzes and Betzes seg 1 seg 1 barleys were compared chemically and in rat growth trials. Biological value and TPD were measured in a metabolism trial on Hiproly, Hiproly Normal, Bomi and the Bomi mutants.

Proximate analysis of the barleys were determined (Appendix Table 10). Average Kjeldahl protein of the five Bomi mutants was essentially the same as the parent barley Bomi (13.5% vs. 13.4%) on a dry matter basis. The Carlsberg II mutants were higher in Kjeldahl protein than Carlsberg II (12.9% vs. 11.4%) which was also observed in the Betzes (12.7%) and Betzes seg 1 seg 1 mutant (14.8%). The percentage of protein in the Hiproly and Hiproly Normal pair was consistant with previous determinations (20.6% and 17.9%, respectively). Amino acid composition of the barley proteins (g/16 gN) were determined (Appendix Table 11). All of the Riso mutants showed a significant increase (12 to 56%) in percentage lysine over the parent Bomi and Carlsberg II with the exception of Bomi Riso #7. A rise in percentage lysine was accompanied by a decrease in the percentage of Glutamic acid and proline in the barley proteins. Arginine, threonine and the two nonessential amino acids, alanine and aspartic acid appeared to be increased in the mutant barley proteins. The Bomi Riso #1508 mutant evidenced the greatest percentage increase (55.6%) of lysine over the parent followed by the Bomi Riso #8 (32.5%) and Bomi Riso #13 (30.5%) mutants.

Rats fed Bomi Riso #1508 and Carlsberg II Riso #56 gained equally as well as rats fed casein and produced PER values only slightly lower than the Casein diet (Appendix Table 12). Bomi mutants #7 and #1508 produced PER values significantly higher than Bomi. The Bomi mutant which had the lowest percentage of lysine produced the slowest gain, poorest feed efficiency and lowest PER of the Bomi barleys. Although rats fed the two Carlsberg II mutants gained faster ($P < .05$) than the rats fed the parent Carlsberg II, only Carlsberg II Riso #56 produced a PER significantly ($P < .05$) higher than the parent.

There was essentially no difference in the performance of rats fed the Betzes pair. Available information for Hiproly and the Betzes seg 1 seg 1 mutant was summarized (Appendix Tables 1 and 14). The Betzes seg 1 seg 1 mutant, based on pairs grown in 18 environments, had higher protein and higher lysine in the barley and in the protein than did its' normal isotype whether lysine was determined on the amino acid analyzer, by UDY, or by microbiological assay.

Biological value and TPD of the Bomi mutants, Bomi and Hiprolys were determined (Appendix Table 13). Biological value of the barley proteins was correlated with the percentage of lysine ($r = -.86$). A negative correlation was found between TPD and percent lysine ($r = -.84$)

and between BV and TPD (r = -.80). The Bomi Riso #1508 and #8 had the highest BV of the barleys compared. The parent barley of the mutants, Bomi, was equivalent to Hiproly in BV in addition to comparable performance in the growth trial.

Additional high lysine genes

During the past year the available samples of an additional six shrunken endosperm mutants were analyzed by micro-biological assay for the presence of increased lysine, (Appendix Table 15). At least three of these seg 3 in Compana, seg 6 in Ingrid and sex 1 in Compana have a higher lysine in the protein than their normal isotype. The seg 5 mutant had a significantly lower percent lysine in the protein than its normal isotype. The six genes are non-allelic.

Chromatographic fractionation of the salt-soluble proteins of Hiproly and Hiproly Normal barleys.

The major protein classes of barley protein (albumin + globulin, hordein and glutelin) were extracted from Hiproly and Hiproly Normal barleys. The results indicated that the salt-soluble proteins (albumin + globulins) accounted for 41.8% and 43.5% of the total lysine in Hiproly and Hiproly Normal, respectively, (Appendix Table 16). The salt-soluble and glutelin proteins combined accounted for 78.7% of the total lysine in Hiproly and 80.6% in Hiproly Normal.

The salt-soluble proteins of these two barleys contained identical protein components as indicated by comparison of their molecular weights, chromatographic and electrophoretic composition. One chromatographic fraction or peak accounted for 50.3% in Hiproly Normal (Appendix Table 17). The first three chromatographic peaks from the salt-soluble proteins of Hiproly contained 52.0% more lysine than comparable peaks in Hiproly Normal. These fractions contained higher percentages of aspartic acid, lysine and valine and lower percentages of glutamic acid and cystine/2 in Hiproly than in Hiproly Normal.

Three major chromatographic peaks in the salt-soluble protein of Hiproly were substantially higher in lysine than the comparable peaks in the salt-soluble protein of Hiproly Normal.

High lysine gene transfer systems

Considerable effort is being expended on the development of marked translocations for use in gene transfers. At least two translocations for each arm of each chromosome are being used. Data on the more advanced lines (Appendix Table 18) indicate the presence of 41 mutants induced in or near a translocation interstitial segment that may be useful in effecting gene transfers.

High lysine male sterile facilitated recurrent selection populations

A composite of non semi-sterile plants with plump seed and with male sterile in the population were grown in isolation in Arizona during

the winter of 1975-76. Harvest was from male sterile plants. This population is based on lines of very narrow genetic base, Hiproly, Betzes, Compana, and Titan. Seed will be available for distribution in the fall of 1976.

Effect of Fertilizer Application on Lysine Content

A field experiment was conducted in which four barley varieties, six soil fertility variables and four spray treatments were used to investigate whether the lysine content of barley grain could be increased. Keeney (1969) reported that the percent lysine, as well as the concentration of most other essential amino acids in corn grain, was significantly increased by potassium fertilization. Hojjati and Melki (1972) reported an increase in protein, lysine and methionine in wheat grain due to increased level of nitrogen fertilization and an increase in lysine content of grain protein as the level of added potassium increased. Experiments involving the effects of urea sprays on yield and protein, and 2, 4-D spray effects on these factors have also been reported (Finney, et al, 1957: Hill, 1964: Saduphal and Das, 1966). In this study it was of interest to determine effects of these factors singly and in combination on protein and lysine content of four selected barley lines with selected genetic capacities.

Varieties employed in this study were selected for high protein and high lysine genetic character, with low (normal) sisters for comparison. Hiproly, a high protein, high lysine barley (CI 3947 - Munck, et al., 1968) and a sister line (CI4362), unofficially designated "Hiproly Normal", are phenotypically and agronomically similar, with both having high protein contents but the latter having a lysine percentage similar to normal barley. The low (normal) protein lines employed were Glacier, with its sister High Amylose Glacier. The latter has a lysine content somewhat higher than Glacier, but is similar in other respects. Seeds of the Hiproly pair are naked, while those of the Glacier pair have hulls.

Results on protein content, percent lysine in the protein, and percent lysine in the grain, as influenced by main effects, were obtained, (Appendix Tables 19, 20, 21). The large difference in protein content of the Hiproly pair as compared to the Glacier pair was observed (Appendix Table 19). The usual higher lysine content of the Hiproly grain was obtained. It is suggested that soil fertility variables, at this location, had little influence on protein or lysine levels of barley when averaged over the four varieties, (Appendix Table 20). This same general pattern was observed for each of the varieties when analyzed individually, application of P and K without N resulted in a depression of protein, and an application of 40 lb N/A was adequate to restore the original level. Removing K from the application had no measurable influence.

No significant influence was measured for these parameters averaged over varieties when foliar spray applications of urea or 2, 4-D were made during the early heading stage of growth, (Appendix Table 21). There was a tendency for lysine content of grain to be increased from spray treatments on Hiproly and Hiproly Normal, whereas they tended to decrease or have no influence on lysine content of grain for Glacier and High Amylose Glacier (Appendix Table 22).

Relationship of Hormones and Enzymes to Plant Growth, and Nutritive Value:

Seed of twenty five barley cultivars, which were produced under the same environment, were evaluated for speed of germination, speed of elongation, percentage seed dormancy, speed of emergence and growth rate.

The two cultivars which had the highest percentage seed dormancy, (Steptoe and Vantage) were slow to emerge from soil (46.7 and 64.8 respectively) and the seedlings did not grow rapidly, (Appendix Table 23). Those dormant cultivars also had 2 low indices for speed of germination and elongation. The cultivar "Hein Flo 50-1072" produced the most dry matter per 100 seedlings and ranked high in speed of emergence, germination and elongation.

Hulless Compana, an isogenic line of Compana derived from a Stamm/7* Compana cross was inferior to Compana for speed of elongation, emergence, and weight per 100 seedlings. The two lines were similar in percent dormancy. Breaking of seed dormancy by prechilling did not increase the speed of elongation of dormant cultivars, but did increase the speed of germination of these cultivars.

Studies were begun to determine an acceptable procedure for assaying for gibberellic acid activity. The literature abounds with extraction and assay procedures designed to give information about gibberellic acid. The assays either are for particular enzymes in the sequence leading to degraded starch, or are for the final product, reducing sugars. The extraction procedures are designed to isolate gibberellic acid from ground seed (or other vegetative part) material. Procedures for three assays and three extractions were compared. Of the three assays evaluated only the acid phosphotase assay was eliminated due to procedural difficulties in obtaining desired results. Both the α -amylase and the reducing sugar assay were acceptable. However, when the extraction procedures were being evaluated it was found that the reducing sugar assay was producing aberrant results. Upon consultation with organic and biochemists, in an attempt to clarify the cause of these aberrant results, it was suggested that the methanol could be either leaving residues and/or could be extracting some sugars originally present in the dry seeds, either of which would indicate reducing sugars present which were not the result of gibberellic acid activity. The buffer extraction would not be as likely to extract any sugars present in the dry seed and if combined with the α-amylase assay, would not cause false readings. The buffer extraction would also not precipitate out the protein bound GA's which would be lost in the precipitate with a methanolic extraction. Protein bound GA's are recovered in the buffer extraction by hydrolyzing the protein complexes and precipitating out the free proteins, leaving the free GA in suspension. Now that the extraction and assay procedures have been evaluated, work will begin on 25 cultivars to determine their ability to generate α-amylase, an indicator of gibberellic acid activity.

Operational significance

The percentage of lysine in barley protein is a major determining factor of the PER and BV as measured with rats. True digestibility of protein is apparently negatively related to BV which may indicate differences in digestibility of protein fractions or differences in digestibility of individual amino acids. This is in agreement with Eggum (1973). If these findings are consistant in future studies, the determination of digestibility for protein components or individual amino acids will be indicated.

Most of the lysine in Hiproly and Hiproly Normal barleys occur in the salt-soluble and glutelin protein fractions. The higher lysine

content in Hiproly over Hiproly Normal is due mainly to the higher lysine content of its salt-soluble and glutelin proteins. These results are in agreement with Ingversen and Køle (19) obtained with high-lysine Emir barley. The genotypic differences in the components of the chromatographic fractions of the salt-soluble proteins of Hiproly and Hiproly Normal should be of interest in breeding work for improving protein quality.

The observation that the high lysine genes and associated shrunken endosperms of Riso 13 and 1508 in Bomi, Riso 29, 86 in Carlsberg II, and the sex 1 gene in compana exhibit xenia in a first cross indicate male sterile facilitated recurrent selection populations can be established very rapidly and selection for plump seed in large segregating populations carried out. We do not know why the xenia expression of high lysine for the above Riso mutants has not been reported in the literature.

The use of appropriate marked translocations and the utilization of xenia permits us to place two high lysine genes in a population in the homozygous condition and determine if the action of two genes in the same plant are additive or complimentary. The gene action has been reported as additive for the Riso 1508 mutant and Hiproly genes. The method of detection can leave some doubt as to the presence of both genes in the plants studied. In those mutants expressing xenia this can be accomplished with greater assurance.

The reported environmental responses for Hiproly vs its' normal isotype (Appendix Table 1) and for seg 1 Betzes and its' normal isotype (Appendix Table 14) indicate a very marked difference in the response of these two genes to the environment for lysine in the barley and in the protein and for kernel weight. This is indicated by the differences in the regression coefficients of the two varieties. Selection of high lysine genes probably should be in the direction of those that interact the least with the environment.

Seed dormancy is a factor common to many barley cultivar. The presence of seed dormancy in cultivars used in LDC's could result in poor stands due to slow germination and poor emergence. The techniques for determining seed dormancy developed in these studies can be useful in evaluating new cultivars adapted for LDC's.

Rapid seed germination and seedling growth is related to the ability of enzymes to rapidly break down the stored food reserves. The results of studies on speed of germination and elongation suggest that certain cultivars (such as Heines Flo 50-107) have greater enzymatic activity than other cultivars. Previous research by Eslick indicates that enzymatic activity is related to more efficient rat gains or increased feed or food value of these barley cultivars.

To date, we have not been able to demonstrate the favorable influence of fertilizers and foliar spray treatments on lysine that are reported in the literature. These results suggest that additional studies need to be conducted to determine conditions under which results such as those reported by others might be obtained. Detailed studies under controlled conditions to determine times, rates, frequencies, etc. might provide additional guidelines on which to pursue further field efforts. It would appear that fertility should not be a factor in carrying out selection for high-lysine lines and that in commercial production the expression of high lysine in the protein of barley would not be effected by fertilizers or foliar sprays.

Mrs. Christin Groppe, a noted home economist and nutritionist from the University of California, has spent considerable time in Korea studying Korean dietary habits. She has found that "barley can be used in any recipe where rice is called for with two differences: use twice as much liquid as called for if rice were used and cook it twice as long as you would for rice (or soak the barley in liquid before cooling)". She further notes that because there is not enough water used in cooking barley, and the barley is not cooked long enough, it has a chewier texture than rice eating people are used to. In Korea the big problem is the cultural food patterns - rice is a status food while barley is a poor man's food. While at the International Rice Research Institute in the Philippines Dr. I. Ikehashi indicated there were no differences among rice varieties in flavor. There were "apparent" flavor differences associated with texture differences which were in turn determined by amylose: amylopectin ratios, however. Preferences by Asiatic peoples were for those in the north to prefer the all amylopectin (waxy or glutinous types) with the preference changing, as one progressed from Japan south and then west to India, toward those types containing amylose.

We recently supplied the All Japan Barley Processors Association with paired 2 kil. samples of waxy and normal endosperm isotypes of Compana, Betzes, and Titan. In a preliminary report they have indicated that the waxy is superior to the normal in stickiness, ease of cooking, and flavor. This could result in overcoming the image of barley as a "poor man's rice" and could have certain advantages in other countries.

Side effects

The negative correlation observed between BV and TPD indicates the need for a search for barley protein that enjoys both high digestibility and high biological value. This could mean complete genetic alteration of barley proteins as they now exist. The effect of cooking or processing barley for human consumption on protein quality, digestibility and biological value should be investigated.

The work on barley enzymes and hormones, when completed, will suggest various screening techniques which can be used to select barley lines with high enzymatic activity, which in turn may be related to nutritive value. These studies also suggest methods for evaluating barley cultivars for seedling vigor. Results of these studies suggest that hulless barley may be difficult to produce due to poor seedling growth rate which results in poor emergence.

Since all of the induced Riso high lysine mutants are reported to have shrunken endosperms and an examination of nine spontaneous shrunken endosperm mutants shows at least five of these to have high lysine one might conclude that the most effective selection method for additional mutants would be a sieve. These plants can also be recognized in some field plantings.

Five shrunken endosperm mutants are known to express xenia and all are high lysine. This type of mutant is more easily manipulated in the initial stages of a breeding program.

It is not surprising that a number of the high lysine barley mutants also exhibit the opaque characteristic.

A double translocation (T3-7c+T3-7d) has recently been added to the world collection of translocations. In a cross involving a normal barley there should be no crossing over between the doubled translocation chromo-

somes 3 and 7 and their normal counterparts in a translocation heterozygote. It is then theoretically possible to move any genes on a normal chromosome 3 or 7 into any genotypes without having to test for the gene in question and having all genotype homozygous for the genes on chromosomes 3 and 7. As an example the yellow dwarf resistance, scald resistance, and net blotch resistance genes of chromosome 3 and the high lysine of hiproly can be moved into a segregating population in the homozygous state without breaking linkages and without testing for homozygosity.

Research Design

There will be no major modifications of analytical or animal testing procedures. However, a step-wise multiple correlation analysis will be included to determine the relative importance of amino acid and protein composition on animal performance. It is anticipated that data thus generated, and including previously accumulated data, can be used to draw conclusions in regard to nutritionally superior barleys.

The double translocation T3-7c+T3-7d, will be investigated for use in establishing wider genetic base populations homozygous for the hiproly gene. The same stock can be used for a positive test of additivity of high lysine genes.

Those high lysine genes expressing xenia can very rapidly be incorporated into broad base male sterile facilitated recurrent selection populations. This approach to high lysine barley breeding still remains the most feasible. Sieving out the very largest seed from such populations can recover the necessary seed weights for high yields in spite of a shrunken appearance or may accumulate some suppressor genes for the shrunken character. Experience with Hiproly indicates the feasibility of this approach for other genes.

If one associates protein alteration with opaqueness then thousands of seeds (lines) can be screened on a light table. This suggests applying a mutagen to a hulless white aleurone pure line and selecting out the off-type seed and examining them, much as has been done in the corn work.

If one assumes suppressors for the shrunken endosperm character exist, then this suggests applying a mutagen to a stock containing a high lysine gene and sieving for the presence of the mutated suppressor.

The availability of a fairly large number of stocks with high lysine seems to indicate less need for screening the world barley collection than was initially projected. We should complete rescreening all of the two-row barleys in the world collection during the coming year.

Protein fractionation and characterization is assuming less significance in terms of allele identification and more in terms of nutrition.

Research techniques used in these studies for evaluation of enzymatic activity will be used in the future. At the completion of these studies correlation between various techniques and enzymatic activity will be determined.

E. WORK PLAN FOR THE COMING YEAR

Anticipated accomplishments

Complete microbiological assay of two-row barleys in the world collection. The last 715 of these will be grown in the field.

Comparative data on lysine determinations from the Udy, amino acid analyzer, and the microbiological assay method will be summarized. Approximately 100 samples should be available for this comparison.

Comparative data from protein determinations by the Neotec grain quality analyzer and by the Kjeldahl method will be summarized and interpreted. Several hundred data sample pairs are available.

Washonupana, Nubet, and Nupana will be treated with diethylsulphate to induce opaque mutants. Compana sexl sexl and Hiproly will be treated similarly to induce plump mutants.

Sufficient barley, grown at three environments, will be produced to complete rat feeding trials (biological comparisons) and analytical determinations of Riso mutants 7, 8, 9, 13, 29, 56, 86, and 1508.

The association of shrunken endosperm of the xenia expressing mutant Riso 1508 with high lysine will be verified and a male sterile facilitated recurrent selection population established. Crosses will be made to broaden the genetic base of this population.

An initial male sterile facilitated recurrent selection population with the Hiproly gene for high lysine homozygous will be grown and available for very limited distribution in the fall of 1976. An improved population will be grown and available for distribution in the late spring of 1977. Crosses leading to a much broader genetic base population of desirable genotypes will be made using the double translocation method of gene transfer. Crosses to test the reliability of the doubled translocation technique will be made.

The Riso mutants and checks will be grown in replicated trials in 11 environments to complete data collection for agronomic worth and protein and lysine stability measurements.

Analysis will be made of the F_2 of high-amylose Glacier high lysine crosses with trisomics to assign the gene to a chromosome or chromosomes.

M_4's from four plants of each of 492 M_3 lines will be checked for the presence of lethals in the intersticial segments of 15 translocations. Fifty three M_5 and M_6 lines will be checked to verify the presence of the lethal and determine if it is gametic. This material is for use in gene transfer systems.

Thirty-five F_6 to F_8 fertile, plump, good yielding lines (from single row tests in Arizona) will be compared for agronomic traits in replicated yield trials.

Evaluation of 25 barley cultivars for seed dormancy, speed of germination, speed of elongation, speed of emergence, dry matter production, respiration rates and gibberellic acid activity will be completed. All of these evaluations will be correlated to determine which is the most practical means of evaluating enzyme activity of barley cultivars.

The effect of nitrogen fertilization on the biological value of barley protein will be determined.

Repeat nutritional evaluation of Washonupana barley.

Initiate chemical and biological evaluation of high-fat barleys

and covered and hulless isogenic lines of Betzes barley.

Develop improved techniques for sharper separation of barley proteins through chromatography and electrophoresis.

Develop techniques and solvents for improving the extractability of alkaline and acidic buffers and other agents.

Investigate the effect of percentage composition of the Osborn fractions on true protein digestibility and biological value of barley protein.

The general analytical, animal, agronomic, and genetic procedures as outlined in the original proposal will be followed with modifications as indicated in sect.ons C4 and E1 of this report. From the research standpoint we anticipate no unusual factors that will impede accomplishments.

OBJECTIVE II - To increase the yield of barley grown in semi-arid regions of the world, particularly in LDC's.

C. Accomplishments to date

Canopy Color

Short wave reflection, net radiation measurements and Bowen Ratio calculations over Compana and Golden Compana barley plots indicated that color differences available in present barley varieties may be a useful tool to reduce the heat load of crops grown in hot semi-arid environments. Reflection was greater and net radiation less with the light colored lines. Bowen Ration calculations on those days where good data were collected indicated the ET was generally less with the light colored line. The Golden Compana used less soil water throughout the growing period, again indicating that the light colored lines may be grown under conditions of less water.

Drying rate

Rates of drying studies on 50 barley varieties that cover, hopefully, a wide range of drought tolerances indicated significant differences among varieties. One of the most promising measurements of this study is the ratio of initial plant weight to plant dry weight. Those varieties with the lowest ratio are, in general, the varieties that experience indicates do the best under arid conditions.

Plant water potential

Plant water potential measurements and modulus of elasticity calculations were made on the 50 varieties. These data have not been completely analyzed but there is hope that these or similar measurements will be useful screening tools for plant breeders in selection of parents for breeding barleys for semi-arid areas.

Leaf width

Hannchen and Betzes barley lines (Hordeum distichum L.) isogenic for leaf width (narrow, midwide and wide) were evaluated for their influence on water-use efficiency (WUE) 1973-1975. The effects of three planting patterns; 30.5 cm between rows and 6.6 cm within rows, 15.2 cm between rows and 13.2 cm within rows, and 15.2 cm between rows and 6.6 cm within rows, on WUE were evaluated in 1973 using Hannchen isotypes.

Total evapotranspiration (ET), yield and WUE were consistently lower for the wide-leaved isotypes. Yields of the narrow and midwide-leaved isotypes were similar in 1973 and 1975. The midwide isotype had the greatest WUE in 1974 and 1975, but did not differ from the narrow isotype in 1973.

The higher density planting in 1973 (802,000 plants/ha) produced a 12.4% higher yield (3620 kg/ha) than planting in 30.5 cm rows at the lower density (414,000 plants/ha). When planted in a near equidistant pattern at the lower density, yields were similar to the higher population density and exceeded yields obtained from 30.5 cm row spacings at the same lower density. The more uniform distribution of plants at the

lower population density also produced a 14% higher stand establishment.

The wide-leaf isotype produces fewer tillers per plant, but more kernels per ear and a higher weight per kernel.

Stomatal density differed between varieties and among isotypes and decreased with each successively lower leaf on a plant tiller. Mean stomatal aperture lengths differed between varieties, among isotypes, among leaf positions on a tiller, and between adaxial and abaxial surfaces of leaf blades. There was an inverse relationship between stomatal density and aperture length.

Root data suggest that lateral root branching of the Hannchen narrow-leaved isotype is not as extensive in the upper soil profile as it is for the other two Hannchen isotypes.

Root data and stomatal observations could not be correlated with water use of WUE.

Altering barley leaf width affects yield and yield components, stomatal density and aperture length, leaf area duration, cumulative water use, and WUE.

Relationship of leaf area to "photosynthetic sink".

Field results with Hannchen leaf width isotypes (narrow, N, midwide, MW, & wide, W) can be used to evaluate the effects of leaf width, planting patterns, and planting densities on the relationship of "photosynthetic sink" produced (grain) to leaf areas (photosynthetic source). The efficiency of grain production per unit of leaf area (Appendix Table 24) at the approximate time of maximum LAI was calculated as $\frac{\text{mg grain}}{\text{cm}^2\ \text{LA}}$. N and MW lines appeared to be more efficient than W-leaved lines (11.8, 11.3 and 9.9 mg/cm^2 respectively). The leaves of plants in the higher density planting (800,000 plants/ha) were less efficient for MW & W but similar to lower density plantings (410 and 470,000 plants/ha) for N-leaved lines. Near equidistant spacing at the lower density appeared to increase grain yield over planting in 30.5 cm rows but the efficiency of leaves was similar.

Day length sensitivity

Sixty-eight accessions of barley including 50 varieties and 18 lines isogenic for earliness are being evaluated for day length sensitivity (Appendix Table 25). Both replications of this study have been completed, but analysis of the data is not yet completed.

In the interim between the two replications of the screening study another study was completed to determine if a particular vegetative stage corresponded to the initiation of a floral condition in the barley growing point. If such a stage does exist, it would enhance field estimation of the time of floral initiation. Earlier work by O. T. Bonnett[2/] indicated that when a barley plant possesses four visible leaves, the growing point has established at least a minimal floral condition. Ten varieties of barley representing a wide range of rates of development (based on their performance in the first replication of the screening study) were chosen to determine if the four leaf stage is a good indicator of floral initiation. The varieties Floya, Olli, Early Betzes (Compana Dwarf), Titan, Prior, Steptoe, Marie, Dicktoo, Late Compana and Eskishier were used in the study.

The plants received two different photoperiod treatments. 80° F, 14-hour days and 60° F, 10-hour nights with one of the treatments including the breaking of the dark period by 1 hour of low intensity light from 11:30 p.m. to 12:30 a.m. Six replications of each variety with 5 plants per pot (one for each sampling date) were grown in each treatment.

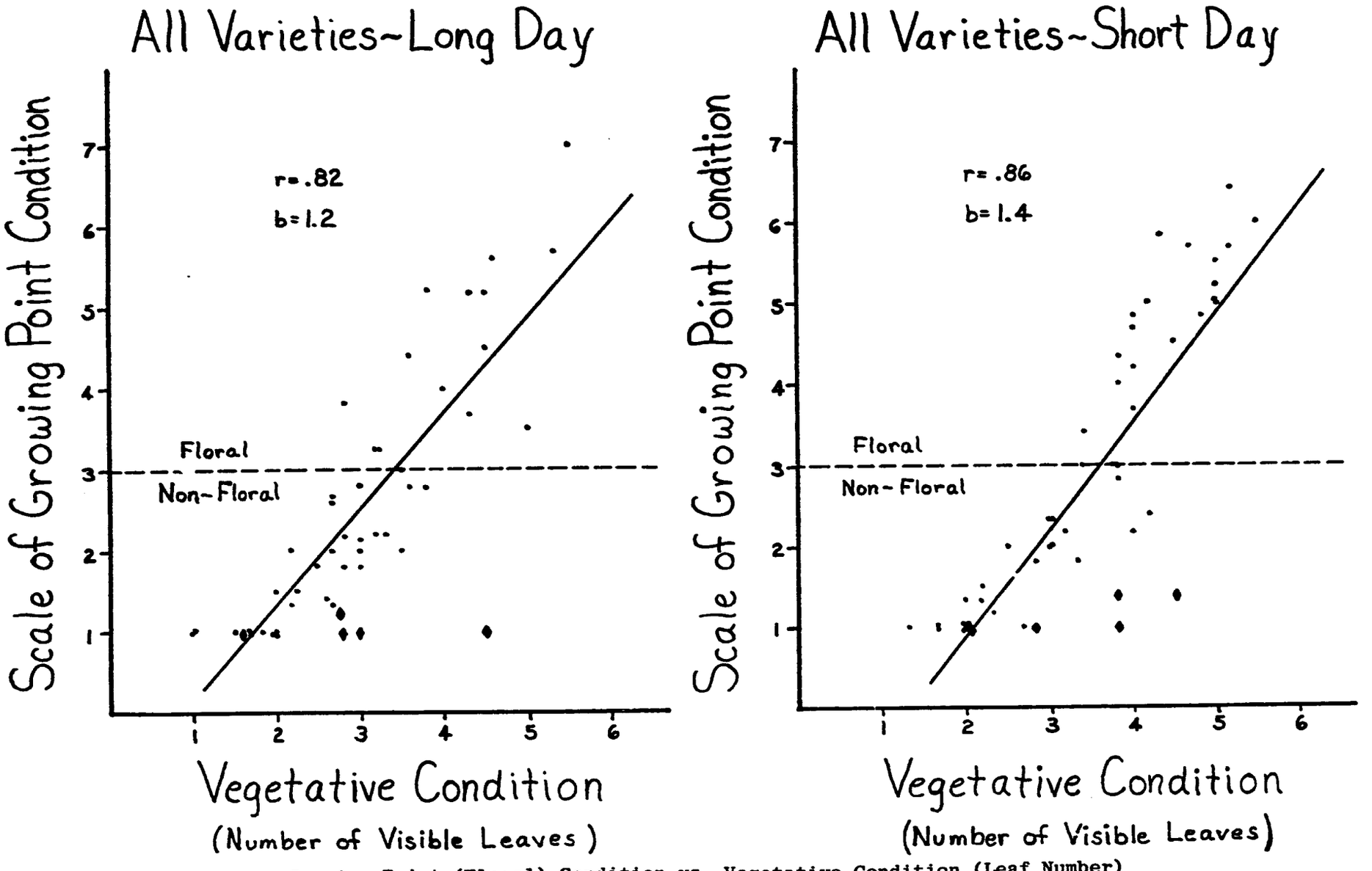
The plants were sampled at 8, 12, 16, 20 and 24 days after planting. The samples were dug from the soil and placed in 95% ethanol to kill and preserve them. Their visible leaves were counted and the shoot apex dissected under a binocular microscope to assess the morphology of the growing point. A scale similar to that of D. Aspinall and L. G. Paleg (1963)1/ was used to rate the growing point development.

Some varieties showed higher correlations between vegetative stage (leaf number) and floral condition than did others. The individual variety correlations also varied under the photo-period treatments. Scatter diagrams constructed from the data of all varieties' means clearly show that the growing point has been induced and initiated a floral condition if four leaves are visible. (See Figure 1). Only one variety, Dicktoo, a winter barley, fails to show this relationship. This study supports the work of O. T. Bonnett,2/ first reported in 1935, and suggests that the barley seedling is induced during the 2-3 leaf and the floral condition is initiated by the time the fourth leaf is visible.

1/ Aspinall, D. and L. G. Paleg. 1963. Effects of day length and light intensity on the growth of barley. I. Growth and development of apex with a flourescent light source. Bot. Gaz. 124: 429-437.

2/ Bonnett, O. T. 1966. Inflorescenses of Maize, Wheat, Rye, Barley and Oats: Their initiation and development. University of Illinois, College of Agriculture, Agricultural Experiment Station, Bulletin 721: 59-77.

FIG. 1



Growing Point (Floral) Condition vs. Vegetative Condition (Leaf Number)
(Based on mean values by sampling date.)
• Spring Barleys
♦ Winter Barley (Dicktoo)

Isogenic analysis

We have been striving to complete a series of Titan isogenics (Appendix Table 26). These and other isogenes will be used to quantify a number of pleotropic effects or associations. These effects are of particular significance to plant breeders practicing visual selection on a plant or row basis. During the past year isotypes of Betzes for wide leaves, narrow leaves, brachytic 2, ms 3 dwarf 2, Hannchen dwarf, many noded dwarf, 2-row and 6-row fertile and sterile laterals, Compana dwarf, glossy seedling 4, and glossy sheath 5 were completed. Several di-isogenes of some were obtained. Compana isotypes for brachytic, erectoides d, long basal internode, erectoides a, and glossy sheath 4 were completed. Stocks T67 through T72 were completed for Titan. Several isotypes of Carlsberg II were completed. Seed of completed isogenics is available to anyone requesting seed.

Leaf area

We have initiated work to classify 25 two-row and 25 six-row commercially grown varieties for drouth tolerance. We are accumulating all back yield data on these 50 varieties grown in regional and Montana trials. Several hundred paired yield values for each variety under a diversity of environments will be available for analysis.

Last year leaf areas were determined on these varieties. From preliminary evaluation of previous data (Appendix Tables 27 through 31), we may conclude that leaf areas are smaller in 2-row varieties and larger in 6-row varieties. Large differences exist within each group. Differences in area may be attributed to length or width or a combination of both. Leaf area distribution up and down the culm is the same for both six- and two-row varieties but varies among varieties in each group.

It is interesting that the better dryland varieties within each row-type, in general, have smaller leaf areas than those not generally considered drouth resistant. This may be attributed to pleotropic effects associated with earliness.

2. Operational Significance

Our data on reflection as related to water use fits with data of others that increased reflection may be a useful tool in decreasing the heat load on plant canopies. Also, the drying and Bowen ratio work supports data by others indicating that simple measurements of plant water status may be useful tools in plant selection for specific environments. We are of the opinion that this work has advanced to the point where we will create 3 recurrent selection populations to develop a genetic background that will better accommodate light color genes.

Dr. A. Gustafson has indicated to us that the early maturity mutant ea-a as represented by Marie is day length insensitive. This should provide us with a ready starting point for day length insensitive studies.

3. Side effects of the work

We are of the opinion that work with isogenics is yielding information for immediate application as well as information that will have a direct

usefulness in understanding the larger problem of drouth resistance.

Probably one of the greatest hindrances to work on drouth tolerance is the lack of a series of varieties where it may be said this variety is truly drouth resistant, this one is not. Can all of the differences be attributed to leaf area, plant color, maturity, awns, etc. or are there physiological differences that provide drouth resistance?

Three readily measurable attributes of a barley plant are quite sensitive to water stress (1) number of seed per spike for the seedling or rosette stage (2) plant height for the pre-boot to heading stage, and (3) seed weight for the week after flowering to physiological maturity stage (app. 40% moisture). If these three measurements are made in water stressed and non-stressed environments and the results expressed as "measurement under stress"/"measurement with no stress" then the magnitude of the ratio (%) may indicate the responsiveness of the plant to water stress at these three stages. Each stage would be influenced, to a degree, by what happened in the previous stage or stages. This effect could be removed by proper analysis.

There are marked differences in silica content of awns. If silica content is passive uptake related to water transpired from the awns then it is conceivable that ash content of the awn could be related to water used by the plant from filling to maturity. It is not clear how this might relate to the rapidity of starch deposition in the seed, if at all, nor is it known whether barley plants should transpire a lot or little water through the awns for maximum yields in water stress situations.

There are a number of genes that may result in early maturity without materially effecting yield. To name a few, these are dark plant color to absorb more of the radiation energy and thus promote growth during the cool part of the season; larger leaves to intercept more of the radiation; and lowered minimum effective temperatures. After physiological maturity the rate of drydown could probably be materially speeded up by darkening the lemma or aleurone color, by shedding the awns, by growing 2-row rather than 6-row varieties, and varieties with lax rather than dense spikes. Rapid dry-down could result in less exposure to wind, hail, rain, birds, etc. and get the grain off the land sooner if another crop is to be planted immediately. The problem is subject to analysis with isogenics on hand.

These additional concepts are to be incorporated into this portion of the project.

4. Research design

No significant modification of our approach to detailed measurements of water use efficiency of isogenic lines is contemplated. Equipment has been obtained for more precise micro-meteorological measurements.

E. WORK PLAN FOR COMING YEAR

Plant growth, photosynthesis (including light saturation), water use and yield of Betzes lines isogenic for leaf chlorophyll content and lines di-isogenic for maturity and chlorophyll content will be determined.

A procedure for determining silica content of barley awns will be developed. Ash weight as a measure of silica will be compared with a standard procedure, either a gravimetric technique or an atomic absorption technique.

Evaluation of 25, 2-row and 25, 6-row commercial barley varieties for drought resistance will be expanded to include chlorophyll stability. Chlorophyll concentration at Bozeman and two or more locations will be determined. Dry down rates of seedlings, leaves of more mature plants and spikes will be determined. We will compare variety yields obtained over a period of years (back to 1935) at many locations by a modification of the Finlay-Wilkinson technique. Seed per spike, weight per seed, and heights will be determined on material grown at 10 locations in Montana in multiple row plots in 1976.

We will continue our work on using water status of plants as a screening technique to choose those varieties with the best possibility of producing under semi-arid conditions. Another year should establish the possibility of beneficially using the screening techniques we are evaluating.

Effect of several plant characteristics, i.e. lemma color, lax spikes, 2-row, dehiscent awns, and maturity on maturation rate will be determined.

The relative suitability of the 2-row and 6-row genes to early and late maturity types will be determined in yield trials at 8 locations.

We will initiate work on describing pleotropic effects associated with maturity genes.

We will continue checking some 33 varieties for allelism of maturity genes.

OBJECTIVE III - To reduce losses caused by barley diseases, particularly in LDC's

C. Accomplishments to date

Major emphasis this past year has been on stem rust and scald. In addition, net blotch, leaf rust, covered smut, and BSMV received attention. Most work was toward the goal of establishing barley populations homozygous for disease resistance while maintaining heterozygosity for other agronomic characters. Work was also initiated on development of barley populations containing diverse sources of disease resistance or resistance due to minor genes (horizontal resistance). Work on BSMV was aimed at developing resistance to seed transmission.

Stem Rust

F_2 seed from crosses between male sterile (msg 10) resistant (TT) Vantage-derived plants and susceptible translocation stocks involving chromosome 1 were planted in a stem rust nursery in 1975. A stem rust epiphytotic (race 15-B-2) was created in the nursery by the use of spreader rows of susceptible wheat. Stem rust infection was good and fairly uniform throughout the nursery. Each F_2 plant was classified for stem rust reaction (resistant, intermediate, susceptible) and sterility (sterile, semi-fertile, fertile). The results of each F_2 population were evaluated to determine if a suitable translocation stock had been found. An example of this evaluation is shown in Figure 2.

Rust Reaction	F (25)	SF (50)	S (34)	
R	11	11	2	24
I	3	15	14	32
S	11	24	18	53

Sterility

Figure 2. Rust reaction and sterility classes for F_2 plants of 1106-1 (Vantage) x B222-51 (T1-5p Inis).

Assuming no errors in classification, an F_2 population showing only the parental phenotypes (resistant-sterile and susceptible-fertile) and the intermediate (intermediate-semi-fertile) would be the one involving the desired translocation (breakpoint beyond T gene). A recurrent selection population would then be set up with this translocation. The results from all F_2 populations indicated (even assuming misclassifications) the translocations involved were not desires.

There is some concern about the accuracy of the stem rust readings. This is prompted by F_2 ratios that often were uneffected (1:2:1 or 3:1 ratios were anticipated). Results of seedling tests in a controlled environment room with reserve F_2 seed of several populations were compared to the field results (Appendix Table 32). The distributions are in several cases quite different. Miller and Lambert (Agronomy J. 47: 373-7, 1955) also reported discrepancies between seedling and adult reactions. We hope to correlate seedling and adult stem rust reactions by testing the same plants in both stages.

Crosses were made in 1975 between 80 additional susceptible translocation stocks and the same Vantage-derived male sterile resistant parent. F_1 plants from these crosses are presently growing in Arizona.

Scald

F_1 plants of translocation stocks involving chromosome 3 x scald resistant parents (Atlas 46, Osiris, Modoc, Trebi, La Mesita, and Turk) were grown and harvested. Scald reactions were determined by artificial

inoculation with a mixture of isolates. All reactions were intermediate.

Trisomic F_1's of the Betzes trisomic series x scald resistant cultivars Jet and Kitchin were grown in the greenhouse in 1975. F_2 seedlings of these crosses have been evaluated for scald reaction (Lebanon isolate). Altered segregation ratios indicate the linkage group in which the resistance genes are located. Our results indicate that Kitchin contains a single gene for resistance on chromosome 4 (Appendix Table 33) and Jet contains 2 recessive genes, one on chromosome 3 and the other on chromosome 4 (Appendix Table 34).

An effort to develop narrow-based recurrent selection populations containing a number of sources of scald resistance was begun in 1975. The populations are as follows: 1. an 11-variety 2-rowed composite crossed onto male sterile msg 10; 2. the same 2-rowed composite crossed onto male sterile msg 23; 3. an 11-variety 6-rowed composite crossed onto male sterile msg 10; and 4. The same 6-rowed composite crossed onto male sterile msg 23. Scald resistant cultivars Trebi, Jet, Kitchin, Steudelli, Atlas 46, La Mesita, Modoc, Nigrinudum, and Turk were crossed onto male sterile plants in each of the four populations. F_1 plants from these crosses are presently growing in Arizona.

We have also initiated a population in which minor genes for scald resistance will be concentrated. The base population is CC XXX-F, essentially a composite containing the germplasm of the world collection with male sterility to facilitate recombination. In a series of seedling tests more than 10,000 plants were inoculated with the scald organism (using a mixture of Montana, Lebanon, and Turkey isolates). Resistant and susceptible plants were discarded. Intermediate reaction plants were retained and grown to maturity and harvested. By eliminating resistant plants the major genes for resistance will hopefully be removed. Intermediate reaction plants will hopefully contain minor genes for resistance, which can be concentrated by further selection. This type of resistance is often called horizontal and is a more stable form of resistance.

Net Blotch

Trisomic F_1's of the Betzes trisomic series x net blotch resistant cultivars Tifang, CI 7584, and CI 9819 were grown in the greenhouse in 1975. F_2 seedlings of these crosses have been evaluated for net blotch reaction (Pt-8, Tunisia isolate). Altered segregation ratios indicate the linkage group in which the resistance genes are located. Our results indicate that Tifang contains a single gene on chromosome 3 (Appendix Table 35); CI 7584 contains a single gene on chromosome 2 (Appendix Table 36); and CI 9819 contains two genes on chromosome 3 and 5 (Appendix Table 37). These results (and for scald resistant cultivars above) are quite significant. These are the first cases of disease resistance genes being located with the use of the primary trisomic analysis.

Leaf Rust

Uredospores of an isolate of *Puccinia hordei* from Beja, Tunisia was increased on susceptible varieties and preserved for later use by lyophilization. About 80 cultivars reported in the literature were tested for reaction to the Beja isolate, (Appendix Table 38). A number of cultivars showed good levels of resistance.

Covered Smut

Tests using two isolates of Ustilago hordei from Tunisia gave intermediate reactions on the variety Betzes. The series of primary trisomics is in Betzes. In order to use this trisomic series, it must either have a good level of resistance or susceptibility. In an effort to obtain this in Betzes genetic manipulation of the smut cultures was attempted. Single haploid sporidia from ordered tetrads of the two Tunisia isolates were mated in all compatible combinations and inoculated onto seedlings of Betzes and Odessa (the universal susceptible). In this experiment infection levels were very low. We are terminating work on genetics of resistance to covered smut. Time is the major consideration and can better be used on other diseases.

Barley Stripe Mosaic Virus

Since the results of the survey of some of the LDC's revealed that barley stripe mosaic disease was important and serious in farmers' fields and in experiment station plots, Eslick and Sharp suggested that work on this disease be started in 1975. Thus, research begun some years ago on the resistance to the disease could now be continued as part of the AID project. The primary objective of this research was to control the causal virus (BSMV) by preventing it from being passed through seed generation after generation. Hence the research emphasis was placed on the resistance of barley to the seed transmission of BSMV. Resistance of seedlings, based on their response to mechanical inoculation with the virus, was not emphasized, even though this approach has been given preference by other barley scientists for years. BSMV research under the AID project in 1975 encompassed two aspects. One aspect pertained to the development of germplasm resistant to the seed transmission of BSMV. The second aspect concerned itself with the genetic inheritance of barley to the seed transmission of the virus.

Work on the development of germplasm involved the further evaluation and selection of lines from original Modjo x Betzes crosses and seven subsequent backcrosses to Betzes, all the while selecting for nonseed transmission of BSMV. Early screening was done with undesignated Montana strains of the virus by Eslick and Hockett, while final screenings have been achieved with the MI-3 isolate of BSMV. This work has resulted in several barley lines which appear to be resistant to the seed passage of MI-3.

One study of the inheritance of resistance to the seed transmission of BSMV was completed in 1975 using MI-3 in crosses of Modjo (CI 3212) and Vantage, and Modjo and a doubled haploid barley, HB 1681. A preliminary analysis of parental, S_1, F_1, and F_2 data suggest that when Modjo was used as the female parent in crosses, a single recessive allele conditioned the barley for resistance to seed transmission of the virus. However, when Modjo was used as the male parent in crosses, the observed values departed significantly from the expected values, for a one allele model, indicating, perhaps, that maternal or cytoplasmic inheritance is involved at times in this inheritance of resistance.

E. WORK PLAN FOR THE COMING YEAR

Stem Rust

During the summer of 1976, the F_2 populations involving additional translocations (presently F_1's in Arizona) will be grown and evaluated in stem rust nursery in further attempts to identify a usable translocation stock. In addition, F_3 seed will be harvested from fertile and semi-fertile F_2 plants for evaluation in greenhouse seedling tests. This will, hopefully, remove the problems of field testing described earlier.

We will initiate work this summer on broad-based resistance. CC XXX-F (described earlier) will be planted in the stem rust nursery and resistant and intermediate reaction plants will be harvested. The resistant plants will serve as a base population to contain all major resistance. The intermediate plants will be the base for a population resistant to stem rust due to minor genes. Also, stem rust re istant cultivars will be crossed to the four narrow-based agronomically-adapted composites.

Scald

F_2 populations of scald resistant x translocation stocks will be grown and inoculated with a scald isolate. Individual F_2 plants will be classified for scald reaction and semi-sterility (and in a few populations, for an erectoides character). If only parental and intermediate phenotypes occur in a population, then this will indicate that the translocation breakpoint is distal to the Rh genes.

Scald resistant cultivar 'Kitchin' will be crossed to translocation stocks involving chromosome 4. 'Jet' will be crossed to translocations involving both chromosomes 3 and 4.

Seed from intermediate reaction scald plants, derived from CC XXX-F, will be grown and inoculated. These plants will be observed for segregation of scald reaction. Only intermediate reaction plants will be harvested. This will be done to eliminate plants selected in the original population that are heterozygous for major gene resistance. CC XXX-F will also be screened for resistant reaction plants (major genes resistance).

F_2 seed of crosses between four composite populations and scald resistant cultivars (described earlier) will be grown and inoculated with scald isolates. Resistant plants will be recrossed to the original composite populations to broaden the germplasm base in the resistant population.

Net Blotch

Resistant cultivars Tifang, CI 7584, and CI 9819 will be crossed to translocation stocks involving chromosomes 3, 2, and 3 and 5 respectively. F_1's will be grown in Arizona in 1976-77. CC XXX-F will be handled as with earlier diseases. Also, a number of net blotch resistant cultivars will be crossed to the 2- and 6-rowed composite populations.

Leaf Rust

The cultivar Franger is resistant to the Beja isolate and is reported to contain gene Pa_4 for resistance, linked to MI (powdery mildew resistance) on chromosome 5. Cultivars Sudan and Reka I are reported to

contain resistance genes on chromosomes 4 and 2, respectively. Franger, Sudan, and Reka I will be crossed to translocation stocks involving these chromosomes. Other cultivars resistant to leaf rust will be crossed to the Betzes trisomic series to locate their resistance genes.

Work will also be initiated with CC XXX-F and the 2- and 6-row populations.

Covered Smut

Work on covered smut will be confined to development of recurrent selection populations containing diverse sources of resistance. The extent of this work will depend on obtaining high levels of infection under field conditions. We hope to evaluate CC XXX-F for covered smut resistance. Also, several covered smut resistant cultivars will be crossed to the four composite populations.

Barley Stripe Mosaic Virus

Evaluating germplasm resistant to the seed transmission of BSMV will continue in 1976. A population from an original Modjo x Betzes cross will be screened using target area and virulent Montana isolates of the virus. Other germplasm from the world collection of barleys will be similarly screened. Those lines showing little or no seed transmission will be developed further as resistant stocks. Some of the European, Ethiopian, and Manchurian barleys show promise according to Timian (Pl. Dis. Reptr. 59: 981-988, December, 1975).

Testing Entries in Mid-East Nurseries

Seedling pathogenicity tests will be conducted on breeding materials released by international research centers to Middle East countries for testing. Some effort will be expended in attempting to establish some central clearing laboratory for checking all seed moving among breeding programs for freedom from BSMV.

Dissemination of research findings

Publications

Bockelman, H. E., R. F. Eslick, and E. L. Sharp. 1976. Reaction of CCXXX-F and an inbred bulk of the world collection to Montana and Middle East isolates of scald. Barley Genetics Newsletter 6:89.

Calvert, C. C., C. W. Newman, B. R. Moss and R. F. Eslick. 1975. The nutritional significance of varying combinations of amylose and amylopectin in Barley. BN 18:33-34.

Calvert, C. C., C. W. Newman, Robert Eslick and K. G. Goering. 1975. Waxy vs normal barley in rat and pig diets. Vol. 26: Proceedings, Western Section, American Society of Animal Science.

Calvert, C. C., C. W. Newman, R. F. Eslick and K. G. Goering. 1976. Comparison of waxy, high-amylose and normal barley starches in purified rat diets. Nutrition Reports International 14:55.

Carroll, T. W. and D. E. Mayhew. 1975. Electron microscopy of barley stripe mosaic virus in barley during anther and pollen development. In Proceedings of the American Phytopathological Society. 2:112. (Abst.)

Carroll, T. W. and D. E. Mayhew. 1975. Barley stripe mosaic virions associated with spindle microtubules in barley cells undergoing microsporogenesis. Proceedings of Third International Barley Genetics Symposium. (In press). (Abst.)

Cunfer, B., D. E. Mathre and E. A. Hockett. 1975. Factors influencing the susceptibility of male - sterile barley to Ergot. Crop Science. 15:194-196.

Eslick, R. F. and E. A. Hockett. 1974. Genetic Engineering as a key to water-use efficiency. Agric. Meteor. 14:13-23.

Ferguson, H., J. Brown and R. F. Eslick. The influence of morphological features of barley on genotype - environment interactions - some examples. BN 18:56.

Heilmann, R. H. The influence of barley leaf width isotypes (*Hordeum distichum* L.) and associated characteristics on water-use efficiency. Ph. D. thesis.

Hockett, E. A. 1975. The genetic male sterile barley collection. BGN 5:84-86.

Hockett, E. A., J. A. Benson, and R. F. Eslick. 1975. Registration of Purcell barley. Crop Sci. 15:603.

Hockett, E. A. and J. G. Moseman. 1975. Cooperative state - USDA regional barley nurseries. BN 18:140-142.

Hockett, E. A. and K. C. Feltner. 1975. Sterility induced in barley by a chemical gametocide. Agron. Absts. 67:55.

Jarvi, A. J. and R. F. Eslick. 1975. Shrunken endosperm mutants in barley. Crop Science 15:363-366.

Moss, B. R., C. W. Newman and A. Beekler. Waxy Compana as a dietary ingredient for poultry. BN 18:32-33.

Newman, C. W., B. R. Moss and R. F. Eslick. 1975. Nutritional value of Hiproly barley for rats and pigs. BN 18:36-38.

Newman, C. W., R. F. Eslick and R. C. Rasmuson. 1974. Effect of barley variety on protein quality and nutritional value for rats. J. Anim. Sci. 38:71.

Rahman, M. M. and R. F. Eslick. 1975. Linkage of male sterile genes with seedling lethal genes. BGN 5:42-44.

Ramage, R. T., M. Paluska and R. F. Eslick. 1975. Cytological and breeding behavior of a large fragment of chromosome 6. BGN 5:51-53.

Ramage, R. T. and R. F. Eslick. 1975. Translocation Linkage tests - T2-7a x male sterile genes. BGN 5:46-48.

Shaw, A. F., E. A. Hockett and M. J. Jackson. 1975. Malting barley production. Mont. State Univ. Bull. 1131:1-12.

Waters, R. F. 1975. Microbiological Assay of high lysine mutants in Hordeum sp. BN 18:40.

Papers presented

Calvert, C. C., C. W. Newman, Robert Eslick and K. G. Goering. 1975. Waxy vs normal barley in rat and pig diets. Proc. WS Am. Soc. Animal Sci. 26:108.

Calvert, C. C., C. W. Newman, B. R. Moss, A. M. El-Negoumy and R. F. Eslick. 1976. High-amylose barley in rat and pig diets. Proc. WS Am. Soc. Animal Sci. 27:119.

Carroll, T. W. Presented paper at American Phytopathological Society meeting, Davis, California. Electron microscopy of barley stripe mosaic virus in barley during anther and pollen development. June 17, 1975.

Newman, C. W. and D. O. Elliott. 1975. L-lysine and DL-methionine supplements in barley-soy pig diets. Proc. WS Am. Soc. of Animal Sci. 26-105.

Meetings Attended

Brown, J. attended the national American Society of Agronomy Meetings at Knoxville, Tennessee including a symposium on Measurements of Soil and Plant Water Status. Aug. 24-30, 1975.

Carroll, T. W. Attended cereal virology workshop at Brookings, South Dakota, and presented a report on viral diseases of barley in Montana. December 16-17, 1975.

Ferguson, A. H. and J. H. Brown consulted with CIMMYT staff and other barley workers from the USA, Canada and Australia at Cindad De Obregon, Mexico about isogenic analysis, varietal adaptation, and water-use efficiency. March 25-28, 1976.

Ferguson, A. H. and J. H. Brown consulted with faculty and observed plant materials and laboratory techniques at the University of Arizona, Tucson, Arizona relative to drought tolerance and genetic diversity for various traits in barley. March 29-30.

Visitors

Caraganal, A. R. Jr., San Miguel Corporation, Manila, Philippines. Discussed barley breeding with E. A. Hockett and R. F. Eslick.

Carleton, A. E., Research Director, Montana Seeds, Conrad, Montana. Discussed Barley breeding with R. F. Eslick and E. A. Hockett.

Chiarappa, L., U.N. FAO Chief Plant Pathologist, Rome. Visited and discussed barley diseases in the Middle East. March 31, 1976.

Craddock, J. C., Crops Research Division, USDA. Beltsville, Maryland. Consulted on cooperative work on winter-spring determination on World Collection Barleys conducted at Bozeman.

Duecker, Kurt C., Schreier Malting Co., Sheboygan, Wisconsin. Discussed barley breeding with R. F. Eslick and E. A. Hockett.

Escuro, P. B., University of Philippines, Laguna, Philippines. Discussed barley breeding with E. A. Hockett and R. F. Eslick.

Gleason, L., Barley breeder, Cargill Inc., Ft. Collins, Colorado. Discussed barley breeding with R. F. Eslick and E. A. Hockett.

Haus, T. E., Colorado State University, Ft. Collins, Colorado. Attended an Editorial Committee meeting of Barley Genetics Newsletter.

Helms, J. H., University of Alberta, Edmonton, Alberta. Discussed barley breeding problems and diseases of common interest to Alberta and Montana. Nov. 14, 1975.

Jarvi, A. J., Barley Breeder, Cargill Inc. Ft. Collins, Colorado. Discussed barley breeding with R. F. Eslick and E. A. Hockett.

Klatzbuecker, R. A., Jos. Schlitz Brewing Company, Milwaukee, Wisconsin. Discussed barley breeding with R. F. Eslick and E. A. Hockett.

Matchett, R. W., Barley breeder, Northrup King and Co. Discussed barley breeding with R. F. Eslick and E. A. Hockett.

McProud, W. L., Office of Rural Development, Seoul Korea. Discussed barley breeding with R. F. Eslick and E. A. Hockett.

Moseman, J. G., Crops Research Division, SUDA, Beltsville, Maryland. Consulted on barley breeding and disease resistance work in progress.

Ramage, R. T., ARS, USDA, University of Arizona, Tucson, Arizona. Harvested summer barley crop and participated in various project connected activities.

Reid, D. A., ARS, USDA, University of Arizona, Tucson, Arizona. Consulted on winter barley breeding.

Rohwer, R. G., Grain Processing Corporation, Muscatine, Iowa. Discussed progress on work with barley starch processing and breeding with K. J. Goering and R. F. Eslick.

Shaner, G., Purdue University Plant Pathologist. Visited and discussed leaf diseases of wheat and barley. April 10, 1976.

Thompson, R. K., Branch Experiment Station, University of Arizona, Mesa, Arizona. Harvested summer barley and wheat crop and participated in various project connected activities.

Tsuchiya, T., Colorado State University, Ft. Collins, Colorado. Attended an Editorial Committee meeting of Barley Genetics Newsletter.

Weinberger, Dr., In charge of the barley laboratory at the University of Wisconsin. Visited with A. M. El-Negoumy in May and discussed common work interests and the possibility of doing cooperative work together.

Wood, V., Barley Breeder, North American Plant Breeders, Berthoud, Colorado. Discussed barley breeding with R. F. Eslick and E. A. Hockett.

Zialcita, L. P., Jr., San Miguel Corporation, Manila, Philippines. Discussed barley breeding with E. A. Hockett and R. F. Eslick.

Recurrent selection population seed was sent to ALAD in Lebanon to be planted for use at the proposed workshop. Seed was also sent to Dr. H. Ahokas in Finland; Dr. Ing Moncef Harrabi, INRAT Ariana, Tunisia; Dr. Odd A. Olsen, Agricultural University of Norway; Dr. Enrique Rodriguez, CIMMYT, Mexico.

A barley improvement workshop was planned, dates and location set and the program was being developed when the war in Lebanon broke out and it was necessary to postpone it. The workshop is being scheduled for next year in a different location.

A number of contacts were made with barley researchers throughout the world at the following:

1. R. F. Eslick and L. P. Carter attended the AID Crop Production Division Contractors meeting held at Mississippi State University.
2. R. F. Eslick, E. L. Sharp and E. A. Hockett participated in the Third International Barley Genetics Symposium in Munich, Germany.
3. In November and December 1975, R. F. Eslick served as a consultant on the development of the barley research program in Korea. On that same trip he consulted on barley supply, sources, usage, preferences and marketing problems in Japan, Taiwan, Hong Kong and the Philippines. He also visited IRRI headquarters in the Philippines.
4. In March 1976, A. H. Ferguson and Jarvis Brown visited the CIMMYT barley improvement program at Obregon, Mexico.

The project is just completing its second year and material available for utilization in LDC's is very limited at this point in time.

All staff involved with the barley research effort at Montana State University meet regularly for seminars at which the staff report progress, discuss future directions of research and coordinate their efforts.

Inquiries for publications and information on the barley research program have been received from the following countries: India, Czechoslovakia, Nigeria, Italy, Spain, Yugoslovia, Canada, Australia, Malaysia, Germany, England, Chile, Austria, Mexico, Poland, Isrial, New Zealand, Columbia, Portugal, France, Korea, Tunisia and Turkey.

Plans for the coming year

Planning and program development will be accomplished during the coming year on the barley improvement workshop. Location and dates will be set, invitations sent and specific presentations and activities will be planned.

Seed will be made available to; ICARDA, CIMMYT, any L.D.C.'s upon request and other barley breeders in the United States.

Proposed budget for 1976-77

Category	Proposed budget
Salary and Wages	124,191
Fringe Benefits	10,499
Equipment	12,050
Travel and Per Diem	9,800
Publication	1,600
Other Direct Costs	7,758
Indirect Costs	84,102
TOTAL	250,000

Involvement of minority personnel and women

Professional staff - 1 woman
Classified staff - 5 women
Graduate Research Assistants - 6 women
Summer and hourly - 19 women - 1 Spanish

SMITHSONIAN
SCIENCE INFORMATION EXCHANGE, INC.
1730 M STREET, N.W. PHONE 202-331-5311
WASHINGTON, D.C. 20036

BIX NO.

NOTICE OF RESEARCH PROJECT

SUPPORTING AGENCY:

Agency for International Development

AGENCY'S NUMBER(S):

Contract No: AID/ta-C-1094
and/or
Control No:

TITLE OF PROJECT:

Improvement of the Nutritive Quality and Productivity of Barley for Semi Arid Regions

PRINCIPAL INVESTIGATOR, ASSOCIATES

	School or Division	Department
R. F. Eslick	College of Agriculture	Plant & Soil Science Dept.
L. P. Carter	College of Agriculture	Plant & Soil Science Dept.

RECIPIENT INSTITUTION:

Name and Address: Including Zip Code.
Montana State University
Bozeman, Montana 59715

PERIOD FOR THIS NRP:

Start Date: March 25, 1974
End Date: March 24, 1977
Annual Funding: 200,000

SUMMARY OF PROJECT: Be brief-200 word maximum: (Include Objective, Approach, Current Plans and/or Progress)

The objectives are: to increase the nutritive value of barleys, to increase drought drought tolerance and yield of barleys in semiarid regions, and to decrease losses caused by barley diseases in LDC's.

The first two years work under this project has emphasized nutritive value. We have formulated some working hypotheses relative to evaluating drouth resistance and have verified some aspects. The work with diseases has progressed very rapidly. We believe we have advanced to the point where a significant outreach program can be initiated.

The microbiological assay technique for determining lysine has been perfected to the point where it is a reliable screening tool. Animal performance data (Growth, PER, and BV) support the chemical analysis for protein and amino acid composition of Hiproly and Hiproly Normal barleys. Animal performance is highly correlated to the essential amino acid content of the barleys.

A double translocation has been located that should be effective in transferring the Hiproly gene to a population as well as disease resistance genes (scald, net-blotch, barley yellow dwarf) on chromosome 3. Four additional high-lysine non-allelic loci have been added to the high lysine collection. All have shrunken endosperm. Recurrent selection populations for seed size and agronomic characters can be readily established using xenia to select for the gene.

Altering barley leaf width affects yield, yield components, stomatal density, aperature length, leaf area duration, cummulative water use and water use efficiency.

Initial first releases of a scald resistant population and a high lysine (Hiproly source) population can be made in 1976.

Appendix

Table 1. Protein, lysine and agronomic comparisons between Hiproly Normal and Hiproly.

Character measured	number of comparisons	Hiproly Normal (x) mean	Hiproly Normal (x) range	Hiproly (y) mean	Hiproly (y) range	Difference + $\bar{x} - \bar{y}$	byx ‡	r^2 §
Kjeldahl Protein, %	26	17.20	13.2-19.3	18.45	14.0-20.5	-1.24**	0.65**	.530**
G.Q.A. Protein, %	26	16.55	12.5-18.8	17.17	12.7-19.6	-0.62**	0.64**	.520**
Udy Protein, %	26	16.08	11.5-19.7	19.63	14.6-21.8	-3.55*	0.47**	.388**
Transmittence, %	26	39.4	33.5-45.0	46.6	41.0-51.8	-7.26**	0.29**	.090
Lysine in barley, %	26	.448	.360-.515	.581	.415-.670	-.133**	0.99	.455**
Lysine in protein, %	26	2.61	2.18-3.09	3.15	2.53-3.46	-.539**	0.14**	.016
Yield, Q/ha	8	21.9	10.8-35.8	14.9	8.6-27.2	6.98**	0.75	.886**
Plump, on 6/64 sieve, %	26	73.7	15.8-95.3	17.7	1.0-47.3	55.0**	0.25**	.141
Thin, thru 5½/64 sieve, %	26	12.1	1.3-57.2	46.0	13.0-93.6	-33.9**	1.16	.416**
Kernel weight, mg.	26	49.2	39.9-57.0	38.4	32.9-45.1	10.8**	0.48**	.501**
Test weight, Kg/hl	8	71.4	67.7-77.5	66.1	58.2-71.6	5.35**	0.78	.652
Plant height, cm.	7	74.7	40.6-101.6	72.2	43.2-96.5	2.5	0.90*	.992**
Date headed, days from 1/1	6	175.5	175. -179.	178.5	175-182	-3.0	0.38	.223
Lodging, %	2	46.0	3.0-90.0	25.0	0.0-50.0	21.0	0.54	1.000

\+ Significant differences by paired t-test are starred.

‡ Significant differences from a slope of 1.0 are starred.

§ Significant correlations of paired values are starred.

Appendix
Table 2.

High lysine selections from the progeny of various parents possessing the high lysine trait. Samples were grown in Bozeman 1973 Hp nursery.

Plot No.	Cross or Selection	Lys % in grain	Lys % in protein
B73 Hp2	(Stamm x 7 Compana) x Hiproly	.600	3.42
B73 Hp8	" " "	.628	3.36
B73 Hp11	" " "	.580	3.01
B73 Hp14	" " "	.580	3.19
B73 Hp25&26	" " "	.640	3.50
B73 Hp28	" " "	.580	3.15
B73 Hp32	" " "	.615	3.70
B73 Hp40	" " "	.580	3.15
B73 Hp43	" " "	.680	3.62
B73 Hp47	" " "	.640	3.46
B73 Hp64	" " "	.615	3.46
B73 Hp68	" " "	.600	3.26
B73 Hp70	Hiproly	.660	3.42
B73 Hp74	(Compana ms 10 ms 10 x Hiproly)	.590	3.34
B73 Hp75	" " "	.580	3.31
B73 Hp76	" " "	.580	3.45
B73 Hp80	" " "	.600	3.49
B73 Hp96	" " "	.615	3.42
B73 Hp109	" " "	.700	3.80
B73 Hp113	" " "	.640	3.40
B73 Hp115	" " "	.640	3.46
B73 Hp120	Hiproly	.660	3.53
B73 Hp125	(Betzes Ms b ms b x Hiproly)	.590	3.14
B73 Hp139	" " "	.660	4.00
B73 Hp140	" " "	.590	3.43
B73 Hp148	" " "	.640	3.68
B73 Hp154	" " "	.580	3.31
B73 Hp155	" " "	.615	3.51
B73 Hp157	" " "	.640	3.58
B73 Hp158	" " "	.700	3.63
B73 Hp161	" " "	.640	3.52
B73 Hp162	Hiproly	.700	3.65
B73 Hp179	Titan Ms 1 ms 1 x Hiproly	.700	3.74
B73 Hp193	" " "	.700	3.89
B73 Hp206	" " "	.760	4.18
B73 Hp207	" " "	.790	4.65
B73 Hp210	" " "	.640	3.62

Appendix
Table 3

High lysine selections from the progeny of various parents possessing the high lysine trait, grown in the Bozeman 1975 Hp nursery.

Selection number and identification		Lys % in grain	Lys % in protein
Hp-34	Riso Mutant #86 x Hp119-2(74)	.595	3.61
Hp-35	" " " "	.580	3.92
Hp-41	Riso Mutant 1508 x Hp121-1(74)	.610	4.62
Hp-42	Riso Mutant 1508 x Hp121-2(74)	.630	4.53
Hp-43	" " " " -3(74)	.588	4.45
Hp-44	" " " " -4(74)	.680	4.89
Hp-75	Hiproly x T3-7C - 603	.595	3.63
Hp-78	" " " 651	.613	3.66
Hp-79	" " " 660	.665	3.59
Hp-80	" " " 675	.650	3.63
Hp-81	" " " 584	.595	3.46
Hp-83	" " " 699	.595	3.48
Hp-84	" " " 700	.750	4.70
Hp-90	Hiproly x Ts - 7g 745	.588	3.38
Hp-95	" " " 780	.613	3.52
Hp-96	" " " 788	.670	4.08
Hp-104	" " " 947	.580	3.26
Hp-107	" " " 961	.580	3.37
Hp-115	Compana ms 10 x Hiproly	.630	3.35
Hp-116	" " "	.630	3.25
Hp-148	" " "	.588	3.54
Hp-152	" " "	.595	3.23
Hp-154	" " "	.660	3.73
Hp-155	" " "	.595	3.40
Hp-156	" " "	.660	3.69
Hp-172	" " "	.580	3.02
Hp-185	Betzes ms b x Hiproly	.595	3.67
Hp-208	" " "	.640	3.98
Hp-209	" " "	.595	3.56
Hp-210	" " "	.595	3.52
Hp-211	Betzes ms b x Hiproly	.650	3.69
Hp-214	" " "	.680	3.68
Hp-215	" " "	.655	3.68
Hp-216	" " "	.670	3.72
Hp-217	" " "	.680	3.74
Hp-219	" " "	.650	3.71
Hp-224	Titan ms 1 x Hiproly	.580	3.41
Hp-225	" " "	.580	3.54
Hp-240	" " "	.610	3.98
Hp-241	" " "	.630	3.68
Hp-242	" " "	.630	3.65
Hp-244	" " "	.640	3.98
Hp-247	" " "	.620	3.60
Hp-255	" " "	.595	4.10
Hp-270	Riso Mutant #1508	.580	4.64
Hp-271	Compana ms 10 x Hiproly, F_5	.580	3.56
Hp-272	Compana ms 10 x Hiproly, F_6	.595	3.48
Hp-275	Titan ms 1 x Hiproly, F_5	.580	3.52
Hp-281	Riso Mutant #8	.580	4.23
Hp-285	Riso Mutant #13	.580	4.26
Hp-350	Compana x Hiproly	.580	3.43
Hp-356	Hiproly	.738	3.96
Hp-360	Berdahl Hiproly	.580	4.11

Appendix
Table 4. Proximate composition and calcium and phosphorus composition of two-rowed barleys.

Diet No.	CI No.	Protein	Ether extract	Crude fiber	NFE	Moisture	Ash	Ca	P
1	906	16.1	1.7	4.6	66.0	5.9	5.7	.01	.40
2	3383	16.4	1.7	4.7	63.3	5.9	8.0	.01	.36
3	6400	16.2	2.2	5.3	61.6	5.8	8.9	.01	.36
4	6407	15.4	1.1	4.3	65.3	6.5	7.4	.01	.32
5	7131	13.8	1.3	5.2	67.6	6.2	5.9	.02	.33
6	7622	15.1	1.2	4.8	68.1	5.9	4.9	.02	.36
7	8192	15.2	1.9	5.0	69.2	5.6	3.1	.01	.43
8	10236	13.8	1.4	4.2	71.5	6.6	2.5	.01	.38
9	10328	16.6	1.7	5.3	67.2	6.1	3.1	.03	.47
10	10375	15.1	1.3	3.7	71.4	5.8	2.7	.01	.42
11	11201	13.4	1.3	4.5	72.3	5.9	2.6	.02	.35
12	11308	14.4	1.5	4.5	71.0	5.7	2.9	.01	.38
13	11310	15.7	2.0	4.9	68.2	6.2	3.0	.04	.45
14	11315	15.2	1.9	4.2	70.0	6.3	2.4	.03	.41
15	12099	13.9	1.9	4.3	71.0	6.4	2.5	.03	.42
16	12147	15.8	2.1	4.0	69.6	5.6	2.9	.04	.46
17	12171	17.0	1.3	4.2	69.2	5.8	2.5	.03	.44
18	3947	19.7	1.9	2.1	67.9	6.1	2.3	.00	.53
19	12103	13.5	1.7	3.7	72.7	6.1	2.3	.02	.36
20	5438	15.4	1.4	3.8	71.2	5.6	2.6	.03	.41
21	294318[a]	16.4	1.6	4.2	69.4	6.0	2.4	.02	.43
22	10421+	13.2	1.7	4.2	71.7	7.0	2.2	.04	.36
23	13827	14.7	1.9	3.7	70.1	7.2	2.4	.01	.37

[a]Montana
+ - Unitan, a six-rowed variety

Appendix
Table 5 - Amino acid composition of two-rowed barleys and Unitan, b/16g N

Diet No.	C.I. No.	Alanine	Arginine	Aspartic acid	Glutamic acid	Glycine	Histidin	Iso-leucine	Leucine
1	906	3.57	4.90	5.81	26.82	3.43	2.24	3.57	6.93
2	3383	3.57	5.04	5.66	26.51	3.33	2.17	3.64	7.05
3	6400	3.57	5.02	5.78	26.29	3.42	2.20	3.65	7.14
4	6407	3.64	4.71	5.87	26.39	3.39	2.23	3.72	7.20
5	7131	3.55	5.07	5.91	25.84	3.55	2.20	3.55	7.18
6	7622	3.69	5.21	5.93	25.56	3.45	2.24	3.69	7.13
7	8192	3.73	4.95	6.16	25.63	3.41	2.27	3.65	6.89
8	10236	3.90	5.23	6.47	27.04	3.55	2.30	3.72	7.18
9	10328	3.58	5.44	5.66	26.36	3.22	2.29	3.80	6.95
10	10375	3.40	4.84	5.90	27.59	3.33	2.27	3.48	6.80
11	11201	3.77	5.21	6.01	25.13	3.50	2.24	3.68	7.00
12	11308	3.62	5.27	5.93	25.43	3.46	2.14	3.62	7.16
13	11310	3 59	5.06	6.09	26.32	3.59	2.27	3.67	7.04
14	11315	3.63	5.16	6.04	25.87	3.30	2.18	3.71	7.01
15	12099	3.74	5.26	6.33	25.04	3.48	2.32	3.65	6.95
16	12147	3.77	5.28	6.26	26.09	3.39	2.26	3.77	6.94
17	12171	3.43	5.18	5.59	27.46	3.30	2.22	3.63	6.93
18	3947	3.76	4.99	6.81	25.07	3.46	2.06	3.70	6.75
19	12103	3.63	5.23	6.20	25.42	3.37	2.13	3.54	7.09
20	5438	3.35	4.66	5.32	28.11	3.42	2.26	3.64	6.70
21	294318	3.39	4.63	5.39	28.54	3.04	2.14	3.66	6.77
22	10421+	3.55	5.19	5.82	26.21	3.37	2.18	3.64	6.82
23	13827	3.54	4.85	5.77	26.92	3.38	2.23	3.62	6.85

Diet No.	C.I. No.	Lysine	Methi-onine	Phenyl-alanine	Proline	Serine	Threonine	Tyrosine	Valine	Protein Recovered,%
1	906	3.50	1.61	5.81	12.46	4.76	3.57	2.87	4.62	14.28
2	3383	3.41	1.71	5.81	12.40	4.50	3.49	3.10	4.73	12.90
3	6400	3.50	1.67	5.78	12.61	4.48	3.42	2.89	4.79	13.16
4	6407	3.47	1.82	5.62	11.75	4.63	3.72	2.98	4.71	12.09
5	7131	3.80	1.60	5.74	12.08	4.65	3.46	2.87	4.73	11.84
6	7622	3.53	1.68	5.77	12.10	4.65	3.53	3.13	4.73	12.48
7	8192	3.49	1.78	5.52	12.00	4.79	3.65	3.24	4.79	12.33
8	10236	3.72	1.86	5.94	12.15	4.96	3.81	3.28	4.88	11.28
9	10328	3.44	1.72	5.66	12.03	4.66	3.44	3.30	4.87	13.96
10	10375	3.46	1.59	5.97	12.02	4.76	3.48	2.80	4.54	13.23
11	11201	3.59	1.80	5.57	11.67	4.67	3.59	3.23	4.85	11.14
12	11308	3.54	1.65	5.93	12.18	4.44	3.46	3.37	4.69	12.15
13	11310	3.81	1.69	6.09	11.22	4.69	3.67	2.86	4.69	13.64
14	11315	3.46	1.77	5.88	11.93	4.57	3.38	3.30	4.83	12.41
15	12099	3.65	1.78	5.61	11.23	4.72	3.74	3.39	4.63	11.22
16	12147	3.47	1.66	5.66	11.76	4.75	3.54	2.87	4.75	13.26
17	12171	3.30	1.62	5.72	12.52	4.85	3.30	2.89	4.71	14.86
18	3947	4.23	1.76	6.17	12.45	4.58	3.58	2.82	4.87	17.03
19	12103	3.54	1.68	5.67	11.96	4.52	3.54	3.37	4.69	11.29
20	5438	2.99	1.60	5.83	12.96	4.59	3.42	2.99	4.52	13.73
21	294318	3.11	1.59	5.81	13.27	4.49	3.32	2.97	4.42	14.47
22	10421+	3.28	1.73	5.37	11.92	4.73	3.46	3.37	4.82	10.99
23	13827	3.38	1.69	5.69	12.38	4.77	3.46	2.92	4.69	13.00

a. Unitan - + six-rowed barley

Appendix
Table 6. Growth, feed consumption, feed efficiency and protein efficiency ratios of rats fed iso-nitrogenous two-rowed barleys and casein diets.

CI No.	Diet No.	Gain *	Feed consumed *	Feed/gain ratio *	Adjusted P.E.R. *
906	1	58.2^{ab}	288.5^{a}	5.06^{cd}	1.96^{bc}
3343	2	46.4^{abcde}	258.5^{a}	5.65^{abc}	1.77^{cdef}
6400	3	45.8^{bcde}	250.1^{a}	5.67^{abc}	1.78^{cdef}
6407	4	47.2^{abcd}	256.1^{a}	2.65^{abc}	1.85^{bcdef}
7131	5	53.1^{abcde}	278.6^{a}	5.28^{bcd}	1.92^{bcd}
7622	6	48.6^{abcde}	253.0^{a}	5.37^{bcd}	1.87^{bcde}
8192	7	41.0^{de}	235.1^{a}	5.86^{abc}	1.72^{cdef}
10236	8	49.2^{abcde}	253.7^{a}	5.55^{abc}	1.82^{cdef}
10328	9	47.4^{abcde}	256.7^{a}	5.55^{abc}	1.78^{cdef}
10375	10	54.9^{abc}	275.7^{a}	5.12^{cd}	1.94^{bcd}
11201	11	50.2^{abcde}	265.4^{a}	5.46^{bcd}	1.83^{cdef}
11308	12	44.4^{cde}	248.5^{a}	5.78^{abc}	1.76^{cdef}
11310	13	51.4^{abcde}	265.7^{a}	5.41^{bcd}	1.83^{bcde}
11315	14	45.3^{bcde}	244.4^{a}	5.52^{abc}	1.80^{cdef}
12099	15	53.8^{abcd}	275.6^{a}	5.27^{bcd}	1.91^{bcd}
12147	16	47.2^{abcde}	263.6^{a}	5.80^{abc}	1.67^{def}
12171	17	40.0^{e}	233.6^{a}	5.99^{ab}	1.68^{def}
3947	18	59.4^{a}	274.8^{a}	4.67^{de}	2.09^{b}
12103	19	52.1^{abcde}	280.5^{a}	5.33^{bcd}	1.85^{bcdef}
5438	20	39.3^{e}	243.4^{a}	6.31^{a}	1.59^{f}
294318	21	40.9^{de}	254.4^{a}	6.07^{ab}	1.64^{ef}
10421	22	49.4^{abcde}	276.0^{a}	5.62^{abc}	1.77^{cdef}
13827	23	48.0^{abcde}	272.7^{a}	5.85^{abc}	1.71^{cdef}
Casein	24	59.7^{a}	246.2^{a}	4.17^{e}	2.41^{a}

* Means in the same column followed by different superscript letters, differ significantly ($P < .05$)

Appendix
Table 7. Biological value and true protein digestibility of high and low PER two-rowed barleys.

CI No.	Diet No.	PER[a]	Biological Value	True Protein Digestibility
906	1	1.96	66.0[bc]	74.5[c]
7131	5	1.92	68.5[bc]	74.9[c]
10375	10	1.94	67.9[bc]	75.4[c]
11310	13	1.88	67.1[bc]	80.0[c]
3947	18	2.09	72.6[b]	74.1[c]
12147	16	1.67	59.1[c]	78.2[bc]
12171	17	1.68	63.8[bc]	74.9[c]
5438	20	1.59	65.6[bc]	82.0[b]
294318	21	1.64	57.0[c]	81.2[bc]
13827	23	1.71	61.6[bc]	80.1[bc]

a PER obtained in growth trial
bc Means in the same column with different superscript letters differ significantly, ($P < .05$)

Appendix
Table 8. Composite means of biological value and true protein digestibility of high and low PER two-rowed barleys.

Barleys	Biological value	True protein digestibility
High PER[a]	68.3[c]	75.7[c]
Low PER[b]	61.4[d]	79.3[d]

a Five barleys selected from trial I on basis of highest PER performance.
b Five barleys selected from trial I on basis of lowest PER performance.
cd Means in same column with different superscript letters differ significantly ($P < .01$)

Appendix

Table 9. Correlation coefficients of amino acids with biological value and true protein digestibility.

	Amino acid	Biological value	True Protein Digestibility
4	Alanine	.21	-.34
5	Arginine	.12	-.50
6	Aspartic acid	.53	-.51
7	Glutamic acid	-.56	-.53
8	Glycine	.68	-.26
9	Histidine	-.22	.26
10	Iso leucine	-.35	.35
11	Leucine	.11	-.32
12	Lysine	.71[a]	-.60
13	Methionine	.34	-.10
14	Phenylalanine	.69[b]	-.16
15	Proline	-.30	.20
16	Serine	.00	-.40
17	Threonine	.49	-.15
18	Tyrosine	-.60[a]	.77[b]
19	Valine	.48	-.54

a $P < .05$
b $P < .01$

Appendix

Table 10. Proximate composition of Danish barley mutants, Hiproly and Betzes isogenics.

Barley	Protein	Extract	Fiber	NFE	Moisture	Ash	Ca	P
Hiproly	18.9	2.3	1.6	66.5	8.2	2.5	.03	.54
Hiproly Normal	16.5	2.1	1.5	69.6	7.9	2.4	.03	.52
Bomi	12.4	1.9	5.2	70.2	7.4	2.9	.02	.38
Bomi Riso[7]	11.8	2.1	3.9	71.3	8.0	2.9	.01	.39
Bomi Riso[8]	12.5	3.4	5.5	67.4	7.8	3.4	.03	.46
Bomi Riso[9]	13.0	2.1	5.6	68.8	6.9	3.6	.02	.47
Bomi Riso[13]	12.7	4.2	6.1	66.4	7.1	3.5	.02	.45
Bomi Riso 1508	12.7	3.1	6.5	66.8	7.3	3.6	.03	.43
Carlsberg II	10.5	2.0	4.6	71.7	8.1	3.1	.01	.38
Carlsberg Riso 29	10.8	3.2	5.1	70.0	7.9	3.0	.02	.40
Carlsberg Riso 56	12.9	2.2	4.4	69.7	7.8	3.0	.02	.45
Betzes	11.6	2.0	2.5	73.0	8.4	2.5	.01	.38
Betzes segl	13.8	2.3	6.3	67.0	6.8	3.8	.04	.43

Appendix
Table 11 - Amino acid composition of Danish barley mutants, Hiproly and Betzes isogenics

	Alanine	Arginine	Aspartic acid	Glutamic acid	Glycine	Histidine	Iso-leucine	Leucine
Hiproly	4.19	5.07	6.63	24.95	3.31	2.06	3.56	6.81
Hiproly Normal	3.28	4.44	5.32	28.26	3.00	1.98	3.34	6.48
Bomi	3.85	4.88	6.01	25.45	3.29	2.16	3.66	7.14
Bomi Riso 7	4.20	5.35	6.78	23.40	4.01	2.39	3.44	7.07
Bomi " 8	4.63	6.46	8.10	21.31	3.95	2.41	3.66	7.04
Bomi " 9	4.21	4.82	6.22	24.19	3.94	2.28	3.59	7.19
Bomi " 13	4.57	5.68	7.92	22.18	3.82	2.33	3.63	6.99
Bomi "1508	5.27	6.81	9.78	17.93	4.79	2.68	3.64	7.00
Carlsberg II	4.17	4.86	6.71	24.19	3.47	2.20	3.59	7.06
Carlsberg Riso 29	3.90	5.73	7.80	22.25	3.44	2.41	3.90	7.34
Carlsberg Riso 56	5.23	5.59	7.21	21.62	3.96	2.34	3.33	6.67
Betzes	3.81	4.81	6.21	25.75	3.31	2.10	3.61	7.01
Betzes segl segl	4.28	5.06	6.63	24.26	3.75	2.18	3.58	6.81

	Lysine	Methi-onine	Phenyl-alanine	Proline	Serine	Threonine	Tyrosine	Valine	% Protein
Hiproly	4.19	1.87	6.13	11.38	4.50	3.50	3.38	4.69	15.99
Hiproly Normal	3.07	1.50	6.48	13.38	4.37	3.28	2.69	4.03	14.65
Bomi	3.57	1.69	5.63	11.83	4.69	3.57	3.10	4.79	10.65
Bomi Riso 7	4.01	1.81	5.16	10.51	4.97	4.01	3.25	4.87	10.47
Bomi " 8	4.73	1.83	4.92	9.74	4.73	3.86	2.70	5.11	10.37
Bomi " 9	3.77	1.67	5.43	11.31	5.35	3.77	2.98	4.91	11.41
Bomi " 13	4.66	1.77	5.22	9.79	4.75	3.91	3.17	4.94	10.73
Bomi " 1508	5.56	1.82	4.31	7.57	5.27	4.41	3.07	5.27	10.43
Carlsberg II	3.82	1.85	5.32	10.65	4.63	3.70	3.24	4.75	8.64
Carlsberg Riso 29	4.70	1.95	5.16	9.86	5.16	4.13	3.21	3.33	8.72
Carlsberg Riso 56	4.59	1.89	5.95	10.36	4.86	4.05	3.24	4.59	11.10
Betzes	3.41	1.80	5.51	11.42	4.71	3.61	3.21	4.71	9.98
Betzes segl segl	4.01	1.75	5.24	11.52	4.97	3.75	3.14	4.71	11.46

Appendix
Table 12. Growth, feed consumption, feed efficiency and protein efficiency ratios of rats fed isonitrogenous barley & casein diets for 21 days, Trial 2

Barley	Avg Gain	Avg Feed	Avg Feed/gain	Avg PER
Hiproly	71.8^{bcde}	365.9^{ab}	5.12^{bcd}	2.06^{def}
Hiproly Normal	65.4^{cdef}	360.4^{abc}	5.58^{ab}	1.80^{g}
Bomi	68.4^{bcdef}	337.8^{bcd}	5.09^{bcd}	2.13^{de}
Bomi Riso 7	74.0^{abcd}	323.6^{bcd}	4.44^{ef}	2.38^{abc}
Bomi Riso 8	77.0^{abc}	361.0^{abc}	4.71^{def}	2.25^{bcd}
Bomi Riso 9	59.6^{ef}	331.2^{bcd}	5.74^{a}	1.83^{fg}
Bomi Riso 13	74.3^{abcd}	393.6^{a}	5.36^{abc}	1.99^{efg}
Bomi Riso 1508	84.5^{a}	359.1^{abc}	4.32^{ef}	2.48^{ab}
Carlsberg II	66.7^{cdef}	321.3^{cd}	4.86^{cde}	2.20^{cde}
Carlsberg Riso 29	80.1^{ab}	353.0^{abcd}	4.40^{ef}	2.37^{abc}
Carlsberg Riso 56	84.8^{a}	360.0^{abc}	4.29^{f}	2.44^{ab}
Betzes	63.1^{def}	315.8^{d}	5.09^{bcd}	2.05^{def}
Betzes segl	60.7^{ef}	317.2^{cd}	5.36^{abc}	2.00^{efg}
Casein	80.0^{ab}	338.1^{bcd}	4.30^{f}	2.50^{a}

abcdefg Means in the same column with different superscript letters are significantly different($P < .05$)

Appendix
Table 13. Biological value and true protein digestibility of Hiproly isogenics, Bomi and Bomi mutants.

Barley	PER+	Biological+ Value	True Protein‡ Digestibility
		%	%
Hiproly	2.06	75.82	75.97
Hiproly Normal	1.80	73.50	86.82
Bomi	2.13	75.14	75.39
Bomi Riso 7	2.38	84.36	74.03
Bomi Riso 8	2.25	91.76	69.28
Bomi Riso 9	1.83	82.37	77.69
Bomi Riso 13	1.99	87.06	65.88
Bomi Riso 1508	2.48	91.65	69.15

\+ Obtained in growth trial
‡ Each mean is an average of 4 values.

Appendix

Table 14 Protein, Lysine and Agronomic Comparisons Between Betzes and Betzes segl segl .

Character Measured	Number of Comparisons	Betzes(x) mean	Betzes(x) range	Betzes segl segl (y) mean	Betzes segl segl (y) range	Difference $\bar{x}-\bar{y}$ +	byx ‡	r^2 §
Kjeldahl Protein, %	18	14.59	12.3-18.6	15.93	12.8-18.6	-1.34**	0.65**	.768**
GQA Protein %	18	13.64	9.2-21.7	14.64	10.2-16.4	-1.01*	0.40**	.464**
Udy Protein, %	18	14.55	10.9-17.6	17.10	14.6-19.1	-2.55**	0.52**	.526**
Transmittence, %	18	44.6	40.0-51.5	47.2	41.0-53.0	-2.52**	0.58	.314*
Lysine in Barley, %	18	.436	.34-.53	.518	.40-.59	-0.082**	0.34**	.212
Lysine in Protein, %	18	3.05	2.62-3.59	3.25	2.65-4.08	-0.203**	0.58*	.404**
Yield, Q/ha	9	32.8	11.5-49.2	10.1	4.9-31.9	22.7**	0.56*	.677**
Plump, on 6/64 sieve, %	19	46.8	0.0-74.3	3.9	0.0-31.6	42.9**	0.10**	.113
Thin, thru $5\frac{1}{2}$/64 sieve, %	19	27.8	6.5-91.1	88.7	39.5-100.0	-60.9**	0.11**	.023
Kernel Weight, mg	17	34.3	21.9-40.1	18.8	12.4-22.1	15.4**	-0.05**	.005
Test Weight, Kg/hl	8	63.2	59.2-67.7	42.4	30.3-55.7	20.9**	-2.47**	.542*
Plant Height, cm	9	79.5	50.0-116.8	78.2	54.1-108.7	1.3	0.79*	.938**
Date Headed, days from 1/1	9	180.1	173.5-185.6	183.4	171.0-192.4	- 3.3*	1.71**	.943**
Date Mature, days from 1/1	2	210.2	207.5-213.0	212.0	206.3-217.7	- 1.8	2.07	.998

+ Significant differences by paired t-test are starred.
‡ Significant differences from a slope of 1.0 are starred.
§ Significant correlations of paired values are starred.

Appendix

Table 15 Protein and lysine contents of barley and protein of several shrunken endosperm mutants grown at Bozeman, Mt. (except as noted) over a period of years.

Year grown	% protein			% lysine in barley			% lysine in protein		
	Compana seg3 seg3	Compana Seg3 Seg3	difference	Compana seg3 seg3	Compana Seg3 Seg3	difference	Compana seg3 seg3	Compana Seg3 Seg3	difference
1970	17.9	15.7	2.2	.392	.335	.057	2.20	2.14	.06
1971	16.0	14.8	1.2	.370	.325	.045	2.31	2.19	.12
1972	16.2	15.1	1.1	.390	.320	.070	2.41	2.12	.29
1974 +	13.1	-	-	.342	-	-	2.61	-	-
avg.	16.7	15.2	1.5	.384	.327	.057*	2.31	2.15	.16
	Compana seg4 seg4	Compana Seg4 Seg4	difference	Compana seg4 seg4	Compana Seg4 Seg4	difference	Compana seg4 seg4	Compana Seg4 Seg4	difference
1970	20.6	15.7	4.9	.370	.335	.035	1.80	2.14	-.34
1971	20.7	14.8	5.9	.355	.325	.030	1.71	2.19	-.48
1972	15.8	15.1	0.7	.370	.320	.050	2.34	2.12	.22
1974 +	16.7	-	-	.340	-	-	2.04	-	-
avg.	19.0	15.2	3.8	.365	.327	.038*	1.95	2.15	-.20
	Compana sex1 sex1	Compana Sex1 Sex1	difference	Compana sex1 sex1	Compana Sex1 Sex1	difference	Compana sex1 sex1	Compana Sex1 Sex1	difference
1967	18.1	15.3	2.8	.425	.310	.115	2.35	2.03	.32
1970	17.8	15.4	2.4	.470	.312	.158	2.64	2.05	.59
1970	18.0	15.7	2.3	.420	.335	.085	2.33	2.14	.19
1971	21.2	14.8	6.4	.530	.325	.205	2.50	2.19	.31
1972	17.3	14.2	3.1	.405	.315	.090	2.34	2.22	.12
1974 +	12.1	-	-	.344	-	-	2.84	-	-
avg.	18.5	15.1*	3.4	.450	.319	.131**	2.43	2.13	.30*

Appendix
Table 15 (Cont.)

	% protein			% lysine in barley			% lysine in protein		
	Glacier seg5 seg5	Glacier Seg5 Seg5	difference	Glacier seg5 seg5	Glacier Seg5 Seg5	difference	Glacier seg5 seg5	Glacier Seg5 Seg5	difference
1970	18.1	13.2	4.9	.380	.310	.070	2.10	2.35	-.25
1971	20.7	13.5	7.2	.460	.325	.135	2.22	2.41	-.19
1972	18.1	12.9	5.2	.380	.310	.070	2.10	2.40	-.30
avg.	19.0	13.2	5.8*	.406	.315	.091	2.14	2.39	-.25*
	Ingrid seg6 seg6	Ingrid Seg6 Seg6	difference	Ingrid seg6 seg6	Ingrid Seg6 Seg6	difference	Ingrid seg6 seg6	Ingrid Seg6 Seg6	difference
1972	15.2	13.2	2.0	.420	.330	.090	2.76	2.50	.26
1974 ‡	12.0	13.4	-1.4	.335	.325	.010	2.79	2.42	.37
1975	15.8	14.1	1.7	.500	.390	.110	3.16	2.77	.39
avg.	14.3	13.6	0.7	.418	.348	.070	2.90	2.56	.34*
	Ingrid seg7 seg7	Ingrid Seg7 Seg7	difference	Ingrid seg7 seg7	Ingrid Seg7 Seg7	difference	Ingrid seg7 seg7	Ingrid Seg7 Seg7	difference
1972	16.1	13.2	2.9	.355	.330	.025	2.20	2.50	-.30
1974 ‡	12.3	13.4	-1.1	.325	.325	.000	2.64	2.42	.22
1975	16.2	14.1	2.1	.445	.390	.055	2.75	2.77	-.02
avg.	14.9	13.6	1.3	.375	.348	.027	2.53	2.56	-.03

+ Arizona grown, not included in averages.
‡ Arizona grown.

Appendix
Table 16. Protein and Lysine Contents of the Osborne Fractions of Whole Hiproly (CI 3947) and Hiproly Normal (CI 4362) Barleys.

Parameter	Total	Salt-soluble Proteins	Hordein	Glutelin	Insoluble Proteins
		Hiproly (CI 3947)			
Protein (g/100g whole grain)	18.7	4.9	6.0	6.4	.95
% of total protein		26.8	32.9	35.1	5.2
lysine(mg/100g whole grain)	752	274	98	242	42
% of total recovered lysine		41.8	14.8	36.9	6.4
% lysine in Protein	4.0	5.6	1.6	3.8	4.4
		Hiproly Normal (CI 3462)			
Protein (g/100g whole grain)	18.2	4.6	6.4	5.8	.9
% of total protein		26.	36.2	32.8	5.1
lysine(mg/100g whole grain)	510	184	40	157	42
% of total recovered lysine		43.5	9.5	37.1	9.9
% lysine in Protein	2.8	4.0	.6	2.7	4.7

Hiproly (CI 3947): recovery of protein = 97.6%
recovery of lysine = 87.2%

Hiproly Normal (CI 3462): recovery of protein = 97.3%
recovery of lysine = 82.9%

Appendix
Table 17. Protein and Lysine Contents of the Chromatographic Fractions (Peaks) of Salt-soluble Proteins from Hiproly (CI 3947) and Hiproly Normal (CI 4362) Barleys.

	Fraction No. (Peaks)					
	1	2	3	4	5	Total
Hiproly (CI 3947)						
Fraction wt, gms.	.602	.139	.366	.064	.070	1.241
Protein content:						
protein in fraction,%	32.0	88.9	94.9	33.8	26.1	
protein, gms.	.192	.120	.350	.054	.018	.734
% recovered	26.2	16.4	47.6	7.3	2.5	100.0
Lysine Content:						
mg.	15.0	9.0	31.0	5.0	1.6	61.6
% recovered	24.4	14.6	50.3	8.1	2.6	100.0
% in protein	7.84	7.28	8.90	5.10	4.93	
Hiproly Normal (4362)						
Fraction wt, gms.	.640	.138	.294	.118	.052	1.242
Protein content+						
protein in fraction.%	31.1	84.3	86.8	89.6	21.5	
protein, gms	.198	.120	.260	.100	.010	.638
% recovered	28.8	17.4	37.8	14.5	1.5	100.0
Lysine Content‡						
mg.	11.0	6.0	19.0	7.0	.6	43.6
% recovered	25.2	13.8	43.5	16.1	1.4	100.0
% in protein	5.5	5.17	7.3	7.8	6.5	

+ Nitrogen: Determined by micro-kjeldahl and protein calculated as T.M x 6.25

‡ Lysine: from amino acid analysis

Appendix
Table 18. Development of breakpoint coupled lethals for effecting gene transfers. Arizona, 1975-76

Sib-crosses (Tucson)	family	male sterile	semi-sterile	fertile	Remarks
ms 10 x T1-3e	b	17	27	0	
ms 10 x T1-3e	c	10	11	0	
ms 10 x T1-3e	d	7	6	0	
ms 10 x T1-4e	a	29	5	0	Haplo-viable
ms 10 x T1-4e	b	26	0	0	Haplo-viable
ms 10 x T1-6e	a	13	12	0	
ms 19 x T4-7b	a	34	26	0	
ms 19 x T4-7b	b	26	5	0	
ms 1 x T5-7g	a	13	5	0	
ms 1 x T5-7g	e	20	23	0	
ms 6 x T6-7c	a	113	92	0	
ms 6 x T6-7c	c	5	3	0	
Self pollinations (Sacaton)					
ms 10 x T1-3e	e	13	27	3	
ms 10 x T1-3e	f	19	26	3	
ms 10 x T1-3e	g	13	21	0	
ms 10 x T1-3e	h	40	41	0	Haplo viable?
ms 10 x T1-6e	b	27	27	0	Haplo viable?
ms 10 x T1-6e	c	38	54	1	(seg.Xania thin)
ms 10 x T1-6e	d	12	28	0	
ms 1 x T5-7g	g	67	123	7	
ms 1 x T5-7g	h	22	30	1	
ms 1 x T5-7g	i	84	95	3	Haplo viable?
ms 10 x T1-7k	c	59	108	38	fertiles are dwarf
ms 10 x T1-7k	d	25	38	1	
ms 10 x T1-7k	e	56	98	2	
ms 10 x T1-7k	f	42	42	4	Haplo viable?
ms 10 x T1-7k	g	30	43	18	Normal
ms 10 x T1-7k	h	1	84	5	Seg. V. weak dwarf
ms 6 x T6-7c	e	68	56	0	haplo viable?
ms 6 x T6-7c	f	59	94	0	
ms 6 x T6-7c	g	32	56	0	
ms 6 x T6-7c	h	49	122	22	fertiles v. low vigor
ms 6 x T6-7c	i	51	65	0	haplo viable?
ms 6 x T6-7c	j	13	18	0	haplo viable?
ms 6 x T6-7c	k	26	49	3	
ms 6 x T6-7c	l	23	41	1	seg. a tufted dwarf

Appendix
Table 18. (Cont.)

Outcrosses to ms 10 (mesa)	family	male sterile	semi-sterile	fertile	Remarks
ms 10 x T1-3e	a	0	7	0	
ms 10 x T1-3e	b	1	5	0	
ms 10 x T1-3e	c	0	8	0	
ms 10 x T1-3e	d	3	2	0	
ms 10 x T1-4e	a	6	2	0	Haplo-viable
ms 10 x T1-4e	b	2	0	0	Haplo-viable
ms 10 x T1-6e	a	4	3	0	
ms 10 x T1-7k	b	1	1	0	
Outcrosses to other male steriles					
ms 10 x T1-3e	a	0	15	12	
ms 10 x T1-3e	b	0	20	11	
ms 10 x T1-3e	c	0	11	6	
ms 10 x T1-3e	d	0	21	9	
ms 10 x T1-4e	a	0	13	25	Haplo viable
ms 10 x T1-4e	b	0	0	31	Haplo viable
ms 10 x T1-6e	a	0	28	23	
ms 10 x T1-7k	a	0	24	18	
ms 10 x T1-7k	b	0	28	20	
ms 19 x T4-7b	a	0	13	19	
ms 19 x T4-7b	b	0	13	14	
ms 19 x T4-7b	c	0	17	9	
ms 1 x T5-7g	a	0	18	5	
ms 1 x T5-7g	b	0	15	2	
ms 1 x T5-7g	c	0	19	9	
ms 1 x T5-7g	d	0	21	0	
ms 1 x T5-7g	e	0	9	24	
ms 1 x T5-7g	f	0	35	8	
ms 6 x T6-7c	a	0	16	17	
ms 6 x T6-7c	b	0	32	2	
ms 6 x T6-7c	c	0	22	0	
ms 6 x T6-7c	d	0	19	9	

Family T1-4e (a) is haplo-viable with no x-overs in 59 crosses.

Appendix
Table 19. Protein content, percent lysine in protein, and percent lysine in barley grain of four selected varieties. Values averaged over fertilizer and spray variables

Barley Variety	Grain protein %	Lysine in protein %	Lysine in grain %
Hiproly	20.6	2.35	0.46
Hiproly normal	18.5	1.96	0.36
Glacier	13.3	2.51	0.32
Hi-Amy. Glacier	14.6	2.42	0.35

Appendix
Table 20. Protein content, percent lysine in protein, and percent lysine in barley grain as influenced by N, P and K fertilizer applications. Values averaged over varieties and spray variables

Fertilizer Application N - P - K	Grain protein %	Lysine in protein %	Lysine in grain %
lb/A			
0 - 0 - 0	16.8	2.23	0.38
0 - 50 - 75	15.8	2.43	0.37
40 - 50 - 75	16.7	2.29	0.37
80 - 50 - 75	17.0	2.41	0.38
80 - 50 - 25	16.7	2.23	0.37
80 - 50 - 0	17.0	2.34	0.38

Appendix
Table 21. Protein content, percent lysine in protein, and percent lysine in barley grain as influenced by foliar spray treatment. Values averaged over varieties and fertilizer variables.

Spray (Foliar appl.)	Grain protein %	Lysine in protein %	Lysine in grain %
No spray	16.8	2.23	0.37
Urea	16.8	2.30	0.38
2, 4-D	16.6	2.28	0.37
Urea + 2, 4-D	16.9	2.23	0.38

Appendix

Table 22. Protein content of barley varieties as influenced by foliar spray treatments. Values averaged over fertilizer variables

Foliar Spray	Lysine in grain (%)			
	Hiproly	Hiproly Normal	Glacier	High Amyl. Glacier
No spray	.454	.353	.341	.343
Urea	.477	.370	.322	.357
2, 4-D	.460	.363	.318	.354
Urea + 2, 4-D	.463	.361	.314	.345

Appendix
Table 23. Dormancy, speed of germination, speed of elongation, emergence and seedling weights of 25 barley cultivars.

		Dormancy %	Speed of elongation		Speed of germination		Soil Tests	
			No Pre-chill, Index	4 day Pre-chill, Index	No Pre-chill, Index	4 day Pre-chill, Index	speed of emerg-ence, Index	wt.per 100 seed-lings gms.
1.	Hulless Compana	13.0	39.5	31.2	148.4	82.0	58.7	8.1
2.	Ingrid	7.5	54.6	43.0	133.3	94.9	76.2	6.4
3.	Traill	1.5	45.6	64.8	130.8	122.2	75.5	8.3
4.	Klages	1.0	42.9	46.5	130.4	90.7	69.5	7.4
5.	Betzes	0.0	41.9	57.2	125.7	121.0	72.1	7.5
6.	Compana	13.5	43.2	57.9	123.8	74.8	67.4	9.4
7.	Hannchen	12.0	33.1	48.4	123.3	92.2	64.9	6.7
8.	Haisa II	11.5	49.9	52.7	120.1	100.6	64.8	6.6
9.	Bruens Wisa	12.0	43.5	55.1	118.7	85.6	64.9	7.4
10.	New Moravian	14.5	58.9	55.3	117.3	74.9	73.3	7.5
11.	Heines Hanna	2.0	53.0	54.3	115.5	99.7	68.4	6.7
12.	Nupana (Stamm)	0.5	41.5	44.2	114.7	119.3	56.5	8.9
13.	Dekap	7.0	42.5	60.6	114.2	91.9	71.1	8.4
14.	Piroline	2.0	40.4	61.0	112.3	129.0	69.6	6.3
15.	Heines Flo	1.0	48.0	69.4	110.1	112.0	75.8	9.7
16.	Freja	10.5	47.0	53.2	107.3	102.4	72.7	6.7
17.	Firlbecks III	5.0	35.8	59.2	105.8	72.0	68.0	7.4
18.	Vantage	20.5	51.6	49.4	103.7	59.0	64.8	8.0
19.	Otis	13.0	49.9	63.7	105.3	90.7	66.1	7.6
20.	Horn	3.5	53.1	62.0	101.1	92.4	69.9	8.4
21.	Svalof 50-107	6.5	49.2	62.8	93.1	97.6	66.1	7.3
22.	Sparton	3.5	53.6	69.5	91.1	113.5	67.7	8.1
23.	Munsing	9.0	50.2	48.9	83.1	80.4	71.1	9.2
24.	Unitan	8.5	32.9	62.6	82.8	102.9	63.1	8.0
25.	Steptoe	20.5	50.9	49.6	47.6	37.2	46.7	6.2

Appendix
Table 24. Efficiency of grain production per unit of leaf area (mg Grain ÷ cm^2 Leaf Area).

cm(between rows)	x	cm(within rows)	Leaf Width		
			N	MW	W
30.5	x	6.6	11.9	12.5	10.6
15.2	x	13.2	11.3	11.8	11.3
15.2	x	6.6	12.2	9.7	7.9

Appendix
Table 25 Varieties and lines isogenic for maturity used in the photoperiod sensitivity screening study.

Variety	Variety	Variety
Betzes	C.I. 6625	Late Compana (erta)
Compana	Edda	Spartan C.I. 5027
Horsford	Olli	Bonus C.I. 8093
Arimont	Beecher	Utah B-5708
Atlas 68	Mars	Tammi C.I. 8345
Athenais	Titan early	Trisomic J-18-17
Steptoe	Titan late	Early Carlsberg II
Galt	Titan very late	Bonneville
Unitan	Titan	Ingrid
Eskishier	Titan early (Gateway)	Primus II
Eskishier	Vantage	Tokak
Attilis	Munsing	Dicktoo
Hector	Hannchen	Frontier
Dekap	Hannchen early	Cal. Mariout
Glacier	Gigas	Kearney
Gateway	Early Freja	Tschermak
Erbet	Freja	Carlsberg II
Prior	Early Betzes (Compana Dwarf)	Erbet
Briggs	Early Betzes (Hannchen Dwarf)	Atsel
Marie	Early Betzes (Orange Lemma)	Ubamer
Floya	Late Compana (ert d)	Late Compana
Radskorn	Late Compana (1b)	Kinai 5
Morocco	Late Compana (1b3)	

Appendix
Table 26. Seedstocks of backcross derived Titan isotypes available for distribution.

T-stock No.	Pedigree	derived Titan or characteristics differing from Titan	Contains identified homozygous genes differing from Titan
1	Titan	Recurrent parent	
2	Munsing /7* Titan	derived Titan	
3	"	sterile laterals	i
4	"	2-row, sterile laterals	V, i
5	"	2-row	V
6	Sermo /7* Titan	derived Titan	
7	"	hulless	
8	"	hulless, short awn	n, lk2
9	"	short awn	lk2
10	Munsing /7* Titan/2/Sermo/7* Titan	hulless, sterile laterals	n, i
11	" "	hulless, short awn	n, lk2
12	" "	short awn, sterile laterals	lk2, i
13	" "	2-row, sterile laterals	V, i
14	" "	hulless, 2-row, sterile laterals	n, V, i
15	" "	hulless, short awn, 2-row, sterile laterals	n, lk2, V, i
16	" "	short awn, 2-row, sterile laterals	lk2, V, i
17	" "	hulless, short awn, 2-row	n, lk2, V
18	" "	hulless, 2-row	n, V
19	" "	short awn, 2-row	lk2, V
20	Belonee /7* Titan	height 95 cm.	
21	"	height 97 cm.	
22	"	height 98 cm.	
23	"	height 90 cm.	
24	"	height 100 cm. derived Titan	
25	Munsing /7* Titan	Munsing lemma color	
26	Stamm /7* Titan	hulless	
27	"	derived Titan	
28	Munsing /7* Titan	blue aleurone	
29	"	rough awn	
30	"	rough awn, blue aleurone	
31	"	derived Titan	
32	B570/7* Titan	derived Titan (maturity)	
33	Gateway /7* Titan	derived Titan	
34	"	early maturity	
35	B570 /7* Titan	erectoides plant	
36	"	derived Titan	
37	"	late maturity	
38	"	late maturity, erectoides plant	

Appendix
Table 26 (cont.)

39	Munsing /7* Titan	rough awn, blue aleurone	
40	"	rough awn, early maturity	
41	"	early maturity	
42	"	derived Titan	
43	"	rough awn	
44	"	late maturity	
45	"	rough awn, late maturity	
46	"	very late maturity	
47	"	blue aleurone	
48	Glacier /7* Titan	derived Titan	
49	"	blue aleurone	
50	Beebe /7* Titan	brachytic (short) plant	
51	"	brachytic (short) plant, rough awn	
52	"	rough awn	
53	"	derived Titan	
54	Red lemma /7* Titan	derived Titan	
55	"	red lemma	
56	Erect leaves /7* Titan	derived Titan	
57	"	erect leaves (pre-boot)	
58	Munsing /7* Titan	awn shedding (dehiscent awns)	
59	"	derived Titan	
60	Munsing /7* Titan /2/Sermo/7* Titan	2-row	
61	Glacier /7* Titan	semi-smooth awn	
62	"	semi-smooth awn, selection	
63	Orange lemma /7* Titan	orange lemma	o
64	"	derived Titan	
65	Munsing /7* Titan	high tiller number selection	
66	Belonee /7* Titan	reduced leaf number	
67	Waxy Oderbrucker /7* Titan	waxy endosperm	wx
68	"	derived Titan	
69	Black lemma /7* Titan	black lemma	B
70	"	derived Titan	
71	ms 3 dwarf /7* Titan	brachytic plant (dwarf)	
72	"	derived Titan	
73	Golden Compana /7* Titan	yellow plant	yh2
74	"	derived Titan	

Appendix
Table 2F (cont.)

75	Albino lemma Liberty /7* Titan	albino lemma	al
76	"	derived Titan	
77	glossy seedling (2b) /7* Titan	glossy seedling	gl1
78	"	derived Titan	
79	Narrow leaf Hannchen /7* Titan	narrow leaf	nlh
80	"	derived Titan	
81	no flag-leaf /7* Titan	minute flagleaf and third outer glume	
82	"	derived Titan	
83	Yellow plant /7* Titan	yellow plant	f4
84	"	derived Titan	
85	Yellow green spike /7* Titan	glossy spike	
86	"	derived Titan	
87	Black lemma /7* Titan	2-row sterile lateral	
88	"	sterile lateral	

Appendix
Table 27 Leaf blade areas of 15 commercially grown 2-row varieties and 15 commercially grown 6-row varieties, values are means of 5 determinations, n leaf is the flag leaf.

Variety	C.I. No.	Leaf and area -- mm^2						No. of culms with deviating no. of leaves from 4.
		n leaf	n-1 leaf	n-2 leaf	n-3 leaf	1st 4 leaves	all leaves	
Two-Row Varieties:								
Horn	926	942	1766	1804	1369	5881	5881	
Haisa II	10420	834	1934	1581	1255	5604	5604	
Firlbeck's III	10088	458	1540	1824	1659	5480	5480	
Hannchen	531	835	1673	1739	1165	5412	5412	
New Moravian	7559	741	1607	1679	1272	5299	5428	1 (+1)
Heines Hanna	9532	651	1389	1478	1365	4883	4883	
Betzes	6398	457	1349	1498	1165	4468	4468	
Piroline	9558	331	1036	1588	1310	4266	4811	3 (+1)
Ingrid	10083	588	888	1263	1299	4038	4038	
Compana	5438	469	1390	1169	936	3965	3965	
Freja	7130	414	1166	1108	1035	3723	3723	
Otis	7557	445	1045	1164	953	3606	3606	3 (+1)
Munsing	6009	490	1083	1117	840	3530	3530	
Dekap	3351	465	918	1094	858	3335	3335	
Spartan	5027	421	1042	892	708	3063	3128	1 (+1)
Avg.		569	1322	1400	1146	4437	4514	T = (+8)
Six-Row Varieties:								
Traill	9538	1502	2520	2669	2402	9093	9877	2 (+1)
Hiland	9530	1473	2634	2401	1968	8477	9628	3 (+1)
Trophy	10647	1236	2098	2317	1969	7619	7914	1 (+1)
Trebi	936	1135	2226	2121	1948	7431	8089	2 (+1)
Frontier	7155	1285	1927	2138	1789	7139	7139	
Bonneville	7248	829	1899	2314	2037	7079	7079	
Liberty	9549	1173	2138	2004	1603	6919	6919	
Vantage	7324	869	1920	2147	1889	6826	6826	
Larker	10648	1134	2082	1910	1654	6780	7524	3 (+1)
Unitan	10421	985	2113	1837	1197	6132	6132	
Titan	7055	955	1422	1510	957	4844	4844	
Harlan	7008	673	1522	1336	1123	4654	4654	
Atlas	7323	590	1396	1336	1136	4458	4458	
Gem	7243	565	1372	1261	897	4095	4095	
Glacier	6976	677	1273	1255	858	4063	4063	1 (-1)
Avg.		1005	1903	1904	1562	6374	6616	T (+10)
All Variety Avg.		787	1612	1652	1354	5405	5565	

Plants grown on a 1'x1' spacing in paired 2 and 6 row plots at Bozeman

Appendix
Table 28. Leaf widths of 15 commercially grown 2 row and 15 commercially grown 6-row varieties grown at Bozeman

Variety	C.I. No.	Leaf width - mm nth leaf	n-1 leaf	n-2 leaf	n-3 leaf
Two-row varieties:					
Horn	926	9.2	12.2	12.4	10.8
Haisa II	10420	7.8	11.8	11.2	8.6
Firlbeck's III	10088	6.2	12.2	12.2	11.2
Hannchen	531	7.8	11.8	11.8	9.4
New Moravian	7559	8.8	11.8	12.0	10.0
Heines Hanna	9532	7.2	11.2	11.6	9.8
Betzes	6398	5.6	10.2	10.6	8.8
Piroline	9558	5.2	9.4	11.6	9.8
Ingrid	10083	6.2	8.2	9.6	9.4
Compana	5438	7.2	11.8	10.8	10.2
Freja	7130	5.4	9.6	9.0	9.0
Otis	7557	7.0	10.4	10.4	9.2
Munsing	6009	6.6	10.2	10.0	8.6
Dekap	3351	5.4	8.0	9.0	7.8
Spartan	5027	6.6	10.2	9.6	7.8
Avg.		6.8	10.6	10.8	9.4
Six-row varieties:					
Traill	9538	15.8	18.6	18.6	16.6
Hiland	9530	11.8	16.0	15.4	12.8
Trophy	10647	14.0	17.2	17.4	16.0
Trebi	936	11.4	15.8	15.6	14.0
Frontier	7155	10.4	14.4	14.8	12.4
Bonneville	7248	10.8	15.2	15.8	14.2
Liberty	9549	12.2	16.0	14.2	12.4
Vantage	7324	11.8	17.0	17.4	16.0
Larker	10648	13.0	17.8	16.2	13.8
Unitan	10421	11.0	16.2	15.4	11.8
Titan	7055	11.4	14.2	13.0	9.8
Harlan	7008	8.4	12.8	11.6	10.2
Atlas	7323	8.2	12.6	12.0	10.8
Gem	7243	7.8	12.0	11.2	8.8
Glacier	6976	8.8	11.6	11.8	9.2
Avg.		11.1	15.2	14.7	12.6
All Variety Avg.		9.0	12.9	12.7	11.0

Appendix

Table 29. Leaf lengths of 15 commercially grown 2-row and 15 commercially grown 6-row varieties grown at Bozeman.

Variety	C.I. No.	Leaf length - mm. nth leaf	n-1 leaf	n-2 leaf	n-3 leaf
Two row varieties:					
Horn	926	168	242	244	215
Haisa II	10420	180	275	233	241
Firlbeck's III	10088	125	213	253	250
Hannchen	531	176	237	246	209
New Moravian	7559	142	228	234	214
Heines Hanna	9532	146	207	216	234
Betzes	6398	136	221	237	220
Piroline	9558	104	184	229	223
Ingrid	10083	149	176	219	230
Compana	5438	108	195	180	148
Freja	7130	123	199	204	189
Otis	7557	102	168	186	169
Munsing	6009	120	177	186	166
Dekap	3351	137	189	202	184
Spartan	5027	104	170	156	152
Avg.		135	205	215	203
Six-row varieties					
Traill	9538	159	227	240	242
Hiland	9530	209	276	262	254
Trophy	10647	148	204	223	203
Trebi	936	163	235	224	230
Frontier	7155	200	225	242	241
Bonneville	7248	128	209	246	241
Liberty	9549	161	224	235	215
Vantage	7324	123	188	205	198
Larker	10648	146	196	197	198
Unitan	10421	148	218	200	164
Titan	7055	137	167	194	161
Harlan	7008	134	199	192	184
Atlas	7323	112	184	187	175
Gem	7243	120	191	188	165
Glacier	6976	131	182	178	137
Avg.		148	208	214	200
All Variety Avg.		141	207	215	202

Appendix

Table 30. Analysis of leaf area data obtained on 15 commercial 2-row varieties and 15 commercial 6-row varieties when grown at Bozeman, Tables 27, 28 and 29 preceding.

Source of variation	Degrees of freedom	nth leaf	n-1 leaf	n-2 leaf	n-3 leaf	1st 4 leaves	all leaves
Leaf area - mm^2							
2 vs 6-row	1	7,132,090	12,660,270	9,521,570	6,487,510	140,694,800	165,755,200
Varieties within 2 row and 6 row	28	318,291	715,184	758,364	766,473	8,527,800	10,946,853
Varieties within 2-row	14	173,722	537,170	451,594	321,846	4,273,200	4,119,914
Varieties within 6-row	14	462,861	893,201	1,065,136	1,211,102	12,782,414	17,773,814
Plants within varieties	120	59,270	73,284	111,347	137,619	739,312	882,418

All mean squares are significant at the 1% level

Leaf width - mm					
2 vs 6-row	1	695.53	779.76	572.33	390.43
Varieties within 2-row and 6-row	28	16.03	16.47	16.85	18.24
Varieties within 2-row	14	7.44	9.54	6.64	4.81
Varieties within 6-row	14	24.62	23.41	27.05	31.67
Plants within varieties	120	2.10	1.89	1.92	3.41

All mean squares are significant at the 1% level except for the 4th leaf within 2-row varieties

Leaf length - mm					
2 vs. 6-row	1	6746.7	334.4	27.00	188.2
Varieties within 2-row and 6-row	28	3567.2	4197.4	3750.4	5906.9
Varieties within 2-row	14	3323.8	4743.7	4061.1	5373.3
Varieties within 6-row	14	3810.5	3651.1	3439.7	6440.4
Plants within varieties	120	931.37	604.88	1003.91	1234.39

All mean squares are significant at the 1% level except for genotypes, 2 vs 6-row, which are non-significant.

Varieties within 2-row and 6-row variance is used to test significance of genotypes

Appendix

Table 31. A complex analysis of leaf areas determined on 4 leaf positions of 15 commercial 2-row varieties and 15 commercial 6-row varieties at Bozeman.

Source of variation	Degrees of freedom	Mean squares
Leaf position	3	23,820,266**
2 vs 6-row	1	35,173,700**
Position x 2 vs. 6-row	3	209,233
2 row varieties	14	1,068,303**
2 row varieties x position	42	138,674*
6 row varieties	14	3,195,610**
6 row variety x position	42	145,561*
plants within varieties	480	95,369

** Significant at P = .01
* Significant at P = .05

Since the leaf position areas were determined on a culm this provides correlated data and therefore the error term is apt to be underestimated. This would not alter the conclusion that leaf area is distributed about the same among the 4 leaf positions in both the 2 and 6-row genotypes.

Appendix

Table 32. Stem rust reaction classes of F_2 populations in Seedling (growth chamber) and Adult (field) tests.

	Seedling			Adult		
F_2	0,1*	2	3,4	R	I	S
ms x T1-6w Bonus	51	68	59	45	54	29
ms x T1-6x Bonus	59	67	49	35	61	23
ms x T1-6y Bonus	84	62	29	15	59	47
ms x T1-6ab Bonus	43	73	45	64	20	28
ms x T1-6ac Bonus	75	71	42	33	35	51
ms x T1-2l Bonus	137	89	14	21	51	29
ms x T1-2c Hann.	52	87	34	25	59	46
ms x T1-5a Gull	38	56	17	7	56	42
ms x T1-2p Proctor	22	35	15	17	34	76
ms x T1-5b Mars	47	82	22	6	52	51

*R, 0, 1 = no or very small pustules.

I, 2 = intermediate pustules.

S, 3, 4 = large, coalescing pustules.

Appendix
Table 33. Scald reaction classes of F_2 seedlings of the Betzes primary trisomics x Kitchin.

Trisomic	Reaction Classes[a/] 0,1	2	3	Total	X^2 (3:1)
1	71	35	42	148	.901
2	98	30	33	161	1.741
3	174	58	83	315	.305
4	67	131	103	301	13.644**
5	150	51	82	283	2.385
6	184	40	81	305	.395
7	112	44	60	216	.889

[a/] 0, 1 = no or very small lesions on margins of leaves.

2 = lesions extended in length or size.

3 = leaves wilt.

** = significant at 1% confidence level.

Appendix
Table 34. Scald reaction classes of F_2 seedlings of the Betzes primary trisomics x Jet.

Trisomic	Reaction Classes[a/] 0,1	2	3	Total	X^2 (1:15)
1	12	92	75	179	.063
2	11	111	94	216	.494
3	4	153	139	296	12.685**
4	8	145	161	314	7.345**
5	23	167	125	315	.594
6	15	161	114	290	.575
7	24	168	138	330	.589

[a/] 0, 1 = no wilt or very small lesions on margins of leaves.

2 = lesions extended in length or size.

3 = leaves wilt.

** = significant at 1% confidence level.

Appendix
Table 35. Net blotch reaction classes of F_2 seedlings of the Betzes primary trisomics x Tifang.

Trisomic	Reaction Classes[a/] 0,1	2,3	4	Total	X^2 (3:1)
1	71	53	34	158	1.021
2	68	73	47	188	.0
3	99	120	111	330	13.127**
4	132	97	82	311	.309
5	120	93	68	281	.059
6	86	98	68	252	.529
7	81	70	57	208	.641

[a/] 0, 1 = no or pinpoint lesions.

2, 3 = partly developed dark brown lesions.

4 = brown elongated lesions criss-crossed with net-like venation.

** = significant at 1% confidence level.

Appendix
Table 36. Net blotch reaction classes of F_2 seedlings of the Betzes primary trisomics x CI 7584.

Trisomics	Reaction Classes[a/] 0,1	2,3	4	Total	X^2 (3:1)
1	61	46	30	137	.703
2	40	48	72	160	34.133*
3	145	87	78	310	.004
4	118	107	69	294	.368
5	112	97	77	286	.564
6	123	79	75	277	.636
7	70	68	50	188	.255

[a/] 0, 1 = no or pinpoint lesions.

2, 3 = partly developed dark brown lesions.

4 = brown elongated lesions criss-crossed with net-like venation.

** = significant at 1% confidence level.

Appendix

Table 37. Net blotch reaction classes of F_2 seedlings of the Betzes primary trisomics x CI 9819.

Trisomics	Reaction Classes[a] 0,1	2,3	4	Total	X^2 (15:1)
1	101	90	15	206	.374
2	96	105	18	219	1.450
3	120	160	33	313	9.845**
4	173	116	12	301	2.631
5	116	148	26	290	3.650[b]
6	159	108	21	288	.533
7	90	91	16	197	1.178

[a] 0,1 = no or pinpoint lesions.

2,3 = partly developed dark brown lesions.

4 = brown elongated lesions criss-crossed with net-like venation.

** = significant at 1% confidence level.

[b] P = .05 -.10

Appendix

Table 38. Reaction of selected cultivars to a Tunisia isolate of *Puccinia hordei*.

CI No.	Name	Reaction*
CI 261	Club Mariout	2,3
877	Horsford	1,2
1016	Kwan	2,3
1145	Gold	2
1257	Bolvia	3
1330	Pannier	2,3
4974		0;1
5047		0;1
5051	Reka I	2
5644		1
5647		1
6398	Betzes	1
6488	Lechtaler	1
6489	Sudan	2
7251	Moore	2,3
8811	Franger	2

* 0; = chlorotic flecks

1 = minute pustules

2,3 = intermediate pustules

4 = large pustules