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# IMPROVEMENT OF THE NUTRITIVE QUALITY and PRODUCTIVITY OF BARLEY for SEMI ARID REGIONS

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ANNUAL REPORT NO. 3
March 25, 1976 - March 25, 1977
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## 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. Develop some fertile, plump-seeded, hi-lysine lines for use as donor parents.
f. Assign the Glacier hi-lysine gene to a chromosome.
g. Initiate evaluations of the biological value of proteins in lines determined to be high in lysine.
h. Initiate studies on protein inheritance, including maternal inheritance.
i. Determine the effect of environment, including soil fertility, on lysine stability across environment.
j. 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 June of 1976 Drs. Charles F. McGuire and C. W. Newman, barley quality specialist and nutritionist, respectively, on the project visited CIMMYT headquarters at El Batan. They consulted with Dr. Eva Villegas and others concerned with the quality aspects of the CIMMYT barley improvement program (See attached trip report).

In August Dr. L. P. Carter visited CIMMYT headquarters at El Bataan and consulted with Drs. Glen Anderson and J. P. Srivastava in the development of a program for a barley workshop to be held in the Mideast and sponsored jointly by ICARDA, CIMMYT, and Montana State University through the AID contract (See attached trip report).

During this and the previous year, every effort possible was made to arrange a barley workshop in the mideast. It would appear that all systems are go for a workshop to be held at Amman, Jordan in late April of 1977.

In March Dr. E. A. Hockett, USDA, ARS plant breeder and Dr. Tom Carroll, plant pathologist visited Morroco, Tunisia, Egypt, Jordan, Syria and Turkey. Barley production practices, research, and diseases were observed in the countries visited (See attached trip report).

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

A basic schematic or flow chart of the high lysine barley research effort is presented in Figure 1. Mutants are selected and verified by lysine screening with the microbiological assay method. These mutants are characterized genetically, agronomically, nutritively and for protein and lysine stability. Selected mutants may be put into pedigree, backcross or recurrent selection breeding programs. Mutagenesis may be involved in various places in the total scheme to induce new mutants or improve existing mutants, e.g. restore plumpness to shrunken endosperm high lysine mutants. Various mutants are at various places in the scheme. Utilizable materials from the program include germplasm, information and techniques. Segments of the following report will fit under the various headings found in Figure 1.

### Screening Genetic Material & World Barley Accessions.

Amino acid analyzer values for lysine in barley grain were compared to microbiological assay lysine values by use of a simple correlation program. When data for lysine as a percentage of grain was computed the correlation coefficient was r = .917**. When the data were converted to lysine as a percentage of grain protein, the correlation coefficient was r = .721**. Based on 32 observations of lysine estimates by each technique the conclusion is that the microbiological procedure adequately measures lysine levels in barley grain.

More than 18 nurseries were screened for lysine in 1976. Data from these nurseries is summarized and included in the appendix and indicates the extent of the screening and genetic work. Appendix Table 1 contains a summary of lysine as a percentage of whole grain. Appendix Table 2

summarizes lysine as a percentage of protein. The Neotec Grain Quality Analyzer (GQA) was used to obtain an estimate of grain protein percentage. Where high lysine lines are indicated, by the combination of the microbiological assay and GQA, these can be verified by the amino acid analyzer & Kjeldahl nitrogen tests.

The Hiproly pairs grown in a range of environments exhibit a range of lysine, both as a percent of grain and as a percent of protein. The summary does not identify pairs or the difference in lysine between pairs, only the 2 range of lysine.

A series of selected high lysine barleys were assayed as 75 Inc. After the samples were pearled the kernels were assayed along with material removed in pearling. The data indicate the lysine in the pearled grain to be lower than in pearlings or intact grain. If the lysine as a percent of protein is examined Table 2 the pearlings are lower than either grain or pearled grain.

CI entries grown in 1974 have no outstanding lysine levels based on data in Table 1. Twenty seven of the 192 lines tested had .50% lysine in the grain or higher (up to .55%). Based on the protein content in these barleys, eight samples were between 3.50 and 4.0% lysine.

Entries grown at Mesa in 1974-1975 crop were low in average lysine. Low protein in the grain seemed to be the reason.

HP selections grown in 1975 have a wide range of lysine, with more than half above .50% lysine in the grain.

HAG isogenic entries tended to be very nearly alike in lysine content. When lysine as a percent of protein was calculated twelve samples were 3.50 to 4.0% lysine.

More than 500 HP lines were grown in 1976. A wide range of lysine levels appeared in these selections with 273 of them between .50 and .85% lysine in the grains. About 252 of these had lysine as a percent of protein between 3.50 and 5.75.

During the 75-76 season HP selections were grown at Mesa. Of 257 entries lysine in the grain exceeded .50% in 53 entries. As a percent of protein 190 entries were in the range of 3.50 to 5.75.

A group of shrunken endosperm selections were increased in 1976. Of 46 entries 19 exceeded .50% lysine in the grain. WH selections totaling 226 were grown at Bozeman in 1975. Twenty six of these exceeded 5% lysine in the grain. Thirty one had 3.25 to 3.50% lysine in the protein.

Two row barleys from the world collection are grown at Bozeman each year. In 1973, 292 of these were grown. Two selections CI 13250 and CI 14752 show promise for high lysine, both as a percent of grain and of protein. These entries need to be submitted to complete amino acid analysis to verify the indicated lysine level. An additional 102 CI selections were grown at Bozeman in 1975 (Exp. 31). No entry was promising among this group.

From a maturity study (B60) 153 entries were selected for bio-assay. These had a very narrow lysine range. Differences in maturity apparently had no effect on lysine levels.

Among 73 entries grown at Mesa in 74-75, 20 had lysine in the grain between .50 and .75%. Analysis of lysine in the protein is not yet completed.

HP selections grown at Bozeman in 1974 showed 64 of 107 to have lysine in the grain between .50 and .80%.

A nursery of 530 PI and CI selections was grown in 1974 as 74WH. Of those 131 exceeded .50% lysine in the grain. One hundred and six had lysine in the protein between 3.50 and 4.50%.

The results of these screening tests show a wide range of lysine in barley lines. The data are most applicable in identification of potentially high lysine genotypes. The verification of this rightly belongs in the column chromatographic technique used on an amino acid analyzer. Experience thus far shows that the bioassay is an effective screening test. The Neotec GQA compliments the bioassay in screening as it allows an estimate of lysine in protein as a part of the screening program.

Nutritional evaluation of selected plump 2-rowed barleys:

Seven 2-rowed barleys were selected for further study from the 1973 - MSG barley series on the basis of amino acid composition, animal performance and agronomic potential. Sufficient seed was produced in a common environment in 1975 for rat feeding trials, chemical analysis and future seed increase. Those barleys chosen were representative of a high, medium and low nutritive quality as evidenced by lysine content and rat protein efficiency ratio (PER) measurements. The barleys were Hanna (CI 906), Balder (CI 7131), Brage (CI 11310), Compana (CI 5438), CI 10375 and CI 12103. Hiproly (CI 3947) and Hiproly Normal (CI 4362) were included in the increase as controls. (See Annual Report, 1975-76, pages 6-8 and Appendix Tables 4-9).

Proximate composition and calcium and phosphorus percentages of these barleys and diets prepared from them are shown in Appendix Tables 3 and 4. Diets were prepared to contain 10% protein and were equalized in energy by adjusting the oil and fiber contents (Appendix Table 5). A casein-cornstarch diet was prepared for comparison with the barleys and to adjust the PER. Weanling rats were fed these diets in a 28-day growth trial.

There were no differences ($P>.05$) in gain due to diet (Appendix Table 6) although it appeared that rats fed Brage and Hiproly grew the fastest of those fed barley diets. The other barley diets produced similar gains (67.0 to 73.5 g). Rats fed Hiproly and Brage diets also had the highest PER which were different ($P<.05$) from the PER obtained from the other seven barleys. Feed efficiency ratio differences were similar to the PER in that Brage and Hiproly diets proved to produce the most efficient gains ($P<.05$) of the barleys. Feed consumption was quite uniform among most of the barleys although rats ate less ($P<.05$) of the Compana and Hiproly Normal diets. Casein-cornstarch fed rats gained equally to the barley-fed rats but consumed less ($P<.05$) feed, were more ($P<.05$) efficient and had the highest ($P<.05$) PER.

Biological value (BV), true protein digestibility (TD) and net protein utilization (NPU) were measured on the barleys with the exception of Hiproly and Hiproly Normal (Appendix Table 7). Differences were not statistically significant, although it appeared that Brage, Balder, Hanna and CI 12103 were the best barleys in terms of BV. Bargiers produced the lowest BV and NPU of all barleys. The TD tended to be negatively correlated with BV ($r=-.44$). However, Brage which had the highest BV (85.7%) had the second highest TD and the negative correlation was much more evident when the Brage data were removed from the calculations ($r=-.77$). Although the differences were not significant, Brage produced an NPU value of nearly 70%.

The percentage lysine (g/16g N) was compared from these barleys grown in 3 environments (Appendix Table 8). All of these barleys appeared to have higher levels of lysine than the average feed barley Compana, and appeared to be fairly consistent in lysine content from environment to environment. Balder had the highest average percentage lysine for the three environments (3.93% vs. 3.28% for Compana) and was the most consistent from environment to environment. This finding may be quite important in view of the fact that there were major differences in the percentage of hordein in Balder protein between the 1st and 2nd crop year seeds (Appendix Table 9). The complete amino acid composition of the second crop year barleys is shown in Appendix Table 10. Certain of the cultivars evidenced marked deviation between 1st and 2nd crop year seeds for all of the protein fractions, whereas there was only small deviations in other cultivars. Hanna and Brage were the most consistent for the protein fractions between crop years.

Composition of barley proteins

An SDS-disc gel electrophoresis technique using Cyanogum-41 + 7M urea + .1% 2-mercaptoethanol was developed in our laboratory. This technique gives excellent resolution of barley protein components.

Whole ground defatted barley from the 2 isotypes Hiproly and Hiproly Normal were extracted with pH7 phosphate buffer at various molarities or with phosphate buffer plus other additives. The data is presented in Appendix Tables 11 and 12. The results indicated that phosphate buffer (.005 - .1 M) alone or in presence of .04 - .5 M NaCl, or .1% 2-mercapto-ethanol or .005% Ethylenediaminetetra-acetic acid (EDTA) extracted more or less the same amounts of protein (28 - 35% from Hiproly and 17 - 29% from Hiproly Normal. The proteins had more or less the same electrophoretic composition with a dominance of the albumin + globulin components. Phosphate buffer in presence of .1% sodium dodecyl sulfate (SDS) extracted from 70 - 80% of the barley protein with lower ranges being extracted at higher buffer molarities. The extracted protein had components from the albumins, globulins, hordein and glutelin. The maximum amount of protein was extracted by phosphate buffer in presence of .1% 2-mercaptoethanol + .1% SDS (90 - 94% or in presence of .1% 2-mercaptoethanol + .1% SDS + .005% EDTA (83 - 93%). Here also the lower ranges of protein were extracted at higher buffer molarities. The extracted protein was inclusive of the components of albumin, globulin, hordein and glutelin.

The percentage content of albumin + globulin, hordein and glutelin were determined in 23 samples of barleys of various varieties and sources, Appendix Table 13. The data is presented in Appendix Tables 13a, 14 and 15. The salt soluble proteins (albumin + globulin) ranged from a minimum of 27.5% in Wapana to 39.8% in Hanna. The Hordein ranged from a minimum of 17.2% in the Italian barley to a maximum of 36.9% in Wapana. The glutelin ranged from 23.6% in barley C.I. 12099 to 41% in Lenta. SDS disc gel electrophoresis indicated the existence of 6, 5 and 5 types of components combinations in albumin + globulin, hordein and glutelin respectively. This indicates the existence of genetic variance of components in each of these classes. The concentration of components comparable in molecular weights which occured in various barleys varied considerably. The concentration of these components was determined by densitometry.

Comparison of Glacier and High-amylose Glacier (Glacier Ac 38) barleys:

Previous data have indicated Glacier Ac 38 to have a greater percentage of lysine (g/16 g N) and to produce higher PER in rats than the normal Glacier isotype (see 1974-75 Annual Report, pages (18-19). One rat feeding trial was conducted to provide additional data on these two barleys. In addition, the amino acid composition and protein fraction of five Glacier-Glacier Ac 38 pairs were determined. Glacier Ac 38 is phenotypically and agronomically similar to Glacier although Glacier Ac 38 contains approximately twice as much amylose in the starch as the normal (52 vs 27%) (Appendix Table 16), 8% more lysine in the protein (g/16 g N) (Appendix Table 17) and less hordein and more albumin and Globulins (Appendix Table 18). There were no major differences in the proximate composition of the two isotypes (Appendix Table 16). In addition to the greater percentage of lysine in Glacier Ac 38 compared to Glacier, there is more alanine, arginine, aspartic acid, glycine, threonine, tryptophan tyrosine and less glutamic acid and proline. The protein content in the five Glacier-Glacier Ac 38 pairs studied ranged from a low of 8.6% to a high 13.2%. Percentage hordein was positively correlated ($P<.01$) with protein content ($r=.91$) and percentage lysine was also significantly but negatively correlated (P .05) with protein ($r=-.85$). The differences observed in percentage lysine between the two Glacier isotypes (Appendix Table 17) is probably due to the differences in the protein fractions in the two barleys (Appendix Table 18).

Rat diets were prepared from a Glacier pair produced in 1975 and Hiproly isotypes grown in the same year in a similar environment. A casein-cornstarch control diet was included to adjust the PER and to compare with the barleys (Appendix Table 19). Rats fed the Glacier Ac 38 diet gained faster ($P<.05$), appeared to consume more feed ($P<.05$), were more efficient ($P<.05$) and had a higher average adjusted PER ($P<.05$) than rats fed the normal Glacier (Appendix Table 20). Hiproly produced a faster rate of gain and rats ate more feed ($P<.05$) than those fed the Glacier pair but were not ($P>.05$) different in feed efficiency nor PER from the rats fed high-amylose Glacier diets. Although rats appeared ($P>.05$) to gain more and did consume more ($P<.05$) feed on the Hiproly Normal diet than on the normal Glacier diet ($P<.05$), they were not different in feed efficiency.

Nutritional and chemical evaluation of Bomi- and Carlsberg II-Risø barley mutants:

Bomi Risø mutant 1508, Carlsberg II-Risø Mutant 29 and Carlsberg II-Risø mutant 86 barleys and the parent barleys, Bomi and Carlsberg II were grown at two separate locations in the summer of 1976 (Bozeman and Huntley, Mt). Hiproly and Hiproly Normal were also produced in each location. Proximate components of these barleys are shown in Appendix Table 21. The maize and high-lysine maize cultivars shown were isogenes and were produced at only one location (Huntley, MT). The barleys and maize were prepared in iso-nitrogenous, isocaloric diets and each fed to 10 rats in four separate growth studies comparing each mutant with its parent, Hiproly, Hiproly Normal, maize and high-lysine maize within the location where it was produced. A casein-cornstarch control diet was fed in each study to adjust the PER and compare with the cereals. Proximate composition, calcium and phosphorus percentages are shown in Appendix Table 22 (Bomi-Risø mutants) and in Appendix Table 23 (Carlsberg II-Riso/ mutants). Diet composition are shown

in Appendix Table 24 (Bomi-Risø mutant) and Appendix Table 25 (Carlsberg-Riso mutants).

Rats fed high-lysine maize gained faster (P<.05) than those fed the barley diets in the Bomi-Risø growth trial (Appendix Table 26). These rats also appeared to eat more feed (P>.05) were most efficient (P<.05) and had the highest (P<.05) PER of the cereals compared. The Bomi-Risø mutant 1508 rats gained faster (P<.05) than those fed Bomi, appeared to eat more feed (P>.05) were more efficient (P<.05) and produced a higher PER (P>.05) than those on the Bomi diet. The Hiproly diet was superior to Hiproly Normal and statistically equivalent to the Bomi-Risø mutant 1508 diet. Maize was the poorest (P<.05) of the cereals compared. There were no statistical differences between the Bozeman and Huntley barleys in rat performance with the exception of PER. Those rats fed in the Huntley trial had the higher (P<.05) PER.

High-lysine maize produced the highest PER in the Carlsberg II-Risø growth trial (Appendix Table 27) but the rats did not gain statistically faster (P>.05) than those fed the Carlsberg II-Risø 29 and 86 mutants. Carlsberg II-Risø 86 mutant had the highest PER of the barleys but was not statistically different (P>.05) from the Carlsberg II-Risø mutant. Hiproly did not appear to be comparable to the Hiproly Normal diet and neither of the Hiproly isotypes were superior to the maize. There were no statistical differences in rat performance between location in which the barleys were produced.

In the metabolism trials, the small number of observations per diet (4) make statistical interpretation difficult. The Risø mutant of Bomi, Bomi-Risø 1508, and Carlsberg II, Carlsberg II-Risø 29 and 86, appeared to produce the highest biological value (BV) of the cereals in all three comparisons (Appendix Table 28). Hiproly appeared to have a higher BV, in two of three observations, than Hiproly Normal but was not different from either Bomi or Carlsberg II. High-lysine maize also appeared to have a higher BV than maize but was not different from Bomi or Carlsberg II barleys. The true protein digestibility (TD) of high-lysine maize appeared to be greater than that of maize in each trial. There was little difference in the TD of the Bomi and Bomi-Risø 1508 mutant. However, the TD of the Carlsberg-Risø mutants 29 and 86 appeared to be lower (P>.05) than that of Carlsberg II in one trial and was lower (P<.05) in TD than the parent barley in the second trial.

The amino acid composition of the cereals fed in these studies are shown in Appendix Tables 29, 30 and 31. The protein fractions of the Bomi and Carlsberg II barleys and mutants are shown in Appendix Tables 32 and 33. These data (amino acid and protein composition) include those cereals fed in 1975-76 and 1976-77. (see 1975-76 annual report).

The Bomi-Risø mutant 1508 fed in 1975-76 had the highest percentage of lysine (g/16g N) of any of the barleys or maize. The two Bomi-Riso mutant 1508 samples fed in 1976-77 had approximately 23% more lysine than Bomi but were approximately 21% lower in lysine than the 1508 mutant barley fed in 1975-76. The latter was classed as 99% thin kernels whereas the other two samples of the mutant had 25% plump kernels. It is suspected that the latter two barleys having the lower percentage of lysine and greater plumpness represented mixtures and not pure samples. Further evidence of this is presented in Appendix Table 32. The 1975-76 mutant 1508 had 5% hordein compared to 15% for the pair fed in 1976-77. The PER and BV of the 1975-76 1508 mutant barley was 2.48 and 91% compared to 2.16 and 78% for the 1976-77 1508 mutants. The greater percentage of lysine in the Risø mutants is

probably due to a change in the protein fractions brought about through the mutation. The mutant barley contained less hordein and more of the albumin-globulin fractions than the parent barleys.

The growth trial and metabolism trial data obtained with the barleys were correlated with the amino acid composition in a simple correlation analysis and in a stepwise mutiple regression analysis. The maize and casein data were omitted from these calculations.

Simple correlation coefficients of the amino acids in the barleys and the biological measurements are shown in Appendix Tables 34 and 35. Six amino acids were significantly ($P<.05$) and positively correlated to gain. They were arginine, glycine, lysine, threonine, aspartic acid, and tryptophan. A seventh amino acid, leucine, was significantly ($P<.05$) but negatively correlated to gain. Tyrosine was the only amino acid having a significant ($P<.05$) correlation with feed consumption ($r=-.50$). The correlations with feed efficiency and PER were similar to the pattern exhibited with gain. Lysine had the greatest relationship to PER. This was also true with BV although lysine exhibited a negative relationship with TD. The percentage amino acids in these barleys exhibited opposite relationships with the BV and TD with the exception of proline which had a non-significant correlation of $r=.19$ and $.18$, respectively. For example lysine was positively correlated ($r=.62$) with BV and negatively correlated with TD ($r=-.52$).

Stepwise multiple regression R and $R^2$ values are shown in Appendix Tables 36, 37, 38, 39, 40, 41 and 42. Lysine was the primary amino acid for gain, PER and BV. Lysine also exerted a secondary effect on feed efficiency and was the third most important amino acid contributing to the NPU. The most influential amino acids on feed consumption, feed efficiency, TD and NPU were tyrosine, leucine, tryptophan and leucine, respectively. The eighteen amino acids included in the multiple regression analysis accounted for over 92% of the variance of each of the biological measurements. In all of the parameters except feed consumption and net protein utilization, the majority of that variance was accounted for by the first five amino acids.

Physical and agronomic characterization of the Bomi and Bomi derived and the Carlsberg II and Carlsberg II derived barley are shown in Appendix Tables 43 and 44 respectively. The mutant barleys were all less plump and contained a greater percentage of thin kernels than the parents. Bomi-Risø mutant 13 had the most thin kernels and least plumpness of the barleys. The Bomi-Risø mutant 7 and Carlsberg II-Risø 29 mutants yielded nearly as much as the parents in eight and nine observations, respectively. The Bomi-Risø 7 mutant was practically equal in kernel weight to Bomi, whereas the other mutants had lighter kernels which was evidence of the shrunken endosperm that is typical of high-lysine barley mutants.

Effect of nitrogen fertilization on the nutritive value and chemical composition of selected barleys:

Hiproly (CI 3947), Hiproly Normal (CI 4362), Compana (CI 5438) and Unitan (CI 10421) were grown during the summer of 1976 at three levels of added nitrogen fertilizer. Ammonium nitrate (33.3% N) was added to provide 0, 112.8 and 225.6 kg N per hectare (0, 100 and 200 lbs N per acre) in four replications. Sufficient seed was produced to feed rats in growth and

metabolism trials in addition to making physical and chemical measurements.

The addition of nitrogen fertilizer significantly increased ($P<.01$) the yield of each cultivar. The highest level (225.6 kg/ha) of nitrogen fertilizer produced the greatest yield but was not significantly different ($P>.05$) from the yield produced by 112.8 kg N/ha (Appendix Table 45). Unitan and Compana were the highest ($P<.01$) yielding cultivars and were not significantly different ($P>.05$) from each other although it appeared that Unitan produced more than Compana. Hiproly Normal yielded more seeds per plot ($P<.01$) than Hiproly. There was no significant interaction on yield between cultivar and fertilizer rate.

Increasing levels of nitrogen fertilizer decreased ($P<.01$) kernel weight of the barleys on the average. The greatest effect appeared to be between 0 and 112.8 kg N/ha (Appendix Table 46). There was a significant variety X fertilizer interaction ($P<.05$) on kernel weight. Unitan and Hiproly seed size was not significantly altered between the two highest levels of fertilizer, although seeds produced at the 0 level of nitrogen were larger ($P<.01$) than those produced at 112.8 and 225.6 kg N/ha for both cultivars. Seed size of Hiproly Normal and Compana barleys did not differ and were larger ($P<.01$) than those of Unitan and Hiproly. The latter barley had the smallest ($P<.01$) seeds of the four cultivars. Nitrogen fertilizer application reduced the test weight (kg/hl)($P<.01$) at each level (Appendix Table 47). All cultivars differed ($P<.01$) in the test weight with Hiproly Normal being the heaviest barley and Unitan being the lightest.

The effect of cultivar and nitrogen fertilization on percentage plump and thin kernels are shown in Appendix Tables 48 and 49, respectively. Increasing levels of nitrogen fertilization reduced the plumpness ($P<.05$) and appeared to increase the percentage of thin kernels ($P<.05$). Hiproly had the greatest ($P<.01$) percentage of thin kernels and there were no differences in this regard between the other cultivars. Compana had the greatest ($P<.01$) percentage of plump kernels, although it was not statistically different from Unitan in this respect. Hiproly Normal had less ($P<.01$) plump kernels than Compana and Unitan, but was plumper ($P<.01$) than Hiproly. There was a significant interaction between nitrogen fertilizer rate and cultivar for plumpness. There were no differences in plumpness at the two highest levels of N fertilization for Hiproly and Hiproly Normal, and Unitan did not differ between zero and the 112.8 kg N/ha level of fertilization.

Protein was measured in the barleys by the Udy dye-binding method and by the standard Kjeldahl (nitrogen x 6.25) procedure. The Udy standard curve was standarized with the Kjeldahl determination. Hiproly had the highest ($P<.01$) level of Udy protein followed by Hiproly Normal, Compana and Unitan in order. Hiproly was higher ($P<.01$) in Udy protein than Compana or Unitan and the latter two were not significantly different from each other, Appendix Table 50. Level of nitrogen fertilizer increased Udy protein although there was a significant ($P<.01$) interaction between nitrogen rate and cultivar. Compana and Unitan exhibited increased Udy protein with each increment increase in fertilizer. Udy Protein in Hiproly Normal was increased by fertilizer application but not between the two added levels of nitrogen. Hiproly Udy Protein was not altered at the 112.8 kg level but was increased slightly ($P<.01$) at the 225.8 kg of r level. Kjeldahl protein, Appendix Table 51, resembled the Udy Protein but was lower in the Hiproly samples and was equal to or higher in the other three cultivars. The greatest increase in Kjeldahl protein due to nitrogen fertilizer was in the Compana and Unitan barleys. These two cultivars did not differ in Kjeldahl protein at the zero

level of fertilizer but Compana contained slightly more (P<.01) protein than Unitan at both levels of added nitrogen. Hiproly protein decreased (P<.01) at the first level of added nitrogen but increased at the highest level of fertilizer. The greatest effect of added nitrogen fertilizer on Hiproly was to increase the yield and not protein. Hiproly Normal protein was increased (P<.01) at the highest level of nitrogen fertilizer but the magnitude of increase was only 1.8 percentage points compared to 4.4 and 3.4 percentage points for Compana and Unitan, respectively.

The effect of cultivar and added nitrogen fertilizer on rat gain, feed consumption, feed efficiency and PER is shown in Appendix Tables 52, 53, 54 and 55, respectively. There were no significant differences in growth rate due to barley cultivars, on the average. Rats gained faster (P<.05) on barleys produced at the zero level of nitrogen compared to the highest level of nitrogen. There was a significant (P<.05) interaction between cultivar and fertilizer on growth. There was no effect on gain of rats fed Hiproly due to fertilizer whereas rats fed Compana gained faster (P<.05) on the barley grown at the zero level of nitrogen fertilizer. Feed consumption was not affected by treatment. Rats fed the barleys grown at the zero level of nitrogen were the most (P<.05) efficient and produced the highest (P<.05) PER. Rats fed Hiproly Normal had a lower (P<.05) PER than those fed the other three barleys, on the average. There were no differences between PER of rats fed the Hiproly, Compana or Unitan barleys. A significant (P<.05) interaction occurred between barley and fertilizer for PER values. Fertilizer application did not significantly effect the PER of Hiproly and Hiproly Normal whereas the Compana barley produced at the zero level of nitrogen had the highest (P<.05) PER in this cultivar and the rats fed the Unitan barley produced at the highest level of N had the lowest (P<.05) PER in this cultivar.

The amino acid composition of these barleys is shown in Appendix Table 56. Lysine (g/16 gN) appeared to be reduced in Compana and Unitan but was not consistantly altered in Hiproly and Hiproly Normal. Protein efficiency ratio was significantly (P<.05) correlated to the percentage lysine, r=.59. However, when the Hiproly data was removed from the calculations there was a significant increase in the correlation, r=.98 (Appendix Table 57). The protein fractions of the barleys are shown in Appendix Table 58. The percentage of Hordein appeared to be increased in Compana and Unitan by the addition of nitrogen fertilizer, although there were no differences in this measurement between the two levels of added nitrogen in either cultivar. The increase in hordein was at the expense of the albumin-globulin fraction. There was no apparent change in the protein fractions in Hiproly Normal. In the Hiproly protein it appeared that nitrogen fertilizer increased the percentage of albumin-globulins at the expense of glutelin and the hordein was not changed in this cultivar.

New High Lysine Mutants identified:

Eight spontaneous shrunken endosperm mutants were evaluated for lysine content. The results are presented in Appendix Table 59. The only mutants that do not show statistically significant elevated lysine content are those with only two observations. The percent lysine in the protein for Glacier seg5 and Ingrid seg7 was not different from Glacier and Ingrid respectively. This may be due to the fact that plump kernels occurred in the samples of these mutants.

A sample of Hiproly, which has shrunken endosperm, was treated with diethyl sulfate (DES) in an attempt to induce a supressor gene (s) for the shrunken trait without affecting the lysine content. In addition samples of the hulless cultivars Washonupana, Nupana and Nubet were treated with DES to try to induce high lysine in plump lines. The $M_2$ are currently being grown. The Hiproly progeny will be sieved with plump seed analyzed for lysine content. The Nupana and Nubet $M_2$ progeny will be screened for opaque types using a light table. Opaques that result will be analyzed for lysine content and waxy endosperm.

Nearly completed is the screening for protein and lysine of the two-rowed barley world collection. Seven barley varieties were selected with potential as high lysine lines. All varieties selected have plump kernels.

Characterization of Bomi, Riso Mutant 1508, Inheritance of shrunken Endosperm

The kernels of Riso 1508 have a characteristic dimple of the dorsal or germ side of the seed in our environments. Presented in Appendix Table 60 are data concerning the occurrence of shrunken seed on $F_1$ plants ($F_2$ seed). The data is from crosses of Riso 1508 with nine other varieties. The shrunken endosperm trait is recessive as indicated by an acceptable fit to 3:1 ratio for most of the crosses and this is in agreement with reports in the literature.

Since we are reporting on the shrunken endopserm characteristic of Riso 1508, and this trait has shown xenia in all first crosses, we propose that the trait be designated sex3c.

The $F_2$ plant classification, from plants grown from seed represented in Appendix Table 60, is presented in Appendix Table 61. Again, recessiveness of the shrunken endosperm trait is indicated by an acceptable fit to a 1:2:1 ratio for most of the crosses. Departure from 3:1 and 1:2:1 ratios may be noted in Appendix Tables 60 and 61 and may be due to the presence of suppressor genes or modifiers for shrunken endosperm or differential survival of pollen grains carrying the sex3 allele, as no obvious female sterility was noted. In all cases but one, rejection of the 3:1 or 1:2:1 hypotheses was due to a deficiency of shrunken seed.

Shrunken Endosperm, sex3 sex3, Linkage

Independence is indicated between sex3 and male sterile genes, msg, on chromosomes 1 through 6, Appendix Table 62. Male sterile 19, msg19, according to data of Appendix Table 63, is located on chromosome 7. With the numbers observed, nearly complete linkage between msg19 and sex3 is indicated. The coupled sex3 msg19 genotype was not recovered.

Linkage was also found between the short rachilla hair gene, (s), and sex3. Partial $F_3$ linkage data shows 28.6 ± 3.4 percent recombination of the two genes, Appendix Table 64.

The short haired rachilla gene, (s), is usually assigned to the long arm of chromosome 7 and it has been indicated that the high lysine gene, lys1, of Hiproly is probably 8 units distal to s in the same arm. We have generally considered msg19 to be near the centromere of chromosome 7. The results reported would indicate that the sex3 gene of Riso 1508 is probably near the centromere of chromosome 7. This does not necessarily conflict with the findings of others concerning the independence of Riso 1508's high lysine character and lys1 on chromosome 7.

Lysine Association with sex3 sex3

The frequency distribution, Figure 2 and 3 suggests a distinct percent lysine distribution for each endosperm genotype, and this is confirmed by a heterogeneity $X^2$ test of the frequency distributions of the plump and heterozygous classes. Probability of the same frequency is <.001.

A close association between the high lysine character and the shrunken endosperm character is evident in Figures 2 and 3 and Appendix Table 65. Figure 2 and 3 data is from $F_3$ progeny ($F_3$ seed from $F_2$ plants) from the same crosses as presented in Appendix Table 61.

The Riso 1508 parent and $F_3$ shrunken progeny were not different from each other in percent lysine in the barley or in the protein but both were higher than the other parents or progenies. The heterozygous $F_3$ progenies were intermediate in both characters. Plump parents were not different from $F_3$ plump segregates for percent lysine in the barley but were different for percent lysine in the protein, Appendix Table 65.

The heterozygous $F_3$ progenies are higher in lysine than the normal parents, .493 percent vs .441 percent lysine in the barley respectively, (Appendix Table 65). If xenia is assumed and adjustment for lysine made from the observed frequencies of plump and shrunken kernels, Appendix Table 60, .79 and .21 respectively (e.g. .441 x .79 + .756 x .21 = .507), the observed .493 agrees quite well with the calculated theoretical .507.

It follows that the normal lysine characteristic, expresses complete dominance. In addition, the high lysine character also expresses xenia in the same manner as the shrunken endosperm character.

The two most likely explanations for the above results would be that one trait is a pleotropic effect of the other or that they are two closely linked genes, one for shrunken endosperm, the other high lysine.

A Characterization of Three High Lysine Mutants in Relation to Their Normal Isotypes and Their Environmental Response.

Three mutants with elevated lysine contents, Hiproly (lys1), Betzes seg1, and High Amylose Glacier (amo1) and their respective normal varieties, Hiproly Normal (CI 4362), Betzes, and Glacier were included in nurseries grown in 26, 18 and 21 environments respectively in Montana and Arizona. Paired data were analyzed and summaries of the protein, lysine, and agronomic data are presented in Appendix Tables 66, 67 and 68. Protein was determined by 3 methods, Kjeldahl, Udy dye binding method and with a Neotec grain quality analyzer (GQA). Lysine was determined by two methods, microbiological assay and by the Udy dye binding technique (% transmittance).

Comparison of the three mutants and determination of environmental responses are desirable, and the regression analysis method is one possible way to do this.

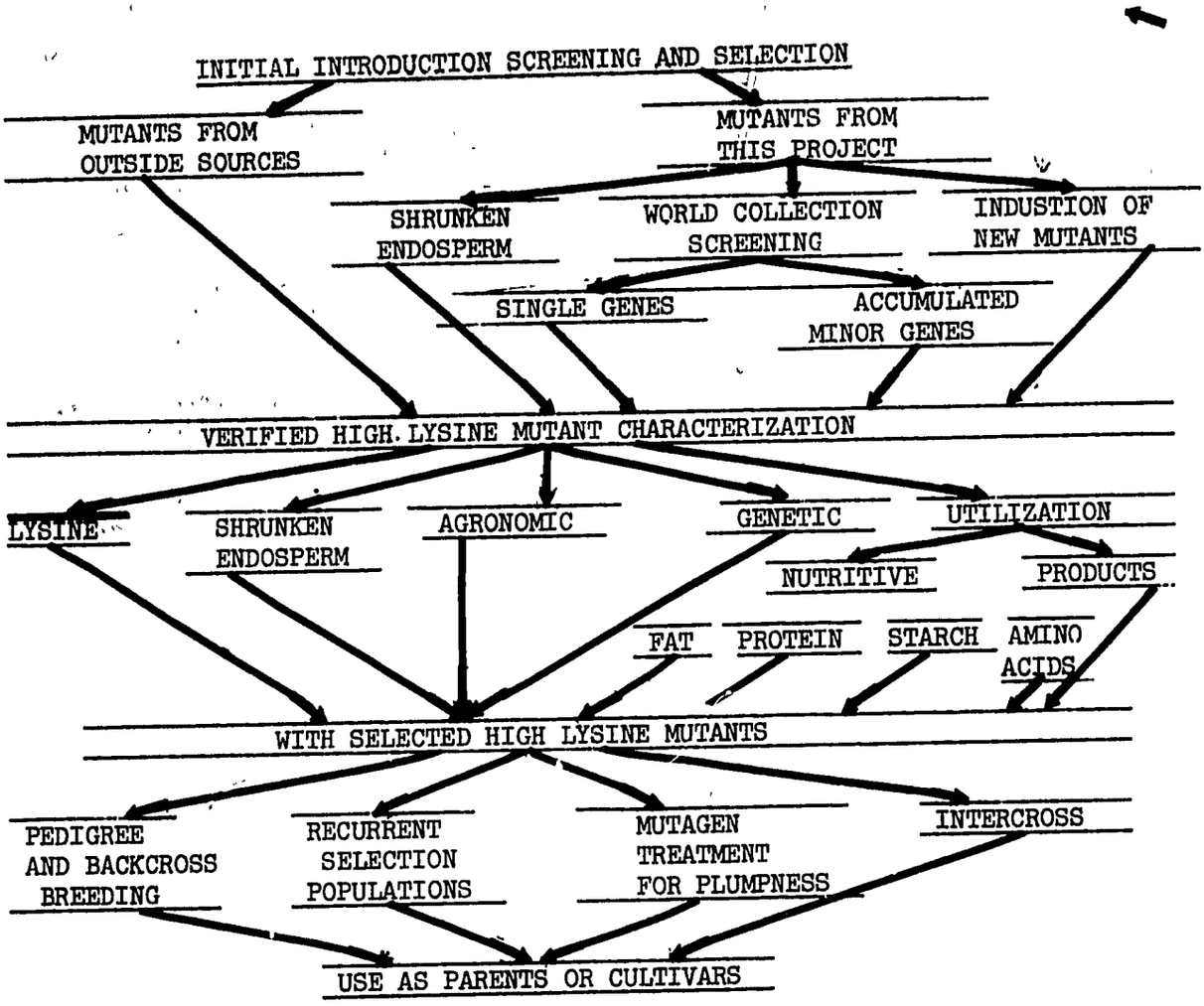


Figure 1. Schematic representation of research activities on barleys for higher nutritive value, Montana State University, 1976-77.

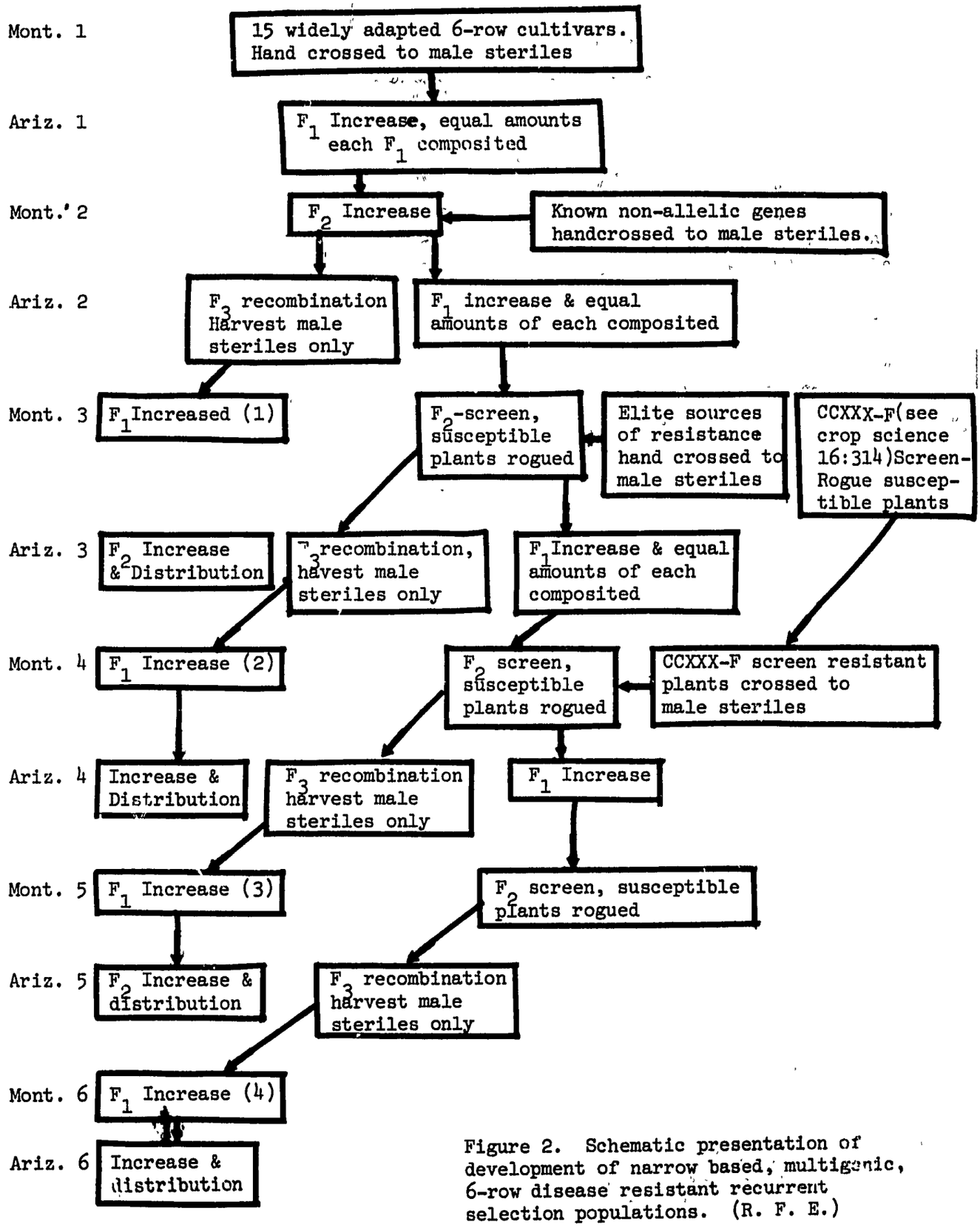


Figure 2. Schematic presentation of development of narrow based, multigenic, 6-row disease resistant recurrent selection populations. (R. F. E.)

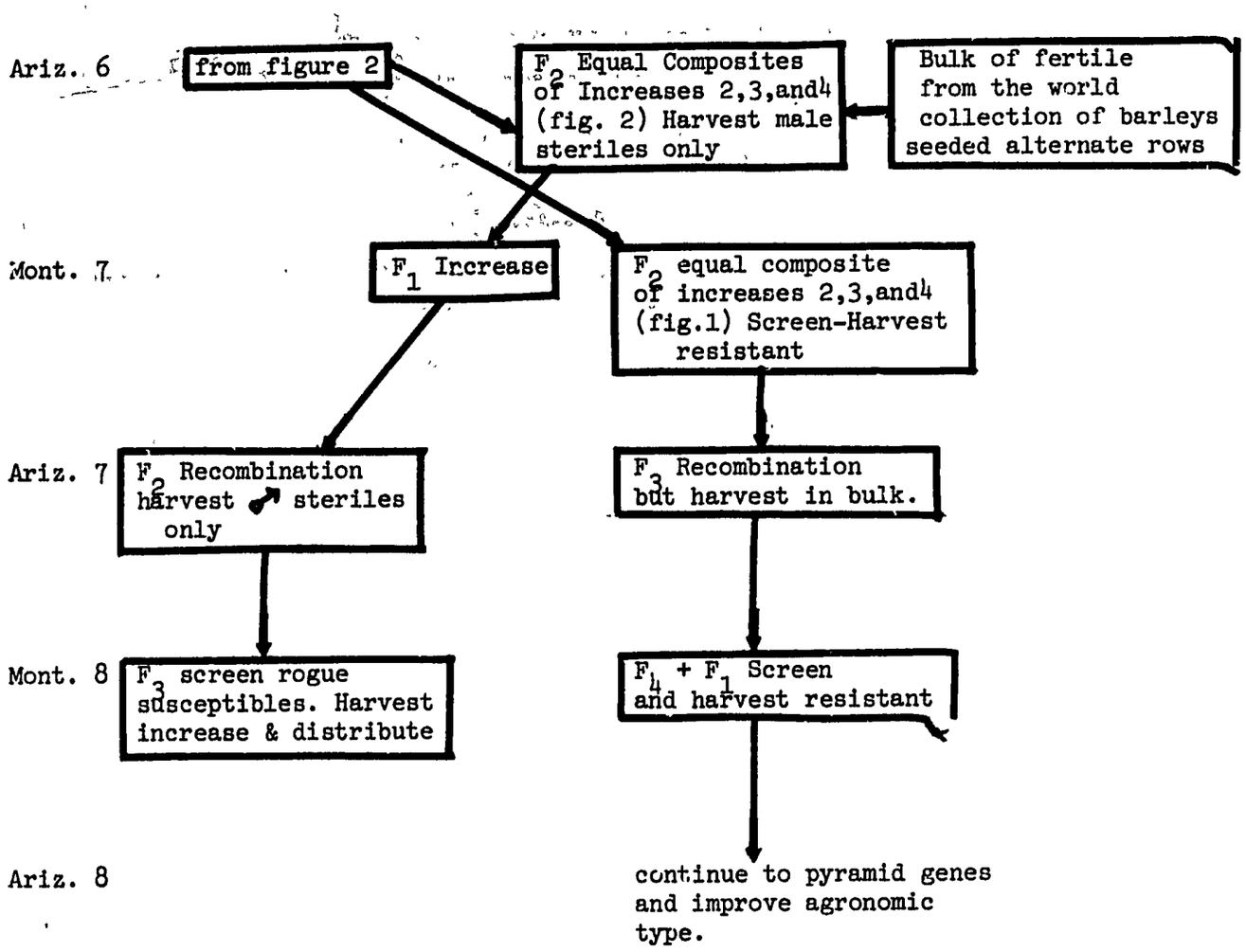


Figure 3. Schematic presentation of development of broadbased, multigenic disease resistant recurrent selection populations; also schematic of gene pyramiding and agronomic improvement.

Case I - Significant difference in means, regression coefficient not different from 1.0.

Significant mean differences may be noted for some agronomic characteristics, protein and lysine content of all three mutants compared to their normal varieties. Only differences in lysine in the barley, yield, percent thin, and test weight for Hiproly and % transmittance (% lysine in protein by Udy method) for Betzes segl may be interpreted as significant in all environments tested. In comparing Glacier and High Amylose Glacier, there is a significant difference in GQA protein, Udy protein, % lysine in the barley and protein, and in kernel weight only.

If one examines the mean and regression coefficient of % transmittance of Betzes segl, we note that the mean difference is significant and the slope, $b_{yx}$, is not different from 1.0. We may conclude that the mean differences prevail throughout the range of environments tested. The same reasoning is applied in formulating the other conclusions above.

Case II - Significant differences between means, regression coefficient significantly different from 1.0.

If one examines the list of mean differences between Betzes and Betzes segl and Hiproly and Hiproly Normal, it will be noted that nearly all are significant at P=.01. If the regression coefficients are checked for significant differences from a slope of 1.0, it will be noted that nearly all, with the exceptions listed in case I above, are significantly different from 1.0. It would follow that such mean differences are thus dependent upon the environments in which the mean differences are determined. We may conclude that there are environments where the means are different and there may be environments where the means are not different.

Case III - Differences between means non-significant and regression coefficient not significantly different from 1.0.

As an average across all environments tested we may conclude there is no difference in date headed between Hiproly and Hiproly normal, and High Amylose Glacier and Glacier do not differ in Kjeldahl protein, yield, % plump, % thin, test weight and height. These statements are based on the fact that the means are not different and slopes ($b_{yx}$) are not different from 1.0 for these characteristics determined with Hiproly and High Amylose Glacier. However, all characters measured are different for Betzes and Betzes segl on the basis of mean difference or regression coefficients significantly different from 1.0.

Case IV - Differences between means non-significant and regression coefficient significantly different from a slope of 1.0.

As an average across all environments in which comparisons were made there is no difference in the height of Hiproly and Hiproly Normal or Betzes and Betzes segl. High Amylose Glacier was not different from Glacier for % transmittance or date headed. Regression coefficients were different from a slope of 1.0 indicating that if the general mean of Betzes, Hiproly, or Glacier had been at some other value, significant differences would probably have been detected for these characteristics.

If one accepts the regression approach, then the graphs presented in Figures 4 and 5 may be constructed from the data of Appendix Tables 66, 67 and 68 and along with the data in these tables, the following comments are made for two of the characters measured, kernel weight and % lysine in the protein.

1. There is variation among the mutants for these two characters in their response to the environment and their association with the performance of normal varieties. (Indicated by the variation in mean differences, $b_{yx}$'s and $r^2$'s which to some extent can be seen in the relative positioning of the lines of Figures 4 and 5.
2. In the range of environments tested the mutants have lower kernel weights than the normal varieties, Figure 4, (indicated by significant t-test of means and the position of the mutant line below the unity line), but the difference diminishes as the kernel weights of the normal isotypes diminish for Betzes seg1 and Hiproly (Indicated by the approach of the mutant lines to the unity line and significant differences of $b_{yx}$ from a slope of 1.0). The Betzes seg1 mutant responds little to environmental changes and has almost no association with Betzes (indicated by a low $r^2$).
3. Concerning percent lysine (figure 5) in the protein, Hiproly displays the least explainable environmental response and this is not associated with the normal isotype (indicated by a low $b_{yx}$, and $r^2$ and non-significant r). Under conditions yielding low lysine in the protein the difference between Betzes seg1 and Betzes is the greatest (indicated by the positioning and significant difference of slope of the line from 1.0 and a relatively high $r^2$). High Amylose Glacier has a higher lysine content than Glacier in most environments (indicated by the significant mean difference, the slope of the line not differing significantly from 1.0, and a relatively high $r^2$).

It is suggested that the most desirable type of high lysine mutant for widespread use would have an $r^2$ of 1.0, a slope of 1.0, and the highest mean possible above a normal barley. Other characteristics and association among them must also be considered.

If this procedure is followed it must be assumed that the environments under which a given set of comparisons are made are a random sample of the environments under which all such comparisons are made. It must also be assumed that the normal isotypes, or those entries represented by the unity line, are not interacting differently to the random sample of environments.

Data similar to the above has been collected for five seg mutants, one sex mutant, and eight Risø mutants and is available for summarization.

Progeny From Hiproly Crosses

Eight $F_6$-$F_8$ high lysine selections from crosses between Hiproly and three normal lysine varieties are being yield tested this year at nine locations in Montana. Initial yield performance data is presented in Appendix Table 69. From this data more yield improvement is indicated. Additional selection from these lines for agronomic characters will be done. Also selections are being made from 46 lines of $F_4$ and $F_5$ progeny from Hiproly

crosses with four normal lysine varieties.

It has been determined by comparing $F_3$ with $F_4$ progeny from Hiproly x normal variety crosses, that once selection for high lysine types occurs no further selection for high lysine is necessary or warranted. (Appendix Table 70). In other words once progeny have been selected as being high lysine, no further selection is necessary for that trait. The breeder can concentrate on the importance of other traits, e.g. agronomic.

## High Lysine Gene Transfer Systems

Suitable translocation stocks can be utilized for various purposes, e.g. gene transfer into male sterile facilitated recurrent selection populations, additivity studies and coupling two similar genes located on the same chromosome.

A double translocation (T3-7c + T3-7d) has been crossed with 30 widely adapted varieties (15 2-row, 15 6-row), the $F_1$'s of which have been crossed with Hiproly to effect the transfer of lys1 to establish narrow genetic base male sterile facilitated recurrent selection populations.

## High Lysine Male Sterile Facilitated Recurrent Selection Populations

One of our initial objectives to accomplish the breeding of high lysine barley cultivars is to develop homozygous high lysine male sterile facilitated recurrent selection populations (RSP's). The association of shrunken endosperm with the high lysine character is a major obstacle to the breeding of high lysine cultivars. RSP's may aid in overcoming this problem if any one of the following three hypotheses are valid:

1. Shrunken endosperm and high lysine are linked characters where recombination could be expected.
2. Suppressor genes for shrunken endosperm exist or can be induced somewhere on the barley genome.
3. The combination of large seed size with shrunken endosperm could maintain the seed weight component of yield.

If hypothesis 1 and/or 2 were realities, early generation, $F_2$, selection, when the criteria for selection is shrunken seed, would be desirable, since desirable recombinants are most likely present in highly segregating populations. If high lysine were truly homozygous in the RSP, sieving in subsequent generations should be an effective selection tool.

Male sterility in a population provides for maximum recombination with a minimum of effort and could be utilized to the maximum by harvesting separately, seed set on the male sterile plants. However, to avoid undesirable genetic drift and to retain a maximum of homozygous recessive genotypes, one could harvest only from male sterile plants in alternating generations with a bulk harvest of the whole population at the other generation.

## RSP15

RSP 15 has the Hiproly (lys1 lys1) gene homozygous. The composition, protein and lysine data for RSP 15a are presented in Appendix Table 71. All components appear to be homozygous for lys1. Appendix Table 72 gives comparable parental data. All protein determinations were done with the

Neotec Grain Quality Analyzer, except as noted, and all lysine analyses by a modified microbiological assay technique. Currently RSP 15a is in its third bulk planting. Presented in Appendix Table 73 is kernel assortment data for the second harvest.

A relationship between sieve size and lysine content seems to exist with a decreasing lysine content concomitant with increasing kernel size. However, the low .360% lysine in the largest-seeded barley is an anomoly, if lys1 was homozygous in every plant in the population and the analysis was correct. With this data questions yet unanswered are raised. Is high lysine a pleotrophic effect of the shrunken endosperm or vice versa? Is it possible to have high lysine and plump seed? We believe additional data are necessary to answer these questions.

Composition, protein and lysine data for RSP 15b are presented in Appendix Table 74. This population is similar to RSP 15a, but is currently in its second bulk planting. The lysine data indicates that all components are homozygous for lys1. The fertile components were sieved with only seed remaining on top of a 5.5/64 sieve planted. The first harvest (a bulk of sterile & fertile plants) of RSP 15b was also sieved and chemically analyzed. These data are presented in Appendix Table 75. A parallel between the data of Tables 74 and 75 may be noted. These are only very preliminary data, however, it does appear sieving may be shifting the population slightly with the plumpest kernels being higher in percent lysine in the twice sieved RSP 15b.

RSP 16

RSP 16 is a bulk of ten varieties and seven male sterile genes (msg's) with Bomi, Riso Mutant No. 1508. This population is currently in its first planting. The component varieties are presented in Appendix Table 76. The criterion for inclusion in the population was shrunken endosperm seed from first cross $F_1$ spikes. The data presented in Appendix Table 76 provides the rationale for this criterion.

The mean percent lysine in the barley of $F_3$ shrunken seed (.755 ± .007) from variety x No. 1508 crosses is significantly ($p<.01$) greater than that of $F_3$ plump seed (.441 ± .004), Appendix Table 77. The $F_3$ progeny represented in Appendix Table 77 are from the same crosses as the $F_3$ progeny that were used to establish RSP 16.

We intend to broaden the genetic base of these populations to include approximately thirty varieties. In addition when a workable transfer system is developed, broad genetic base populations will be established by crossing into the world collection RSP's.

Additional Stock Development

Prerequisites for and by-products of genetics research is stock development.

A number of male sterile stocks in barley homozygous for various high lysine genes have been developed. We are or will be using these stocks to facilitate hand and natural field crossing in our high lysine genetics and breeding program. These stocks can be particularly useful in producing known hybrid seed in quantity when allele testing unknown genes. The stocks are available to anyone requesting seed.

Presented in Appendix Table 78 are the stocks developed. Lysine data is presented as evidence of the presence of high lysine in the stocks.

A Bomi, Risø Mutant No. 1508, chromosome 7 male sterile stock has not been developed. We tried with msg 19 but failed to combine the two characters. Linkage between the two characters is suspected. Crosses have been made between Risø 1508 and other chromosome 7 male sterile genes (msg 16, 18 and z) to further the linkage study and for development of a male sterile stock.

Waxy Endosperm barley

In asiatic countries where barley is frequently served mixed with rice and where glutinous (waxy endosperm) rices are preferred there is interest in using the waxy endosperm barleys, as barley or in mixtures with normal rice.

A waxy endosperm, normal endosperm isogenic pair of barleys have been developed from the cross Waxy Oderbrucker/7* Compana and the resultant cultivar named Wapana. Compana (normal endosperm) and Wapana (waxy endosperm) are compared for a number of agronomic and quality characteristics in Appendix Table 79. The regression analysis and interpretation as discussed in the lysine work is used.

Wapana had more thin kernels, fewer plump kernels, and kernel weights were lower than for Compana. As might be expected, then, the barley and malt nitrogens are higher and test weight is lower. Contrary to the usual association, higher nitrogen-higher diastatic power, the diastatic power is lower.

The decreased kernel weight was apparently reflected in yield as it is about 5% lower than the normal endosperm isotype when the mean yield level of Compana is 28.2 quintals per hectare. However there is a significant regression of Wapana yields on the yield of Compana. At yield levels from somewhat more and less than 17.6 q/ha the waxy endosperm isotype should be expected to yield the same, or more, than the normal endosperm isotype.

Barleys with high fat content

Seven hulless barleys presumably with a high fat content were obtained from Dr. Phil Price, increased and planted in 1975 in sufficient quantity to feed. Other barleys were included in the trial. None of the barleys equalled Compana, a Montana recommended cultivar, in fat content, Appendix Table 80. It was decided not to feed the barleys but to grow them at several locations in Montana in 1976 and recheck the fat contents.

Gibberellic acid activity

The buffer extraction and the alpha-amylase bioassay were used to evaluate 25 barley cultivars for gibberellic acid activity. These cultivars had previously been evaluated for speed of germination, elongation and emergence, seedling growth rate and seed dormancy. Seed of these 25 barley cultivars was produced in 1975 at the Montana Agricultural Research Center at Bozeman, Montana. When using the alpha-amylase bioassay the cultivar having the smallest absorbancy reading has the greatest gibberellic acid activity; as this bio-assay measures the disappearance of starch. The gibberellic acid activity of these 25 barley cultivars

varied greatly (Appendix Table 81). Nugapana (Compana *7/Stamm) had the greatest gibberellic acid activity followed by four cultivars which are being grown for malting: Heines Flo, Piroline, Klages and Betzes. The four cultivars having the poorest gibberellic acid activity are all classified as feed type: Freja, Otis, Dekap, Compana and Nupana (Compana *7/Sermo). Nupana and Nugapana are isogenic lines with a different donor parent for hulless. Gibberellic acid activity of barley cultivars was not associated with speed of germination, elongation and emergence, or seedling growth rate.

Speed of emergence of barley cultivars can be predicted by determining speed of germination in the laboratory; regardless of the level of seed dormancy present. However, seed dormancy affected the total number of seedlings which emerged.

Seedling weight after six-weeks of growth was associated with speed of elongation of the seedlings. Both the speed of germination and elongation are laboratory tests which can be conducted to predict field performance of the barley cultivars. There is a negative correlation between speed of germination and elongation; therefore, it would be difficult to select a barley cultivar which has the capabilities to emerge rapidly and produce maximum growth in six-weeks.

Seed dormancy as evaluated by laboratory tests was also expressed in the fewer numbers of seedling which emerge from soil in greenhouse flats.

Gibberellic acid activity was correlated with food and/or feed value of 21 barley cultivars. Gibberellic acid activity index was negatively correlated with adjusted protein efficiency ratio (-.462*), daily gain (-.377) and feed consumption (-.338). A step-wise regression was conducted to determine the contribution of several seedling germination characteristics to feed value for rats. For average daily gain, feed consumption, and adjusted protein efficiency ratio, the most important characteristic for prediction purposes was speed of germination 6/21/76 minus 10/31/75 determined on prechilled seed. We may conclude that these two measurements of enzymatic activity may in some way account for as much as 36% of the variation in nutritive value.

Several characteristics of barley were used to predict gibberellic acid activity and to determine the contribution of these factors (Appendix Table 82).

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

Canopy Color

One aspect of this year's work has been comparing evapotranspiration over different colored barley isogenes - Golden Compana and Compana using the Bowen-ratio-energy-balance method. There is some evidence that the lighter varieties reflect more radiation and heat up less. This experiment was conducted to see if the lighter isogene also transpired less, thus, perhaps, making it more suitable for semi-arid conditions.

From the cumulative soil water use data, it is apparent that there exist at least three patterns of water use. Period 1 consists of May 31 to June 26 during which the darker Compana used 6mm in more water. During the second period, June 26 to July 20, the lighter Golden Compana used approximately 39mm in more water. Finally, the pattern reversed again and

from July 20 to July 30 the dark isogene consumed 20 mm more water. Golden Compana used 234 mm of water throughout the season; whereas Compana used 225 mm.

The Bowen ratio data cover from July 3 to harvest and show, generally, the same trends as the soil water data. In particular, there was a period of higher water usage by Golden Compana until about July 20 after which the darker variety consumed more. From July 28 to harvest the water use was about equal. We will consider the data from July 22, a day in which the light isogene initially used a little more water followed by a reverse trend in which the dark variety used more for the remainder of the day. Golden Compana used slightly more water from 10:00 a.m. to approximately noon. From noon to about 8:30 p.m., Compana used more water.

Much greater reflection in the light barley and its subsequent smaller net radiation was observed throughout the day (and this held throughout the season). The dark barley maintained a somewhat constant larger $\Delta e$ than the light barley. This, in itself, would indicate a higher ET from the dark than the light isogene. However, ET is a function of the ratio of $\Delta e/T$. Inasmuch, the $\Delta T$, the gradient of temperature, will be analyzed next.

The $\Delta T$ above the light variety was around zero in the early morning and appears to have increased to some small positive number during the day. In contrast, the dark variety early in the day had a large $\Delta T$ and linearly decreased as the day progressed. This large $\Delta T$ early in the day was likely a direct result of the dark barley absorbing radiation faster than the air (and than the lighter canopy). As the day continued the air mass slowly warmed up and, accordingly, the $\Delta T$ slowly decreased. The larger $\Delta T$ (morning) in the dark barley means the proportional loss by sensible heat was greater in the morning for the dark isogene and decreased throughout the day until approximately 6:30 p.m., when the $\Delta T$'s were equal for both lines. Since evapotranspiration is proportional to (latent heat flux/sensible heat flux), the greater the proportion of sensible heat dissipation, the smaller the evapotranspiration. Thus, early in the morning, when the dark isogene had its greatest sensible heat loss, the dark isogene had a smaller evapotranspiration rate. As the day continued, the sensible heat loss decreased in the dark line; and, at approximately noon, the dark line reached a higher evapotranspiration rate than the light line. From noon to evening, the higher ET rate in the dark barley was due to the larger $\Delta e$ and the larger net radiation of the dark canopy.

These data from July 22 represents some typical trends which occurred throughout the season. Specifically, the net radiation was always considerably higher in the dark canopy and the $\Delta T$ usually followed the trend described above (although sometimes to a lesser degree). Soil heat flux, also followed a consistent pattern with more heat moving into the soil under the dark canopy (again depicting greater sensible heat loss in the dark canopy). Variability was more evident in the $\Delta e$ data with many days showing a larger $\Delta e$ above the light canopy - and not necessarily linear increases throughout the day. Generally, ET in the dark isogene was lower in the morning, but increased as the day warmed up. On some days, as for July 22, this increase was enough to result in a larger daily ET total for the dark line; whereas, on other days, the increase was small and the result was a larger daily ET total for the light line.

Any factor that would tend to decrease this $\Delta T$ effect, such as warm days and long days would enhance higher evapotranspiration rates in the

dark isogene. In addition, clear days, with the much greater net radiation entering the dark canopy, will enhance higher evapotranspiration rates in the dark isogene.

Reflection and net radiation data support the idea that the lighter isogenes may be better suited for water-limiting locations. However, the darker lines appear capable of dissipating most of the additional radiation load through sensible heat transfer. Consequently, it appears that the choice of lighter colored varieties over darker ones in dry localities should be restricted to regions in which the sensible heat transfer is less influential and the net radiation large - regions with long, hot, clear days.

Canopy Color & Earliness in Betzes

The effect of pale leaf color from various genetic sources was studied in a Betzes Cultivar background. Since a reduction in leaf chlorophyll concentration also delays maturity we also evaluated one line (PG Erbet) that had both pale leaf color and earliness genes that gave it a maturity comparable to Betzes. The six lines studied were the normal Betzes, early Betzes (Erbet), Pale Green (PG) Betzes, PG Erbet, Vantage yellow in Betzes (Van-Bet) and $F_7F_7$ (pale) in Betzes. The Pale Green (PG) lines have leaves that are only slightly lighter in color than those of the normal dark green lines, Betzes and Erbet.

Grain yields, which averaged 3400 kg/ha, were (from high to low) Betzes & PG Betzes >Erbet > Van-Bet > PG Erbet > $F_7F_7$ in Betzes. Water use from July 2 to September 21 averaged 22.6 cm. The amount of water use was Betzes & PG Betzes > Erbet > PG Erbet > $F_7F_7$ in Betzes. Water use by Van-Bet did not differ from either PG Betzes or Erbet. Betzes, PG Betzes and Erbet used water more efficiently (ave.=169 kg grain/ha per cm of $H_2O$ used) than the other three pale lines which averaged 139 kg grain/ha per cm of $H_2O$ used. Under these semi-arid conditions earliness reduced yield but not water use efficiency (WUE). A slight reduction in chlorophyll concentration (PG) reduced grain yield and WUE only when combined with earliness. With more severe moisture stress Erbet would be expected to outyield Betzes.

Total above ground dry matter production was similar for PG Betzes, Betzes, Erbet and Van-Bet but lower for PG Erbet and $F_7F_7$ in Betzes. Harvest indices, which were similar for all lines, averaged 0.50 which means that one half of the above-ground dry weight was in the grain.

The four pale leafed lines used in this study had light saturation values that were similar to the normal dark green lines, Betzes and Erbet. Specific leaf weights (dry weight per unit leaf area) were higher for the dark green lines.

Chlorophyll Stability

Chlorophyll stability was determined for a set of 25 two-row and 25 six-row tester varieties using a method similar to that used by W. J. R. Boyd & M. G. Walker for wheat in 1972. The chlorophyll in excised barley leaves was much more stable than in excised wheat leaves as shown by Boyd and Walker. We found 70 to 100% of the chlorophyll still present after 5 days incubation at 20°C. under moist conditions compared to 7 to 58% found by Boyd and Walker for wheat. Our barley lines had less variation

in initial chlorophyll content than their wheat lines.

Drought Resistance - Varietal Differentiation in Barley

Another focus of our work involved "water relation" measurements made on 50 barley varieties in an attempt to discover a means of selecting drought resistant varieties. These 50 varieties (25 two-row and 25 six-row) have been grown many years at many stations in the northern mountain and plains area. Thus they have been subjected to a wide range of environmental conditions. We are currently in the process of comparing statistically each variety with all of the other 49 varieties. Thus, we will be able to compare the yield of each variety with all other varieties under conditions of different environmental yield potentials. Presumably then, for instance, those varieties that yield highest under conditions of low environmental yield potential are best able to cope with drought. To date, we have used four measurements or approaches in attempts to differentiate between the varieties.

The first approach involved measuring maximum and minimum osmotic potentials on all varieties during a 24 hour cycle. It is reasonable to expect drought resistant varieties to undergo larger changes with the two extreme water conditions. This would allow the plants to: a) use less water under no-stress conditions, because of the higher osmotic potential; and b) obtain more water under stress conditions, because of the lower osmotic potential.

In the second approach, total water potential and relative water content were measured on leaves that were brought to full turgor and, subsequently, dried down at room temperature. A primary concern was to measure the modulus of elasticity. The modulus of elasticity measures the ratio of the stress, turgor pressure, to the corresponding strain, water content. Thus, if a given stress produces a large strain, a cell with a low modulus would have high elasticity. There is some evidence for a drought resistant variety to have a smaller modulus of elasticity and, therefore, higher elasticity. In addition, the two respective slopes (change in total potential/change in water content) and the potential point at which the slopes changed were measured. The varieties with larger slopes will maintain a higher water content at a lower potential, thus perhaps being better adapted to dry conditions. Also, the varieties that reached a lower potential prior to the change in slope would appear to be more drought resistant. This point corresponds to the "permanent wilting point" concept.

As part of the third approach, total plants, leaves, and heads were collected and allowed to dry down over a period of 48 hrs. The percent water loss was calculated for various intervals of time. It is likely that drought resistant varieties would be slower to lose their water - or show different patterns of dry down.

For the final approach, soil water content measurements were taken after the experimental plots were harvested. Drought resistant varieties could be expected to show better ability to extract more water from the soil - through more extensive rooting and greater drawing ability. However, it could also be argued that drought resistant varieties survive by needing (and using) less total water.

The primary purpose of all these approaches was to see if the water-

related data for the varieties could be correlated to data obtained for these same varieties in the barley breeding program at M.S.U. This involves a regression line giving the best estimate of drought resistant varieties.

The osmotic potentials were taken on two days, July 14 and August 10. The maximum turgor readings were taken at 5:45 a.m., (just prior to sunrise) and the minimum turgor readings at 2:00 p.m. Three 6-in. surgical tubes, each filled with 3 leaves, were collected from each line. After freezing on dry ice, thawing, and mixing the extracted sap, readings were taken with a thermocouple psychrometer until the readings were within ± 1 μυ.

In the second approach, a single leaf was pumped full of water, then allowed to dry at room temperature. Total potential was measured with a pressure bomb (PMS) and the water content with a Mettler balance. Relative water content was calculated as mass of tissue / mass of tissue at full turgor. Only 29 varieties were tested because of shortage of time.

The modulus of elasticity was determined using the following equation for $\Psi$, the total potential,

1) $$\Psi = (\Psi\pi_t + \Psi\tau_t)\frac{(I-B)}{(R-B)} + R[e - (\Psi\pi_t + \Psi\tau_t)] - e$$

$\Psi$ = total potential

$\Psi\pi$ = osmotic potential

$\Psi\pi_\tau$ = osmotic potential at full turgor

$\Psi\tau$ = matric potential

$\Psi\tau_t$ = matric potential at full turgor

$\Psi_P$ = turgor potential

B = bound water

R = relative water content

$R_o$ = relative water content at zero turgor

e = modulus of elasticity.

Rearranged, the equation becomes:

2) $$\Psi_P = R\,[e - (\Psi\pi_t + \Psi\tau_t)] - e$$

it is seen that the intercept is -e. Thus, using only two experimental measurements, $\Psi$ and R, it is possible to include $\Psi\tau$ (usually ignored) and still readily determine e.

For the barley dry down, three different parts of the plants were used. First, whole plants, minus their roots, were taken just prior to the boot stage (there was variability in the stage of growth). Five samples of each variety were taken at 5:45 a.m. The intervals at which water loss was calculated were 1 1/2 hr., 6 hr., 12 hr., and 48 hr. Percent water loss was calculated on an oven dry basis. Next, the first leaf below the flag leaf was subjected to the dry down. Five leaves were taken per sample; and four samples per variety. The intervals for water loss calculation were 3 hr. and 6 hr. Finally, barley heads were dried down. Five samples of 1 head per variety were taken with drying intervals of 1 1/2 hr., 6 hr., 12 hr., and 23 hr.

The fourth approach involved soil water content measurements taken in plots consisting of 4 rows approximately 10 ft. long. Two samples per plot were taken at 6 in. intervals down to 6 ft. Percent water was calculated on an oven dry basis (100°C).

Appendix Table 83 summarizes the data from the four approaches. No attempt at analysis of this table has yet been done. Neither has the regression line for best estimates of drought resistant varieties from the breeding program been completed.

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

This objective is being accomplished by developing male sterile-facilitated recurrent selection populations (RSP's) with resistance to one or more diseases of importance. Stem rust, leaf rust, scald, net blotch, and covered smut, are currently receiving emphasis.

We are using three approaches in the development of disease resistant RSP's:

1. Development of agronomically good RSP's containing known major genes for resistance. These populations are established by crossing 15 2 row or 6 row widely adapted cultivars or cultivars with special traits onto a series of 2 row or 6 row male sterile sources respectively, Appendix Table 84. One method is to then cross several cultivars with known resistance onto the RSP. See Appendix Table 85 for possible parents for a net blotch resistant population. These populations are subsequently screened for resistance. RSP-5Rrs is an example (see Appendix Table 86 for a description of its synthesis). This population was screened for resistance to scald under field conditions in 1976. Seed harvested from resistant plants has been released to a number of locations in the U.S. and Middle East to determine its reaction to local isolates of *Rhynchosporium secalis*. Additional sources of scald resistance are being added to this population, see Appendix Table 86. Seed of agronomically desirable resistant plants returned from these nurseries will then be rebulked to begin another cycle of selection. Hopefully, this will result in a population of good agronomic types and resistance to a wide range of virulences of scald.

2. Development of major gene transfer systems. This method allows establishment of a population homozygous for a single major resistance gene or genes, but heterozygous and variable for other agronomic characters without the necessity of screening for resistance in each cycle of selection. The procedure is as follows:

(a) The chromosomal location of the resistance gene must be known. If necessary, trisomic analysis can be used to locate the gene. This was done for two scald resistant cultivars and three net blotch resistant cultivars, see Appendix Tables 88 through 92.

(b) A translocation stock with a breakpoint on the chromosome containing the resistance gene must be selected with its breakpoint distal to the resistance gene. This effectively prevents crossing-over of genes in the interstitial region. Selection of a translocation stock for scald genes on chromosome 3 is presently under way. T1-3k, T3-4d, and T3-7d are promising translocations (see Appendix Table 93).

(c) The population can then be assembled using the resistant cultivar, the selected translocation stock, an RSP, and an optional marker gene in the same interstitial segment (e.g. seedling lethal).

(d) Considerable effort has been put forth to induce, by use of the chemical mutagen diethylsulphate, lethal genes in the intersticial segments of selected translocations. Additional genetic materials are found in this material and retained. Other translocations are added as the need seems to be evident, i.e. a number of translocations involving chromosome 3 were added to the program this year to find better transfer systems for the disease resistant genes on chromosome 3. A brief summary of progress is given in Appendix Table 94. Use of the translocation homozygote lethals in a transfer system provides a method of gene transfer that can be done by the most inexperienced.

The single gene transfer system will have the most utility for a major gene which has been stable over the years as pathogen populations have changed. A good example is the T gene for stem rust resistance.

3. Development of broad-based RSP's containing many sources of resistance. The beginning populations for these RSP's are a bulk of the spring barleys in the world collection and CC XXX-F, a derivative of the world collection with male sterility added. These populations are screened for resistance in seedling and field tests. To date these two populations have been screened for resistance to stem rust, scald, and net blotch (see Appendix Table 95. The resistant plants are bulked to form a population containing many sources of resistance in a broad genetic base. The male sterility allows continuous recombination and accumulation of the resistance genes to be followed with selection of the better agronomic types.

4. Development of RSP's with minor gene and/or generalized resistance. The base population is the world collection of spring barleys. Plants which show only low levels of resistance are retained. The progeny are then grown to determine if segregation is occurring. Lines which do not segregate, but continue to show these lower levels of resistance are bulked and crossed to a male sterile source. In this RSP selection continues for higher levels of resistance in an attempt to accumulate the minor genes.

5. Testing Entries in Mid-East Nurseries. Seedling tests for stem rust, leaf rust, scald, net blotch, stripe rust, Pseudomonas, and BSMV seed contamination, were conducted on entries in the Elite Barley Yield Trial, 1976, released by CIMMYT. See Appendix Table 96 for the results.

6. Barley Stripe Mosaic Virus. Major emphasis this past year has been on the control of barley stripe mosaic virus (BSMV) through disease resistance. Work focused on two areas of research. One entailed the development of resistant germplasm and the other, the genetic inheritance of resistance in barley to the seed transmission of the virus.

Germplasm development involved further evaluation and selection of lines derived from Modjo-Betzes hybrids which had been backcrossed to Betzes seven times. Selection for non-seed transmission was begun in the second backcross generation. Field inoculation of 18 $F_6$ lines and the 2 parental cultivars was accomplished by the blast method using a composite of 9 strains of BSMV. Three strains were from the Middle East, one strain from North Africa, and five strains originated in North America. Plants were checked for symptoms of barley stripe mosaic (BSM) at about 10-14 day intervals after inoculation until they reached maturity. Seed was harvested from 41 symptomless plants and assayed in the greenhouse for seed transmission. Every seedling was scored for symptoms and selected plants were tested serologically to verify either seed transmission or non-seed transmission. No transmission occurred in the $F_7$ seed from 4 of the $F_6$ plants when a sample of about 50 seeds per plant was run.

In addition, other barleys were evaluated for their possible use in the development of germplasm resistant to the seed transmission of BSMV. Twenty-two entries of low seed transmission barleys selected from the World Collection (Timian, Plant Dis. Reptr. 59:984-988, 1975) were grown in the field and blast inoculated with the 9 strains of BSMV described earlier. Eight selections showing little or no foliar symptoms appeared to be fairly well adapted to our growing conditions in Bozeman. Seed from these selections will be tested for virus transmission this winter.

In an attempt to clarify some of the results of the study completed in 1975 on the inheritance of resistance to the seed transmission of BSMV in Modjo-Vantage hybrids, data from $F_3$ families were used to determine $F_2$ genotypes. Inasmuch as incomplete penetrance and variable expressivity are associated with the seed transmission character, it was difficult to classify the non seed transmitting plants of the $F_2$ generation into resistant or susceptible categories, because of the limited size of most seed samples. Heterozygous susceptible plants may evidence seed transmission at levels difficult to detect. The $F_2$ seed was planted in the field and all resulting seedlings read for symptoms of seed transmission. Later, all plants were blast inoculated with the MI-3 strain of BSMV. Symptom readings were taken several times after inoculation; the final reading was made just prior to the drying stage of development. The $F_3$ seed was harvested from single $F_2$ plants and assayed in the greenhouse. Results are shown in Appendix Table 97. In the Modjo x Vantage cross, a single recessive gene conditioned the barley for resistance to the seed transmission of the virus. However, in the reciprocal cross, the observed values departed significantly from the expected values for a one gene model, indicating that other factors such as maternal or cytoplasmic influence, could be involved in this inheritance to resistance.

A serodiagnostic technique for the detection of BSMV in embryos and of the virus. In this connection, we have already screened 10 seed lots from Tunisia (Submitted by A. Ghodbane), and 35 lines from the CIMMYT World Collection of scald resistant material. This coming summer 237 lines from the CIMMYT 1976 crossing block will be observed for seed transmission of BSMV. If on site visits reveal that BSMV is economically important in the developing countries, and we detect significant levels of BSMV in CIMMYT barleys, then arrangements should be made to clean up all breeding stock which will move internationally.

## DISSEMINATION OF RESEARCH FINDINGS

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Black, Clanton, University of Georgia. MSU-AID Project review team member. February 16-17, 1977.

Boyd, W. J. R., Western Australia. Discussed barley breeding and pathology. June 11, 1976.

Browning, J. A. Iowa State University. Discussed barley leaf diseases. May 12, 1976.

Chiarappa, Dr. Luigi. FAO Rome. Discusses barley diseases. April 1, 1976.

Dutlu, C. Turkish Ministry of Agriculture. Aegian Regional Research Station, Izmir, Turkey. Discussed barley production and diseases in Turkey. October 18, 1976.

Eyal, A. Tel Aviv University. Visiting Professor in Plant Pathology Dept., August, 1975 to June, 1976.

Finlay, Keith. CIMMYT, Mexico. MSU-AID Project review team member. February 16-17, 1977.

Frey, Kenneth. Iowa State University. MSU-AID Project review team member. February 16-17, 1977.

Ghodbane, A. I.N.R.A.T., Ariana, Tunis, Tunisia. Discussed barley production and diseases in Tunisia.

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Lang, Earl. AID Washington D. C. MSU-AID Project review team member. February 16-17, 1977.

Shaner, Dr. Greg. Purdue Univ. Discussed barley and wheat diseases. April 10, 1976.

Knudsen, J. and L. Munk. Royal Agricultural University - Copenhagen. Study tour in Plant Pathology Dept. Sept. 1 - Dec. 1, 1976.

Rodriguez, Enrique. CIMMYT, Mexico. MSU-AID Project review team member. February 16-17, 1977.

Wooding, Frank. Extension Agronomist, University of Alaska. Discussed barley germination and establishment.

Wright, Dr. Bill. Rockefeller Foundation, Turkey. Discussed barley and wheat research problems. September 14, 1976.

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## MEETINGS ATTENDED

Wiesner, L. E. Attended the American Society of Agronomy meeting in Houston, Texas. Nov. 1976.

## OUT OF COUNTRY TRIPS

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McGuire, Charles. Visit to CIMMYT, Mexico. To confer on microbiological assay of barley for lysine content. June 11-17, 1976.

Newman, C. W. Visit to CIMMYT, Mexico. To confer on microbiological assay of barley for lysine content. June 11-17, 1976.

Appendix

Table 1. Summary of lysine microbiological data from numberous barley trials conducted in varied environments.

| Identification | No. of Entries | Lysine as a percentage of Grain, By Classes 1/ | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | .25 | .30 | .35 | .40 | .45 | .50 | .55 | .60 | .65 | .70 | .75 | .80 | .85 |
| Hpp's | 52 | | | | 1 | 13 | 2 | 7 | 7 | 2 | 4 | 7 | 6 | 3 |
| 75 Inc Grain | 32 | | | | 6 | 14 | 2 | 5 | 1 | 2 | 1 | 1 | | |
| 75 Inc pearlings | 30 | | | | 2 | 2 | 4 | 10 | 4 | 3 | 1 | 2 | | 2 |
| 75 Inc pearled Gr. | 30 | | | 9 | 8 | 9 | 2 | | | | 2 | | | |
| Exp 31 74 CI | 192 | | 2 | 3 | 114 | 46 | 27 | | | | | | | |
| Mesa 75-76 | 550 | 115 | 302 | 105 | 24 | 3 | 1 | | | | | | | |
| 75 HP Selections | 30 | | | 2 | 9 | 1 | 2 | 2 | 13 | 1 | | | | |
| HAG Isogen. | 54 | 6 | 27 | 19 | 2 | | | | | | | | | |
| 76 Hp's | 519 | | 2 | 30 | 112 | 105 | 56 | 18 | 29 | 23 | 56 | 50 | 35 | 6 |
| 75-76 Mesa Hp's | 257 | 8 | 28 | 26 | 86 | 56 | 40 | 11 | 2 | | | | | |
| 76 Inc Shrunk. | 46 | | 1 | 4 | 6 | 2 | 4 | | 3 | 11 | 1 | | | |
| B75 WH | 226 | | 10 | 39 | 94 | 58 | 20 | 6 | | | | | | |
| B73 CI | 292 | | 2 | 23 | 194 | 61 | 2 | 6 | 1 | | | 1 | | |
| Exp 31 B75 | 102 | | 2 | 62 | 59 | 11 | 1 | | | | | | | |
| B 60 Maturity Stud. | 153 | | 6 | 96 | 51 | | | | | | | | | |
| Mesa 74-75 | 73 | | 17 | 5 | 14 | 15 | 5 | 7 | 3 | 2 | 1 | 2 | | |
| B74 HP | 107 | | 1 | 9 | 16 | 17 | 4 | 7 | 17 | 5 | 23 | 8 | | |
| 74 WH PI & CI | 530 | | 10 | 15 | 77 | 300 | 105 | 23 | 3 | | | | | |
| Misc | | | 217 | 103 | 100 | 43 | 34 | 11 | 17 | 13 | 8 | 30 | | |

1/ The classes were arbitrarily assigned to show the range of values in each nursery.

Appendix
Table 2. Summary of lysine as a percentage of protein when lysine was assayed microbiologically.

Lysine as a Percentage of Protein, by Classes 1/

| Identification | No. of Entries | 2.0 | 2.25 | 2.50 | 2.75 | 3.0 | Days 3.25 | 3.50 | 3.75 | 4.0 | 4.25 | 4.50 | 4.75 | 5.0 | 5.25 | 5.50 | 5.75 & up |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Hpp's | 52 | | 1 | 6 | 3 | 9 | 9 | 2 | 3 | 5 | 9 | 3 | 1 | 1 | | | |
| 75 Inc. Grain | 32 | | | | | 2 | 4 | 7 | 5 | 7 | 1 | 1 | 3 | | 2 | | |
| Pearlings | 30 | | | 4 | 4 | 5 | 6 | 8 | 3 | | | | | | | | |
| Pearled Grain | 30 | | | | | 1 | 1 | 10 | 1 | 5 | 6 | 2 | 4 | | | | |
| Exp 31 74 CI | 192 | | 7 | 41 | 66 | 42 | 28 | 7 | 1 | | | | | | | | |
| 74 WH PI & CI | 530 | 10 | 5 | 41 | 112 | 140 | 116 | 59 | 26 | 15 | 5 | 1 | | | | | |
| 73 CI | 190 | 2 | 40 | 93 | 48 | 6 | | | | 1 | | | | | | | |
| B75 WH | 226 | 4 | 16 | 40 | 75 | 60 | 28 | 3 | | | | | | | | | |
| 75-76 Mesa Hp's | 251 | | 2 | 4 | 8 | 24 | 27 | 67 | 65 | 26 | 10 | 9 | 3 | 4 | 1 | - | 5 |
| 76 Hp's | 469 | | | 1 | 38 | 79 | 99 | 62 | 36 | 26 | 25 | 20 | 19 | 10 | 6 | 16 | 14 18 |
| HAG Isogen | 68 | 3 | 3 | 8 | 15 | 17 | 10 | 7 | 4 | 1 | | | | | | | |
| B-60 Maturity St. | 79 | | 3 | 44 | 29 | | | | | | | | | | | | |
| Exp 31 B75 | 104 | 1 | 26 | 50 | 25 | 2 | | | | | | | | | | | |

1/ Classes were arbitrarily assigned to show the range of values in each nursery.

Appendix Table 3. Proximate composition and calcium and phosphorus percentages of selected 2-rowed barleys, MSG-75.

| | Percentage (Dry Matter basis) | | | | | | |
|---|---|---|---|---|---|---|---|
| Cultivar | Protein | Ether Extract | Crude Fiber | N-free Extract | Ash | Ca | P |
| 1 Hanna 906 | 14.2 | 2.3 | 3.6 | 76.8 | 3.1 | .01 | .43 |
| 2 Bargiers 3383 | 14.4 | 2.1 | 3.5 | 77.0 | 3.0 | .01 | .43 |
| 3 Balder 7131 | 12.8 | 1.9 | 4.4 | 77.6 | 3.3 | .01 | .43 |
| 4 10375 | 15.4 | 2.3 | 3.4 | 75.8 | 3.1 | .01 | .48 |
| 5 Brage 11310 | 13.5 | 2.1 | 4.5 | 76.7 | 3.2 | .02 | .45 |
| 6 12103 | 12.6 | 1.9 | 4.0 | 78.5 | 3.0 | .02 | .37 |
| 7 Compana 5438 | 14.2 | 1.3 | 3.6 | 78.0 | 2.9 | .02 | .43 |
| 8 Hiproly 3947 | 16.8 | 1.2 | 1.2 | 78.4 | 2.9 | .07 | .52 |
| 9 Hiproly N. 4362 | 14.7 | 0.9 | 1.4 | 80.6 | 2.4 | .04 | .53 |

Appendix Table 4. Proximate Composition and Calcium and phosphorus percentages of diets prepared from selected 2-rowed barleys and casein MSG-75.

| | Percentage (as-fed basis) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Cultivar | Protein | Ether Extract | Crude Fiber | N-free Extract | mois-ture | Ash | Ca | P |
| Hanna 906 | 10.2 | 2.5 | 3.2 | 70.9 | 8.3 | 4.9 | .62 | .71 |
| Bargiers 3383 | 10.2 | 2.8 | 3.4 | 70.9 | 8.0 | 4.7 | .56 | .67 |
| Balder 7131 | 10.2 | 2.6 | 4.1 | 70.1 | 8.0 | 5.0 | .58 | .71 |
| 10375 | 10.1 | 2.9 | 2.8 | 71.8 | 8.0 | 4.4 | .54 | .67 |
| Brage 11310 | 10.2 | 2.6 | 3.9 | 70.3 | 8.1 | 4.9 | .57 | .72 |
| 12103 | 10.6 | 2.5 | 3.7 | 70.2 | 8.3 | 4.7 | .59 | .68 |
| Compana 5438 | 10.1 | 2.4 | 3.2 | 71.8 | 7.9 | 4.6 | .55 | .68 |
| Hiproly 3947 | 10.0 | 3.5 | 2.7 | 70.8 | 9.2 | 3.8 | .56 | .67 |
| Hiproly N. 4362 | 9.8 | 3.6 | 2.4 | 70.3 | 10.0 | 3.9 | .57 | .71 |
| Casein | 10.6 | 4.9 | 0.9 | 74.6 | 5.8 | 3.2 | .56 | .57 |

Appendix Table 5. Percentage Composition of MSG-75 Barley Rat Diets

| Ingredients % Diet | 1 Hanna | 2 Bargiers | 3 Balder | 4 CI10375 | 5 Brage | 6 CI12103 | 7 Compana | 8 Hiproly | 9 Hiproly Normal | 10 Casein |
|---|---|---|---|---|---|---|---|---|---|---|
| Barley | 75.76 | 74.63 | 84.03 | 69.44 | 80.00 | 85.47 | 75.19 | 65.79 | 75.76 | -- |
| Cornstarch | 14.75 | 15.74 | 7.34 | 20.66 | 11.30 | 5.64 | 14.69 | 22.07 | 12.18 | 74.37 |
| Alphacel | 0.94 | 0.98 | 0.00 | 1.22 | 0.08 | 0.28 | 0.88 | 2.72 | 2.53 | 3.44 |
| $CaCO_3$ | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 |
| Vitamins[a] | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Minerals[b] | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| ASP[c] | .25 | .25 | .25 | .25 | .25 | .25 | .25 | .25 | .25 | .25 |
| Oil[d] | 3.50 | 3.60 | 3.58 | 3.63 | 3.57 | 3.56 | 4.19 | 4.37 | 4.48 | 5.09 |
| Casein[e] | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |

a Vitamins - U.S. Biochem. Diet fortification mixture
b Minerals - Bernhart-Tomarelli Modified Salt Mix, ICN Nutritional Biochemicals
c ASP - Antibiotic mixture; aureomycin, sulfamethazine, penicillin, 220.5, 220.5, 110.2 g/K mixture, respectively
d Oil - Mazola pure corn oil
e Casein - U.S. Biochemicals, purified, vitamin-free

Appendix Table 6. Growth performance of rats fed selected 2-rowed barleys (MSG-75)

| Cultivar | CI No. | Gain | Feed Cons. | Feed/ Gain | Adj. PER |
|---|---|---|---|---|---|
| Balder | 7131 | 73.7[a] | 397.9[a] | 5.40[ab] | 2.07[c] |
| Brage | 11310 | 81.4[a] | 405.8[a] | 4.99[b] | 2.24[b] |
| | 12103 | 71.2[a] | 390.0[ab] | 5.48[a] | 1.96[c] |
| Hanna | 906 | 73.0[a] | 390.4[ab] | 5.35[ab] | 2.08[c] |
| | 10375 | 73.4[a] | 405.1[a] | 5.52[a] | 2.04[c] |
| Bargiers | 3383 | 70.8[a] | 386.3[ab] | 5.45[ab] | 2.06[c] |
| Compana | 5438 | 67.0[a] | 381.0[b] | 5.69[a] | 1.99[c] |
| Hiproly | 3947 | 77.7[a] | 388.9[ab] | 5.01[b] | 2.28[b] |
| Hiproly N. | 4362 | 68.0[a] | 383.6[b] | 5.64[a] | 2.05[c] |
| Casein | | 73.4[a] | 316.2[c] | 4.31[c] | 2.50[a] |

* 10 rats per diet
abc - means in the same column bearing different superscript letters are significantly different. ($P < .05$).

Appendix Table 7. Biological value, true protein digestibility and net protein utilization of selected 2-rowed barleys (MSG-75)[a]

| Cultivar | | Biological Value | True Protein Digestibility | Net Protein Utilization |
|---|---|---|---|---|
| Hanna | 906 | 85.4 | 74.1 | 62.9 |
| Bagiers | 3383 | 71.0 | 80.6 | 56.6 |
| Balder | 7131 | 82.6 | 75.6 | 62.2 |
| CI | 10375 | 78.7 | 77.5 | 61.3 |
| Brages | | 85.7 | 81.7 | 69.6 |
| CI | 12103 | 82.1 | 78.0 | 64.0 |
| Compana | 5438 | 77.2 | 83.0 | 64.2 |

a Each mean represents 4 rats.

Appendix Table 8. Percentage of lysine in three generations of selected two-rowed barleys

| Cultivar | C.I. No. | % Lysine | | | |
|---|---|---|---|---|---|
| | | Original Seed | 1st generation Seed | 2nd generation Seed | Avg. |
| Balder | 7131 | 3.90 | 3.97 | 3.92 | 3.93 |
| Brage | 11310 | 3.77 | 3.96 | 3.95 | 3.89 |
| | 12103 | 3.81 | 3.71 | 3.90 | 3.81 |
| Hanna | 906 | 3.83 | 3.63 | 3.85 | 3.77 |
| | 10375 | 3.81 | 3.61 | 3.72 | 3.71 |
| Bargiers | 3383 | 3.67 | 3.55 | 3.63 | 3.62 |
| Compana | 5438 | | 3.10 | 3.46 | 3.28 |
| Hiproly | 3947 | 4.66 | 4.36 | 4.23 | 4.42 |

Appendix Table 9. Comparison of protein fractions of selected two-rowed barleys grown in 2 crop years.

| Cultivar | CI No. | Alb + Glo. | | Hord | | Glut | | Residue | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1st | 2nd | 1st | 2nd | 1st | 2nd | 1st | 2nd |
| Balder | 7131 | 36.8 | 38.3 | 19.3 | 26.9 | 32.9 | 26.4 | 11.0 | 8.41 |
| Brage | 11310 | 32.0 | 35.9 | 33.9 | 33.4 | 23.6 | 25.4 | 10.5 | 5.31 |
| | 12103 | 33.7 | 36.6 | 28.3 | 31.3 | 25.6 | 26.0 | 12.3 | 6.11 |
| Hanna | 906 | 39.8 | 39.0 | 20.0 | 23.1 | 30.9 | 31.7 | 9.3 | 6.2 |
| | 10375 | 29.1 | 37.8 | 33.7 | 26.1 | 25.2 | 29.2 | 12.0 | 6.9 |
| Bargiers | 3383 | 39.4 | 34.2 | 23.5 | 30.5 | 32.0 | 30.3 | 10.1 | 5.10 |
| Compana | 5438 | 29.7 | 30.1 | 34.2 | 39.8 | 27.8 | 25.2 | 8.4 | 4.91 |
| Average | | 34.4 | 36.0 | 27.6 | 30.1 | 28.3 | 27.7 | 10.5 | 6.1 |

Appendix Table 10 Amino acid composition of MSG-75 2-rowed barleys.

| MSG-75 amino acid | 1 Hanna | 2 Bargiers | 3 Balder | 4 10375 | 5 Brage | 6 12103 | 7 Compana | Hiproly | Hiproly N. |
|---|---|---|---|---|---|---|---|---|---|
| Ala | 3.90 | 3.66 | 3.90 | 3.84 | 4.06 | 3.85 | 3.68 | 4.10 | 3.30 |
| Arg | 5.19 | 5.16 | 5.19 | 5.11 | 5.36 | 5.83 | 5.02 | 5.09 | 4.81 |
| Asp | 5.66 | 5.95 | 6.49 | 6.11 | 6.47 | 6.52 | 5.45 | 6.49 | 5.25 |
| Cys | 2.43 | 2.38 | 2.63 | 2.00 | 2.37 | 2.63 | 2.67 | 2.05 | 2.65 |
| Blu | 25.63 | 25.59 | 24.37 | 25.91 | 24.41 | 24.13 | 25.98 | 23.23 | 25.95 |
| Gly | 3.41 | 3.39 | 3.54 | 3.41 | 3.60 | 3.54 | 3.26 | 3.47 | 3.30 |
| His | 2.51 | 2.36 | 2.33 | 2.47 | 2.44 | 2.32 | 3.29 | 2.48 | 2.41 |
| Iso | 3.75 | 3.62 | 3.61 | 3.57 | 3.73 | 3.68 | 3.85 | 3.86 | 3.66 |
| Leiv | 7.32 | 7.24 | 7.36 | 7.16 | 7.22 | 7.31 | 7.21 | 7.20 | 7.18 |
| Lys | 3.85 | 3.63 | 3.92 | 3.72 | 3.95 | 3.90 | 3.46 | 4.23 | 3.34 |
| Met | 1.53 | 1.44 | 1.63 | 1.52 | 1.65 | 1.56 | 1.52 | 1.72 | 1.47 |
| Phe | 5.37 | 5.96 | 5.69 | 6.10 | 5.82 | 5.69 | 5.66 | 6.22 | 6.03 |
| Pro | 11.41 | 11.79 | 11.13 | 11.36 | 10.77 | 11.17 | 11.75 | 11.08 | 12.50 |
| Ser | 4.31 | 4.22 | 4.11 | 4.43 | 4.37 | 4.20 | 4.22 | 4.50 | 4.36 |
| Thr | 3.36 | 3.31 | 3.99 | 3.45 | 3.58 | 3.50 | 3.40 | 3.51 | 3.33 |
| Trp | 2.62 | 2.10 | 2.21 | 1.73 | 1.98 | 1.90 | 2.58 | 2.30 | 2.46 |
| Tyr | 2.78 | 3.30 | 3.39 | 3.34 | 3.26 | 3.34 | 3.04 | 3.44 | 3.35 |
| Val | 4.91 | 4.88 | 4.96 | 4.79 | 4.92 | 4.88 | 4.81 | 5.05 | 4.62 |

Appendix Table 11. Percentage Recovery of Proteins from Hiproly and Hiproly Normal Barleys

| Composition of Extractant | Range of % Protein Recovered | |
|---|---|---|
| | Hiproly | Hiproly Normal |
| .005-.1M phosph. buffer | 28.2-35.8 | 23.1-25.8 |
| .005-.1M phosph. buffer + .04M NaCl | 28.7-35.8 | 18.6-26.3 |
| .005=.1M phosph. buffer + .1M NaCl | 28.7-35.5 | 23.1-26.3 |
| .005-.1M phosph. buffer + .5M NaCl | 32.5-35.8 | 17.7-23.1 |
| .005-.1M phosph. buffer + .1% 1-mercaptoethanol | 32.5-39.0 | 23.1-31.1 |
| .005-.1M phosph. buffer + .005% Ehtylenediaminetetra acetic acid (EDTA) | 28.7-36.3 | 26.3-29.5 |
| .005-.1M phosph. buffer + .1% sodium dodecyl sulfate (SDS) | 75.9-69.9 | 80.0-69.8 |
| .005-.1M phosph. buffer + .1% 2-mercaptoethanol + .1% sodium dodecyl sulfate | 94.3-90.0 | 93.4-90.2 |
| .005-.1M phosph. buffer + .1% 2-mercaptoethanol + .005% EDTA + .1% SDS | 93.2-82.9 | 93.4-83.2 |

Appendix Table 12. Percentage Protein Extracted by phosphate buffer plus other extractants from Hiproly and Hiproly Normal Barleys

| | Molarity of phosphate buffer | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Hiproly Barley | | | | | | | | Hiproly Normal Barley | | | | | | | |
| | .005 M | 0.01 M | 0.015 M | 0.02 M | 0.04 M | 0.06 M | 0.08 M | 0.1 M | 0.005 M | 0.01 M | 0.015 M | 0.02 M | 0.04 M | 0.06 M | 0.08 M | 0.1 M |
| hosphate buffer | 5.2 | 5.2 | 6.0 | 6.0 | 6.0 | 6.6 | 6.5 | 6.6 | 4.3 | 4.3 | 4.3 | 4.7 | 4.8 | 4.7 | 4.6 | 4.6 |
| hosph. buffer + .04M NaCl | 5.4 | 5.3 | 6.0 | 6.0 | 6.0 | 6.6 | 6.6 | 6.6 | 3.7 | 3.7 | 4.3 | 4.3 | 4.3 | 4.3 | 4.5 | 4.9 |
| hosph. buffer + .1M NaCl | 5.3 | 6.0 | 7.1 | 6.9 | 6.6 | 6.6 | 6.6 | 6.6 | 4.3 | 4.3 | 4.9 | 4.9 | 4.9 | 4.9 | 4.9 | 4.9 |
| hosph. buffer + .5M NaCl | 6.0 | 6.6 | 6.6 | 6.6 | 6.6 | 6.6 | 6.6 | 6.6 | 3.3 | 3.7 | 3.9 | 3.7 | 3.8 | 4.3 | 4.3 | 4.3 |
| hosph. buffer + .1% 2-mercaptoethanol | 6.0 | 6.6 | 6.6 | 7.2 | 7.2 | 7.2 | 7.2 | 7.2 | 4.3 | 4.9 | 4.9 | 4.9 | 5.8 | 5.6 | 5.6 | 5.7 |
| hosph. buffer + .1% sodium dodecyl sulphate (SDS) | 14.1 | 14.0 | 14.1 | 14.1 | 14.1 | 12.9 | 12.9 | 12.9 | 14.9 | 14.3 | 14.3 | 14.3 | 14.3 | 13.0 | 13.0 | 13.0 |
| hosph. buffer + .1% 2-mer-aptoethanol + .5% sodium odecyl sulfate (SDS) | 17.4 | 17.4 | 17.4 | 17.4 | 16.6 | 16.6 | 16.6 | 16.8 | 17.4 | 17.2 | 17.2 | 17.2 | 16.8 | 16.8 | 16.8 | 16.9 |
| hosphate buffer + .005% thylenediaminetetracetic cid (EDTA) | 5.3 | 5.4 | 6.6 | 6.6 | 6.7 | 6.6 | 6.6 | 6.7 | 4.9 | 4.9 | 4.9 | 5.5 | 5.3 | 4.9 | 4.9 | 4.9 |
| hosph. buffer + .12-mer-aptoethanol + .5% SDS + .005% EDTA | 17.2 | 17.2 | 15.3 | 15.3 | 15.7 | 16.6 | 16.6 | 16.8 | 17.4 | 17.4 | 15.3 | 15.5 | 15.8 | 16.8 | 16.9 | 16.9 |

Appendix Table 13. Protein Composition of Various Barleys grown at Bozeman, Montana in 1973

| Name of Barley | % Total Protein | % Recovered Protein Fractions | | | | % Total Protein Recovered |
|---|---|---|---|---|---|---|
| | | Albumin + Globulin | Hordein | Glutelin | Residue | |
| Hanna, C.I. 906 | 15.7 | 39.8 | 20.0 | 30.9 | 9.3 | 13.2 |
| Bargiers | 15.6 | 34.4 | 23.5 | 32.0 | 10.1 | 13.9 |
| C.I. 6400 | 15.6 | 38.5 | 19.6 | 31.8 | 10.1 | 13.5 |
| Dornberger | 14.0 | 36.0 | 22.0 | 31.2 | 10.8 | 11.9 |
| Balder | 13.0 | 36.8 | 19.3 | 32.9 | 11.0 | 11.1 |
| Lenta | 14.4 | 35.5 | 22.3 | 31.0 | 11.2 | 13.1 |
| C.I. 8192 | 14.5 | 33.4 | 25.1 | 30.6 | 10.9 | 12.9 |
| C.I. 10236 | 13.8 | 34.7 | 24.9 | 26.1 | 14.3 | 11.9 |
| Italian | 16.9 | 33.3 | 17.2 | 34.1 | 15.4 | 13.9 |
| C.I. 10375 | 14.6 | 29.1 | 33.7 | 25.2 | 12.0 | 14.4 |
| Wiebull's 5573 | 13.4 | 34.7 | 23.3 | 28.9 | 13.0 | 11.7 |
| Bonus | 13.9 | 35.9 | 22.5 | 28.1 | 13.5 | 12.3 |
| Brage | 15.8 | 32.0 | 33.9 | 23.6 | 10.5 | 15.2 |
| Primo II | 15.2 | 35.7 | 20.7 | 30.4 | 13.2 | 12.5 |
| C.I. 12099 | 13.5 | 37.8 | 26.3 | 23.6 | 12.3 | 12.1 |
| Imperial | 15.4 | 39.0 | 22.6 | 24.7 | 13.7 | 13.0 |
| C.I. 12171 | 16.7 | 29.6 | 28.9 | 29.7 | 11.8 | 15.0 |
| Hiproly | 19.6 | 30.1 | 24.9 | 34.5 | 10.5 | 18.5 |
| C.I. 12103 | 13.3 | 33.7 | 28.3 | 25.6 | 12.4 | 11.8 |
| Unitan | 13.0 | 31.7 | 21.5 | 36.3 | 10.6 | 11.1 |
| Shabet | 14.3 | 29.9 | 33.1 | 28.0 | 9.0 | 13.5 |
| Compana | 14.8 | 29.7 | 34.2 | 27.8 | 8.3 | 14.0 |
| Wapana | 16.2 | 27.5 | 36.9 | 27.3 | 8.3 | 13.3 |

Table 13a. Electrophoretic Components in the albumin + globulin Osborne Fraction from Various Barleys grown at Bozeman, Montana in 1973

| Barley Name | % Content of Electrophoretic Components | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Hanna, C.I. 906 | 10 | 25.2 | 25.7 | 12 | 11 | 7.9 | 8 |
| Bargiers | 12.5 | 20.7 | 25.9 | 12.3 | 13.1 | 8.8 | 12.6 |
| C.I. 6400 | 3.4 | 19.2 | 27.6 | 14.2 | 13.7 | 10.1 | 11.8 |
| Dornberger | 4.8 | 30.1 | 36.4 | 9 | 8.2 | 5.1 | 6.4 |
| Balder | 5.2 | 24.3 | 26.4 | 10.3 | 12.4 | 8.8 | 12.1 |
| Lenta | | 21.4 | 38.3 | 13.3 | 20.2 | 7.9 | 3.4 |
| C.I. 8192 | | 58.8 | 41.2 | | | | |
| C.I. 10236 | | 50.8 | 49.4 | | | | |
| Italian | | 41.2 | 58.2 | | | | |
| C.I. 10375 | | 50.6 | 49.4 | | | | |
| Wiebull's 5573 | | 81.1 | 18.9 | | | | |
| Bonus | | 44.8 | 55.2 | | | | |
| Brage | | 38.9 | 61.1 | | | | |
| Primo II | 11.6 | 27.2 | 61.2 | | | | |
| C.I. 12099 | 15.7 | 36 | 38.4 | | | | 9.8 |
| Imperial | | 12.9 | 34.2 | 14.9 | 24.7 | 7.8 | 5.5 |
| C.I. 12171 | | 48.7 | 32.11 | 7.7 | 4.9 | | 6.7 |
| Hiproly | | 29.8 | 33.3 | | 36.9 | | |
| C.I. 12103 | 4.2 | 27.4 | 68.4 | | | | |
| Compana | 7.8 | 31.9 | 60.3 | | | | |
| Unitan | | 28 | 30.4 | | 13.7 | 19.5 | 8.4 |
| Shabet | 2.9 | 34.8 | 35.3 | | 6.8 | 9.7 | 10.5 |
| Wapana | | 27.4 | 27 | 11.2 | 9.7 | 10.1 | 14.4 |

Appendix Table 14. Electrophoretic Components from Hordein Osborne Fraction from Various Barleys grown at Bozeman, Montana in 1973.

| Barley Name | % of Electrophoretic Components | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Hanna, C.I. 906 | 9.9 | 42.9 | 47.3 | | |
| Bargiers | 5.3 | 26.2 | 43.8 | 28.4 | |
| C.I. 6400 | 13.1 | 62.9 | 24.1 | | |
| Dornberger | 2.9 | 19 | 24.3 | 53.8 | |
| Balder | 3.2 | 19.3 | 62.6 | 14.7 | |
| Lenta | 3.4 | 16.9 | 46.7 | 33 | |
| C.I. 8192 | 5.6 | 32.9 | 45.9 | 15.7 | |
| C.I. 10236 | 9.4 | 33.6 | 28.2 | 15.4 | 13.4 |
| Italian | 2.9 | 27.2 | 40.7 | 29.3 | |
| C.I. 10375 | 10.8 | 68.4 | 20.8 | | |
| Wiebull's 5573 | | 44.9 | 55.1 | | |
| Bonus | 1.7 | 75 | 23.2 | | |
| Brage | 1.7 | 34.4 | 63.6 | | |
| Prima II | 3.1 | 28 | 8.3 | 60.7 | |
| C.I. 10299 | 3.8 | 30.9 | 15.3 | | |
| Imperial | | 26.2 | 41.5 | | |
| C.I. 12171 | 8 | 29.9 | 62.4 | | |
| Hiproly | 6.9 | 19.8 | 41.4 | | 31.8 |
| C.I. 12103 | 21.1 | 37.6 | 23.5 | | 26.9 |
| Compana | 7.5 | 26.5 | 29 | | 37 |
| Unitan | 11 | 8 | 75.1 | 6.1 | |
| Shabet | 6.8 | 50.8 | 42.4 | | |
| Wapana | 2.4 | 4.1 | 48.9 | 44.1 | |

Appendix Table 15. Electrophoretic Components of the Glutelin Osborne Fraction from Various Barleys grown at Bozeman, Montana in 1973.

| Barley Name | % of Electrophoretic Components | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Hanna, C.I. 906 | | | 19.5 | 25 | 55.5 | | |
| Bargiers | | 8.9 | | 48 | 32 | 11.1 | |
| 6400 | | | 10.3 | 46.8 | 24.7 | 18.3 | |
| Dornberger | 7.8 | | | 30.3 | 46 | 16 | |
| Balder | | | | 51.6 | 48.4 | | |
| Lenta | 4.3 | 9.5 | | 45.3 | 29.1 | 7.8 | 4.1 |
| C.I. 8192 | | | | 46.5 | 53.6 | | |
| C.I. 10236 | | | | 46.7 | 53.3 | | |
| Italian | | | | 41.3 | 54.8 | 3.9 | |
| C.I. 10375 | | | | 34.6 | 46 | 13.4 | 6.1 |
| Wiebull's 5573 | | | | 65.7 | 94.3 | | |
| Bonus | | | | 62.5 | 37.5 | | |
| Brage | | | | 36.9 | 63.1 | | |
| Prima II | | | | 30.2 | 69.8 | | |
| C.I. 10299 | | | | 31.1 | 68.9 | | |
| Imperial | | | | 28.3 | 34 | | 37.2 |
| C.I. 12171 | | | | 17.2 | 45.4 | 15.3 | 22 |
| Hiproly | | | | 21.2 | 26 | 15.2 | 37.7 |
| C.I. 12103 | | | | 54.4 | 45.7 | | |
| Compana | | | | 29.3 | 43.5 | | 27.3 |
| Unitan | 3.4 | 2.4 | 5.1 | 30.5 | 8.4 | 49.1 | 1.5 |
| Shabet | | | 18.8 | 23.1 | 48.8 | | 9.3 |
| Wapana | | | | 54.6 | 35.9 | | 9.5 |

Appendix Table 16 Composition of Glacier and High Amylose Glacier (Glacier Ac38) Barleys[A].

| | Barley | |
|---|---|---|
| | Glacier | High-Amylose Glacier |
| Item, %:[B] | | |
| Protein | 11.79 | 11.61 |
| Ether Extract | 1.77 | 2.40 |
| Crude Fiber | 6.97 | 6.94 |
| Nitrogen free extract | 76.61 | 75.97 |
| Ash | 3.05 | 3.07 |
| Calcium | .03 | .04 |
| Phosphorus | .40 | .41 |
| Amylose[C] | 27.10 | 52.10 |
| Amylopectin[C] | 72.90 | 47.90 |

A Values represent an average of 5 barleys
B Proximate components, calcium and phosphorous are expressed in a dry matter basis.
C Expressed on a percentage of dry, whole starch

Appendix Table 17. Amino Acid Composition of Glacier and High-amylose Glacier Barley Proteins[a]

| Barley | Glacier | High-Amylose Glacier | % Change |
|---|---|---|---|
| Ala | 3.90[e] | 4.31[d] | 10.5 |
| Arg | 5.24[c] | 5.57[b] | 6.3 |
| Asp | 6.14[e] | 6.69[d] | 9.0 |
| Cys | 2.69 | 2.66 | - 1.1 |
| Glu | 25.36[f] | 23.93[g] | - 5.6 |
| Gly | 3.56[e] | 3.83[d] | 7.6 |
| His | 2.33 | 2.36 | 1.3 |
| Isl | 3.62 | 3.64 | .6 |
| Leu | 6.78 | 6.70 | .3 |
| Lys | 3.72[e] | 4.02[d] | 8.1 |
| Met | 1.57 | 1.60 | 1.9 |
| Phe | 5.42 | 5.40 | - .4 |
| Pro | 11.51[d] | 10.54[e] | - 8.4 |
| Ser | 4.46 | 4.49 | .7 |
| Thr | 3.49[e] | 3.66[d] | 4.9 |
| Trp | 2.23[e] | 2.39[d] | 7.2 |
| Tyr | 3.01 | 3.19 | 6.0 |
| Val | 4.96 | 5.02 | 1.2 |
| Prot | 11.12 | 11.19 | |
| NX 6.25 | 11.79 | 11.60 | |

a Means represents average of 5 barleys
bc, de, fg $P < .01$, $< .05$ & $< .10$ respectively

Appendix Table 18. Percentage of Protein and Protein Fractions in Five Pairs of Glacier and Hiamylose Glacier Barleys

| | | Lysine % | Protein % | Al/Glo % | Hord % | Glu % |
|---|---|---|---|---|---|---|
| Hiamylose Glacier (HAG) | Avg. | 4.02 | 10.8 | 38.4 | 21.4 | 25.8 |
| | Ran. | 3.82-4.56 | 8.8-12.8 | 34.4-40.2 | 14.9-28.3 | 32.2-28.2 |
| Normal Glacier (NG) | Avg. | 3.72 | 10.9 | 33.2 | 24.8 | 28.1 |
| | Ran. | 3.45-4.21 | 8.6-13.2 | 30.7-38.1 | 15.4-32.2 | 22.6-31.2 |

Appendix Table 19. Percentage Composition of Glacier and Hiproly isotypes.

| Diet Ingredients % | 1 Glacier Normal B75 | 2 Hi amylose Glacier B75 | 3 Hiproly B76 | 4 Hiproly normal B76 | 5 Casein |
|---|---|---|---|---|---|
| Barley | 75.76 | 78.13 | 65.79 | 75.76 | -- |
| Cornstarch | 14.79 | 13.14 | 22.07 | 12.18 | 74.37 |
| Alphacel | 0.00 | 0.18 | 2.72 | 2.53 | 3.44 |
| $CaCO_3$ | 0.80 | 0.80 | 0.80 | 0.80 | 0.80 |
| Vitamins | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Minerals | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| ASP | .25 | .25 | .25 | .25 | .25 |
| Corn Oil | 4.40 | 3.50 | 4.37 | 4.48 | 5.09 |
| Casein | -- | -- | -- | -- | 12.05 |

Casein - Purified, vitamin-free, U.S. Biochemicals
Vitamins - Diet fortification mixture, U.S. Biochemicals
Minerals - Bernhart-Tomarelli Modified Salt mix, ICN Nutritional Biochemicals
ASP - Antibiotic mixture; aureomycin, sulfamethazine, penicillin, 220.5, 220.5, 110.2 g/k. mixture respectively.

Appendix Table 20. Growth performance of rats fed Glacier, High-amylose Glacier (Glacier Ac38) Hiproly and Hiproly Normal barleys.

| Cultivar | Gain | Feed Cons. | Feed/ gain | Adj. PER |
|---|---|---|---|---|
| Glacier | $58.4^{c}$ | $307.3^{b}$ | $5.92^{a}$ | $2.03^{c}$ |
| Hi-Amy-Glacier | $65.4^{b}$ | $336.1^{b}$ | $5.18^{bc}$ | $2.34^{ab}$ |
| Hiproly | $77.7^{a}$ | $388.9^{a}$ | $5.05^{c}$ | $2.27^{b}$ |
| Hiproly Normal | $68.0^{ab}$ | $383.6^{a}$ | $5.78^{ab}$ | $2.05^{c}$ |
| Casein | $73.4^{ab}$ | $316.2^{b}$ | $4.33^{d}$ | $2.50^{a}$ |

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

Appendix Table 21. Proximate Composition of Riso/barley mutants, Hiproly, Hiproly Normal, Maize and high-lysine maize

| Cultivar | Location | Trial | Percentage (dry matter basis) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Proteins | Ether Extract | Crude fiber | N-free Extract | Ash |
| Bomi | Boz | 1 | 14.2 | 1.6 | 5.2 | 76.2 | 2.8 |
| Bomi Riso 1508 | Boz | 1 | 14.2 | 2.1 | 5.7 | 75.2 | 2.8 |
| Hiproly | Boz | 1 | 20.8 | 1.9 | 3.0 | 71.8 | 2.5 |
| Hiproly Normal | Boz | 1 | 19.2 | 1.7 | 2.1 | 74.5 | 2.5 |
| Bomi | Hunt | 1 | 13.5 | 2.4 | 3.8 | 77.3 | 3.0 |
| Bomi Riso 1508 | Hunt | 1 | 12.3 | 2.9 | 3.5 | 78.5 | 2.9 |
| Hiproly | Hunt | 1 | 21.1 | 1.8 | 2.1 | 71.9 | 3.1 |
| Hiproly Normal | Hunt | 1 | 18.8 | 2.0 | 1.6 | 75.0 | 2.6 |
| Maize | Hunt | 1 | 10.3 | 3.6 | 2.9 | 81.6 | 1.6 |
| Hi-lys Maize | Hunt | 1 | 10.6 | 4.6 | 2.3 | 80.9 | 1.6 |
| Carlsberg II | Boz | 2 | 14.2 | 2.1 | 3.5 | 77.4 | 2.8 |
| Carlsberg II Riso 29 | Boz | 2 | 14.3 | 3.9 | 4.1 | 74.8 | 2.9 |
| Carlsberg II Riso 86 | Boz | 2 | 14.5 | 3.8 | 3.7 | 75.1 | 2.9 |
| Hiproly | Boz | 2 | 21.9 | 2.2 | 2.2 | 70.4 | 3.3 |
| Hiproly Normal | Boz | 2 | 20.2 | 1.9 | 1.8 | 73.5 | 2.7 |
| Carlsberg II | Hunt | 2 | 11.6 | 2.1 | 3.5 | 79.9 | 2.9 |
| Carlsberg II Riso 29 | Hunt | 2 | 12.5 | 4.2 | 4.0 | 76.2 | 3.1 |
| Carlsberg II Riso 86 | Hunt | 2 | 12.8 | 3.9 | 3.2 | 77.0 | 3.1 |
| Hiproly | Hunt | 2 | 20.7 | 8.0 | 1.8 | 72.6 | 2.9 |
| Hiproly Normal | Hunt | 2 | 19.0 | 2.0 | 1.5 | 74.9 | 2.6 |
| Maize | Hunt | 2 | 9.3 | 4.4 | 2.2 | 82.6 | 1.5 |
| Hi-lys Maize | Hunt | 2 | 10.2 | 4.7 | 2.1 | 81.1 | 1.9 |

Appendix Table 22. Proximate composition, calcium and phosphorous percentages of diet feed in Bomi Riso mutant series, Trial 1.

| | Percentage | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Protein | Ether Extract | Crude Fiber | N-free Extract | $H_2O$ | Ash | Ca | P |
| Bozeman | | | | | | | | |
| Bomi, | 9.2 | 3.6 | 2.8 | 72.7 | 7.1 | 4.6 | .59 | .65 |
| Bomi Riso 1508 | 9.1 | 3.9 | 3.5 | 71.8 | 6.9 | 4.8 | .57 | .66 |
| Hiproly | 8.7 | 3.7 | 1.9 | 76.0 | 6.7 | 3.0 | .51 | .53 |
| Hiproly Normal | 9.0 | 3.7 | 1.7 | 76.2 | 6.5 | 2.9 | .48 | .51 |
| Maize | 9.0 | 3.4 | 2.4 | 72.1 | 9.3 | 3.8 | .60 | .71 |
| Hi lys Maize | 8.9 | 3.4 | 2.6 | 72.5 | 8.7 | 3.9 | .57 | .74 |
| Casein | 9.1 | 3.7 | 1.1 | 76.8 | 6.8 | 2.5 | .58 | .50 |
| Huntley | | | | | | | | |
| Bomi, | 8.5 | 3.7 | 2.9 | 74.3 | 6.9 | 4.2 | .57 | .70 |
| Bomi Riso 1508 | 8.4 | 3.1 | 3.0 | 74.2 | 7.1 | 4.2 | .62 | .71 |
| Hiproly | 8.4 | 4.1 | 1.3 | 76.5 | 6.3 | 3.4 | .59 | .66 |
| Hiproly Normal | 8.4 | 4.0 | 1.4 | 76.4 | 6.3 | 3.5 | .61 | .65 |
| Maize | 9.0 | 4.0 | 1.6 | 73.1 | 8.5 | 3.8 | .62 | .72 |
| Hi lys Maize | 8.1 | 3.3 | 2.0 | 75.6 | 7.2 | 3.8 | .57 | .74 |
| Casein | 8.1 | 3.5 | 0.6 | 79.6 | 5.7 | 2.5 | .57 | .48 |

Appendix Table 23. Proximate composition, calcium and phosphorous percentages of diets fed in Carlsberg-Riso mutant series, Trial 2.

| | Percentages | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Protein | Ether Extract | Crude Fiber | N-free Extract | $H_2O$ | Ash | Ca | P |
| Bozeman | | | | | | | | |
| Carlsberg II, | 8.6 | 3.0 | 2.6 | 74.7 | 6.2 | 4.9 | .61 | .62 |
| Carlsberg II-Riso 29 | 8.6 | 2.8 | 3.1 | 73.7 | 6.0 | 5.8 | .58 | .63 |
| Carlsberg II-Riso 86 | 8.3 | 2.6 | 3.2 | 73.3 | 6.5 | 6.1 | .58 | .62 |
| Hiproly | 8.4 | 3.7 | 1.5 | 76.8 | 6.0 | 3.6 | .56 | .62 |
| Hiproly Normal | 8.3 | 3.6 | .9 | 76.8 | 6.5 | 3.9 | .60 | .67 |
| Maize | 8.2 | 4.0 | 1.6 | 73.1 | 8.5 | 3.8 | .62 | .72 |
| Hi lys Maize | 8.1 | 3.3 | 2.0 | 75.6 | 7.2 | 3.8 | .55 | .70 |
| Casein | 8.1 | 3.5 | .6 | 79.6 | 5.7 | 7.5 | .57 | .48 |
| Huntley | | | | | | | | |
| Carlsberg II, | 8.4 | 3.5 | 3.5 | 74.1 | 6.1 | 4.4 | .60 | .67 |
| Carlsberg II-Riso 29 | 8.7 | 2.8 | 3.6 | 74.0 | 6.5 | 4.4 | .58 | .66 |
| Carlsberg II-Riso 86 | 8.4 | 2.8 | 3.8 | 74.5 | 6.2 | 4.3 | .58 | .65 |
| Hiproly | 8.6 | 4.2 | 1.6 | 76.6 | 5.6 | 3.4 | .56 | .60 |
| Hiproly Normal | 8.2 | 4.0 | 1.0 | 77.8 | 5.5 | 3.5 | .57 | .62 |
| Maize | 8.5 | 3.5 | 1.9 | 73.4 | 8.9 | 3.8 | .58 | .62 |
| Hi lys Maize | 8.4 | 3.4 | 2.4 | 73.9 | 8.0 | 3.9 | .60 | .65 |
| Casein | 8.5 | 3.7 | .3 | 78.7 | 6.2 | 2.6 | .60 | .46 |

Appendix Table 24. Percentage composition of rat diets prepared from Bomi, Bomi Riso Mutants, Hiproly, Hiproly Normal, Maize, high-lysine Maize and Casein (Trial 1 Bomi-Riso series).

| | Bozeman Barleys | | | | | | |
|---|---|---|---|---|---|---|---|
| | HP | HPN | Maize | H-L Maize | Bomi | B-R 1508 | Casein |
| Grain[a] | 44.82 | 48.60 | 93.07 | 90.10 | 66.03 | 66.03 | |
| Casein | -- | -- | -- | -- | -- | -- | 9.72 |
| Maize starch | 44.91 | 40.77 | -- | 3.24 | 25.80 | 26.39 | 77.95 |
| Maize oil | 2.97 | 3.00 | 0.80 | -- | 2.79 | 2.53 | 3.78 |
| Mineral mix[b] | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Vitamin mix[c] | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| $CaCO_3$ | .80 | .80 | .80 | .80 | .80 | .80 | .80 |
| Alphacel[d] | 2.25 | 2.58 | 1.08 | 1.61 | .33 | -- | 3.50 |
| Antibiotic[e] | .25 | .25 | .25 | .25 | .25 | .25 | .25 |

| | Huntley Barleys | | | | | | |
|---|---|---|---|---|---|---|---|
| | HP | HPN | Maize | H-L Maize | Bomi | B-R 1508 | Casein |
| Grain[a] | 41.64 | 46.40 | 94.42 | 84.58 | 63.44 | 70.00 | -- |
| Casein | -- | -- | -- | -- | -- | -- | 9.12 |
| Maize starch | 48.41 | 44.13 | -- | 9.70 | 29.25 | 23.15 | 79.83 |
| Maize oil | 2.84 | 2.67 | .53 | -- | 2.09 | 1.66 | 3.55 |
| Mineral mix[b] | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Vitamin mix[c] | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| $CaCO_3$ | .80 | .80 | .80 | .80 | .80 | .80 | .80 |
| Alphacel[d] | 1.66 | 1.75 | -- | .67 | .17 | .14 | 2.45 |
| Antibiotic[e] | .25 | .25 | .25 | .25 | .25 | .25 | .25 |

HP = Hiproly, HPN = Hiproly Normal, H-L Maize = high-lysine Maize oil B-R 1508 = Bomi Riso 1508 Mutant.

b Bernhart-Tomarelli mineral mixture, modified 1135-B.

c ICN nutritional biochemicals vitamin diet fortification mixture

d non nutritive cellulose

e Chlorotitracycline, penicillin, and sulfa methazine; 220.5, 110.2 & 220.5 g/Kg, respectively.

Appendix Table 25. Percentage composition of rat diets prepared from Carlsberg II, Carlsberg II Riso mutants, Hiproly, Hiproly Normal, Maize, High-lysine maize and Casein (Trial 2, Carlsberg II Riso series).

| | Bozeman Barleys | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | HP | HPN | Maize | HL Maize | Carls-berg II | C-R 29 | C-R 86 | Casein |
| Grain[a] | 39.42 | 42.74 | 94.42 | 84.58 | 61.05 | 59.71 | 58.00 | |
| Casein | -- | -- | -- | -- | -- | -- | -- | 9.12 |
| Maize starch | 51.19 | 47.71 | | 9.70 | 31.13 | 33.78 | 35.19 | 79.83 |
| Maize oil | 2.72 | 2.78 | .53 | -- | 2.33 | 1.34 | 1.40 | 3.55 |
| Mineral mix[b] | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Vitamin mix[c] | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| $CaCO_3$ | .80 | .80 | .80 | .80 | .80 | .80 | .80 | .80 |
| Alphacel[d] | 1.62 | 1.72 | | .67 | .44 | .12 | .36 | 2.45 |
| Antibiotic | .25 | .25 | .25 | .25 | .25 | .25 | .25 | .25 |

| | Huntley Barleys | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | HP | HPN | Maize | HL Maize | Carls-berg II | C-R 29 | C-R 86 | Casein |
| Grain[a] | 41.97 | 45.51 | 94.22 | 84.34 | 73.64 | 66.94 | 65.32 | |
| Casein | -- | -- | -- | -- | -- | -- | -- | 9.10 |
| Maize starch | 48.04 | 44.48 | | 9.54 | 18.74 | 26.83 | 27.66 | 79.38 |
| Maize oil | 3.05 | 2.99 | -- | .15 | 2.39 | 1.18 | 1.38 | 3.86 |
| Mineral mix[b] | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| Vitamin mix[c] | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| $CaCO_3$ | .80 | .80 | .80 | .80 | .20 | .20 | .20 | |
| Alphacel[d] | 1.89 | 1.97 | .73 | .92 | .18 | -- | .59 | 2.61 |
| Antibiotic | .25 | .25 | .25 | .25 | .25 | .25 | .25 | .25 |

a HP=Hiproly, HPN = Hiproly Normal, HL Maize = High-lysine Maize and C-R = Carlsberg Riso

b Bernhart - Tomarelli mineral mixture, modified 1135-B

c ICN nutritional Biochemical Vitamin diet fortification mixture

d non-nutritive cellulose

e. chloratetracycline, penicillin and sulfamethazine; 220.5, 110.2 and 220.5 g/kg, respectively.

Appendix Table 26. Growth performance of rats fed Bomi, Bomi-Riso 1508 mutant Hiproly, Hiproly Normal, Maize and high-lysine Maize (Bomi-Riso series, Trial 1*)

| Cultivar | Gain | Feed Cons | Feed/ Gain | Adj. PER |
|---|---|---|---|---|
| Bomi | $60.3^{de}$ | $372.4^{bc}$ | $6.25^{c}$ | $1.85^{c}$ |
| Bomi Riso 1508 | $75.1^{bc}$ | $408.1^{ab}$ | $5.66^{d}$ | $2.16^{b}$ |
| Hiproly | $67.2^{cd}$ | $394.1^{ab}$ | $6.00^{cd}$ | $2.06^{b}$ |
| Hiproly Normal | $56.4^{e}$ | $395.3^{ab}$ | $7.12^{b}$ | $1.74^{c}$ |
| Maize | $43.6^{f}$ | $338.8^{c}$ | $7.93^{a}$ | $1.56^{d}$ |
| Hi-lys Maize | $84.0^{a}$ | $427.3^{a}$ | $5.15^{e}$ | $2.39^{a}$ |
| Casein | $78.3^{ab}$ | $378.9^{b}$ | $4.86^{e}$ | $2.50^{a}$ |
| Bozeman barleys | $65.7^{a}$ | $392.5^{a}$ | $6.30^{a}$ | $2.00^{b}$ |
| Huntley barleys | $67.1^{a}$ | $383.3^{a}$ | $5.98^{b}$ | $2.08^{b}$ |

* Data from Bozeman barleys and Huntley barley combined, 20 rats per mean.

Appendix Table 27. Growth performance of rats fed Carlsberg II, Carlsberg II-Riso 29 and 86 mutants Hiproly, Hiproly Normal, Maize and high-lysine Maize (Carlsberg II - Riso series, Trial 2)*

| Cultivar | Gain | Feed Cons | Feed/ Gain | Adj. PER |
|---|---|---|---|---|
| Carlsberg II | $66.9^{b}$ | $411.5^{ab}$ | $6.23^{b}$ | $2.00^{d}$ |
| Carlsberg II-Riso 29 | $75.0^{a}$ | $433.5^{a}$ | $5.80^{cd}$ | $2.08^{cd}$ |
| Carlsberg II-Riso 86 | $74.3^{a}$ | $439.9^{ab}$ | $5.93^{bc}$ | $2.13^{c}$ |
| Hiproly | $48.4^{b}$ | $346.6^{c}$ | $7.27^{a}$ | $1.72^{e}$ |
| Hiproly Normal | $53.4^{b}$ | $392.0^{b}$ | $7.50^{a}$ | $1.68^{e}$ |
| Maize | $48.3^{b}$ | $342.6^{c}$ | $7.28^{a}$ | $1.74^{e}$ |
| Hi lys Maize | $79.5^{a}$ | $426.3^{ab}$ | $5.41^{de}$ | $2.36^{b}$ |
| Casein | $79.8^{a}$ | $401.0^{ab}$ | $5.07^{e}$ | $2.50^{a}$ |
| Bozeman barley | $64.9^{a}$ | $391.9^{a}$ | $6.20^{b}$ | $2.03^{a}$ |
| Huntley barley | $66.5^{a}$ | $405.8^{a}$ | $6.42^{b}$ | $2.02^{a}$ |

* Data from Bozeman barley and Huntley barley combined, 20 rats per mean.

Appendix Table 28. Biological value (BV), true protein digestibility (TPD) and net protein utilization (NPU) of Bomi and Carlsberg II-Riso mutants, Hiproly, Hiproly Normal, Maize and high-lysine maize*.

| Cultivar | BV | TPD | NPU |
|---|---|---|---|
| | Metabolism Trial 1, Riso series | | |
| Bomi (Bozeman) | $68.2^{bc}$ | $82.6^{b}$ | $56.4^{a}$ |
| Bomi Riso 1508 (Bozeman) | $80.2^{b}$ | $82.0^{b}$ | $65.9^{a}$ |
| Bomi (Huntley) | $73.8^{abc}$ | $80.9^{b}$ | $59.7^{a}$ |
| Bomi Riso 1508 (Huntley) | $75.7^{abc}$ | $82.5^{b}$ | $62.5^{a}$ |
| Hiproly | $69.3^{bc}$ | $91.0^{a}$ | $61.5^{a}$ |
| Hiproly Normal | $64.7^{c}$ | $87.0^{ab}$ | $56.7^{a}$ |
| Maize | $63.6^{c}$ | $86.6^{ab}$ | $55.4^{a}$ |
| Hi-lys Maize | $66.2^{bc}$ | $91.5^{a}$ | $60.8^{a}$ |
| | Metabolism Trial 2, Riso series | | |
| Carlsberg II (Bozeman) | $73.9^{bc}$ | $85.6^{a}$ | $63.3^{a}$ |
| Carlsberg II Riso 29 (Bozeman) | $82.4^{ab}$ | $72.2^{a}$ | $59.5^{a}$ |
| Carlsberg II Riso 86 (Bozeman) | $86.7^{a}$ | $77.9^{a}$ | $67.7^{a}$ |
| Hiproly | $66.9^{c}$ | $83.4^{a}$ | $55.7^{a}$ |
| Hiproly Normal | $69.5^{c}$ | $82.8^{a}$ | $58.3^{a}$ |
| Maize | $64.8^{c}$ | $77.8^{a}$ | $50.9^{a}$ |
| Hi lys Maize | $69.0^{c}$ | $85.3^{a}$ | $58.6^{a}$ |
| | Metabolism Trial 3, Riso Series | | |
| Carlsberg II (Huntley) | $79.9^{bc}$ | $79.5^{bc}$ | $63.4^{a}$ |
| Carlsberg II Riso 29 (Huntley) | $86.4^{ab}$ | $67.3^{d}$ | $58.2^{a}$ |
| Carlsberg II Riso 86 (Huntley) | $89.8^{a}$ | $69.9^{cd}$ | $62.7^{a}$ |
| Hiproly | $77.0^{cd}$ | $83.0^{ab}$ | $63.8^{a}$ |
| Hiproly Normal | $67.6^{e}$ | $84.5^{ab}$ | $57.0^{a}$ |
| Maize | $69.6^{de}$ | $90.7^{a}$ | $63.3^{a}$ |
| Hi lys Maize | $74.7^{cde}$ | $86.5^{ab}$ | $64.6^{a}$ |

* Each mean represents 4 rats

abcde Means in the same column within trial bearing different superscript letters are significantly different ($P < .05$)

Appendix Table 29. Amino Acid Analysis of Bomi and Bomi Derived Barleys Expressed as a Percentage of the Total Protein Recovered

| Location | Bomi | | | B/R 7[a] | B/R 8[a] | B/R 9[a] | B/R 13[a] | B/R 1508[a] | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Boz-1 | Boz-2 | Hunt | Boz-1 | Boz-1 | Boz-1 | Boz-1 | Boz-1 | Boz-2 | Hunt |
| **Amino acid** | | | | | | | | | | |
| Alanine | 3.89 | 3.90 | 3.91 | 4.26 | 4.66 | 4.23 | 4.59 | 5.31 | 4.55 | 4.41 |
| Arginine | 4.93 | 5.11 | 5.24 | 5.42 | 6.50 | 4.84 | 5.71 | 6.86 | 6.27 | 6.20 |
| Aspartic acid | 6.07 | 6.13 | 6.01 | 6.87 | 8.16 | 6.25 | 7.96 | 9.86 | 7.89 | 7.46 |
| Cystine | 1.99 | 1.95 | 2.00 | 2.03 | 2.04 | 2.11 | 2.06 | 2.03 | 2.12 | 2.21 |
| Glutamic acid | 25.72 | 26.02 | 25.75 | 23.72 | 21.44 | 24.28 | 22.30 | 18.08 | 22.05 | 22.47 |
| Glycine | 3.32 | 3.44 | 3.53 | 4.07 | 3.98 | 3.96 | 3.84 | 4.83 | 4.15 | 4.10 |
| Histidine | 2.18 | 2.14 | 2.19 | 2.42 | 2.43 | 2.29 | 2.34 | 2.71 | 2.43 | 2.42 |
| Isoleucine | 3.70 | 3.72 | 3.72 | 3.48 | 3.69 | 3.61 | 3.65 | 3.67 | 3.64 | 3.57 |
| Leucine | 7.21 | 7.25 | 7.24 | 7.16 | 7.09 | 7.22 | 7.02 | 7.05 | 7.18 | 7.14 |
| Lysine | 3.61 | 3.53 | 3.62 | 4.07 | 4.76 | 3.79 | 4.68 | 5.60 | 4.45 | 4.41 |
| Methionine | 1.71 | 1.77 | 1.72 | 1.84 | 1.84 | 1.67 | 1.78 | 1.84 | 1.92 | 1.89 |
| Phenylalanine | 5.69 | 5.39 | 5.43 | 5.23 | 4.95 | 5.46 | 5.24 | 4.35 | 4.75 | 4.83 |
| Proline | 11.95 | 12.27 | 12.01 | 10.65 | 9.81 | 11.36 | 9.83 | 7.63 | 10.01 | 10.19 |
| Serine | 4.74 | 4.74 | 4.86 | 5.03 | 4.76 | 5.37 | 4.78 | 5.31 | 4.95 | 4.94 |
| Threonine | 3.61 | 3.53 | 3.62 | 4.07 | 3.88 | 3.79 | 3.93 | 4.44 | 4.04 | 3.99 |
| Tryptophan | 1.71 | 1.67 | 1.72 | 1.45 | 2.14 | 1.85 | 2.15 | 2.03 | 2.12 | 2.21 |
| Tyrosine | 3.13 | 2.79 | 2.76 | 3.29 | 2.72 | 2.99 | 3.18 | 3.09 | 2.63 | 2.73 |
| Valine | 4.84 | 4.65 | 4.67 | 4.94 | 5.15 | 4.93 | 4.96 | 5.31 | 4.85 | 4.83 |

a B/R = Bomi Riso mutant.

Appendix Table 30. AMINO ACID ANALYSIS OF CARLSBERG II AND CARLSBERG II DERIVED BARLEYS EXPRESSED AS A PERCENTAGE OF THE TOTAL PROTEIN RECOVERED

| | Carlsberg II | | | C/R 29[a] | | | C/R 56[a] | C/R 86[a] | |
|---|---|---|---|---|---|---|---|---|---|
| Location | Boz-1 | Boz-2 | Hunt | Boz-1 | Boz-2 | Hunt | Boz-1 | Boz-2 | Hunt |
| Amino acid | | | | | | | | | |
| Alanine | 4.25 | 3.95 | 4.18 | 3.98 | 4.44 | 4.60 | 5.26 | 4.39 | 4.58 |
| Arginine | 4.96 | 4.99 | 5.27 | 5.85 | 5.71 | 6.01 | 5.63 | 5.53 | 5.98 |
| Aspartic acid | 6.85 | 6.40 | 6.59 | 7.95 | 7.62 | 7.31 | 7.26 | 7.46 | 7.37 |
| Cystine | 2.48 | 1.98 | 2.31 | 1.87 | 1.45 | 1.60 | 2.00 | 1.84 | 2.09 |
| Glutamic acid | 24.67 | 26.15 | 24.48 | 22.68 | 23.20 | 22.64 | 21.76 | 23.40 | 22.13 |
| Glycine | 3.54 | 3.48 | 3.74 | 3.51 | 3.99 | 4.00 | 3.99 | 3.86 | 4.08 |
| Histidine | 2.24 | 2.16 | 2.20 | 2.46 | 2.27 | 2.30 | 2.36 | 2.28 | 2.39 |
| Isoleucine | 3.66 | 3.76 | 3.85 | 3.98 | 3.72 | 3.80 | 3.36 | 3.68 | 3.78 |
| Leucine | 7.20 | 7.15 | 7.25 | 7.49 | 7.16 | 7.31 | 6.72 | 7.11 | 7.27 |
| Lysine | 3.90 | 3.29 | 3.85 | 4.80 | 4.35 | 4.40 | 4.63 | 4.30 | 4.58 |
| Methionine | 1.89 | 1.88 | 1.98 | 1.99 | 1.90 | 1.90 | 1.91 | 1.93 | 1.99 |
| Phenylalanine | 5.43 | 5.46 | 5.16 | 5.26 | 5.17 | 5.01 | 5.99 | 5.18 | 4.98 |
| Proline | 10.86 | 12.23 | 11.43 | 10.06 | 10.79 | 10.51 | 10.44 | 10.70 | 9.76 |
| Serine | 4.72 | 4.80 | 4.95 | 5.26 | 5.08 | 5.01 | 4.90 | 5.09 | 5.08 |
| Threonine | 3.78 | 3.76 | 3.85 | 4.21 | 3.99 | 4.00 | 4.08 | 3.95 | 3.98 |
| Tryptophan | 1.42 | 1.13 | 1.32 | 1.99 | 1.54 | 1.70 | 1.81 | 1.93 | 2.19 |
| Tyrosine | 3.31 | 2.82 | 2.86 | 3.27 | 2.81 | 3.00 | 3.27 | 2.72 | 2.89 |
| Valine | 4.84 | 4.61 | 4.73 | 3.39 | 4.81 | 4.90 | 4.63 | 4.65 | 4.88 |

[a]C/R=Carlsberg Riso mutant.

Appendix Table 31. AMINO ACID ANALYSIS OF GRAINS EXPRESSED AS A PERCENTAGE OF THE TOTAL PROTEIN RECOVERED

| Amino acid | Normal maize[a] | HL maize[a] | Hiproly[b] | HPN[b] |
|---|---|---|---|---|
| Alanine | 7.27 | 5.98 | 4.21 | 3.29 |
| Arginine | 4.67 | 6.34 | 5.09 | 4.46 |
| Aspartic acid | 8.13 | 10.85 | 6.66 | 5.35 |
| Cystine | 1.90 | 2.32 | 1.57 | 1.92 |
| Glutamic acid | 17.83 | 16.71 | 25.06 | 28.37 |
| Glycine | 3.46 | 4.15 | 3.33 | 3.02 |
| Histidine | 3.11 | 3.78 | 2.07 | 1.99 |
| Isoleucine | 3.63 | 3.54 | 3.58 | 3.36 |
| Leucine | 13.15 | 8.90 | 6.85 | 6.51 |
| Lysine | 3.11 | 4.63 | 4.21 | 3.08 |
| Methionine | 2.08 | 1.71 | 1.88 | 1.51 |
| Phenyalanine | 5.19 | 5.00 | 6.16 | 6.51 |
| Proline | 8.13 | 8.29 | 11.43 | 13.43 |
| Serine | 5.19 | 4.76 | 4.52 | 4.39 |
| Threonine | 3.81 | 4.02 | 3.52 | 3.29 |
| Tryptophan | 1.04 | 1.10 | 1.76 | 1.78 |
| Tyrosine | 3.63 | 2.80 | 3.39 | 3.70 |
| Valine | 4.67 | 5.12 | 4.71 | 4.04 |

[a]HL=high-lysine; represents Boz-2 and Hunt trials.
[b]HPN=Hiproly Normal; represents Boz-1 trials.

Appendix Table 32. PERCENTAGE OF PROTEIN, LYSINE AND PROTEIN FRACTIONS OF BOMI AND BOMI DERIVED CULTIVARS

| Barley | % Protein[b] | % Lysine[c] | % Al/Glo[d] | % Hord[d] | % Glu[d] | % Resi[d] |
|---|---|---|---|---|---|---|
| Bomi (Boz-1) | 12.43 | 3.61 | 37 | 25 | 24 | 13 |
| Bomi (Boz-2) | 12.21 | 3.53 | 39 | 21 | 28 | 13 |
| Bomi (Hunt) | 12.16 | 3.62 | 36 | 20 | 32 | 11 |
| B/R 7 (Boz-1) | 12.12 | 4.07 | 41 | 19 | 24 | 15 |
| B/R 8 (Boz-1) | 13.00 | 4.76 | 48 | 15 | 25 | 13 |
| B/R 9 (Boz-1) | 13.17 | 3.79 | 37 | 21 | 31 | 10 |
| B/R 13 (Boz-1) | 13.09 | 4.68 | 45 | 18 | 24 | 13 |
| B/R 1508 (Boz-1) | 13.13 | 5.60 | 55 | 5 | 24 | 15 |
| B/R 1508 (Boz-2) | 12.60 | 4.45 | 49 | 15 | 19 | 18 |
| B/R 1508 (Hunt) | 11.29 | 4.41 | 45 | 15 | 25 | 16 |

[a]B/R=Bomi Riso mutant.
[b]Protein=N x 6.25.
[c]Lysine=g/16 g N.
[d]Al/Glo=albumins + globulins, Hord=hordeins, Glu=glutelins, Resi=residue.

Appendix Table 33. PERCENTAGE OF PROTEIN, LYSINE AND PROTEIN FRACTIONS OF CARLSBERG II AND CARLSBERG II DERIVED CULTIVARS

| Barley | % Protein[b] | % Lysine[c] | % Al/Glo[d] | % Hord[d] | % Glu[d] | % Resi[d] |
|---|---|---|---|---|---|---|
| C II (Boz-1) | 10.72 | 3.90 | 38 | 28 | 19 | 15 |
| C II (Boz-2) | 12.65 | 3.29 | 35 | 27 | 21 | 16 |
| C II (Hunt) | 10.02 | 3.85 | 36 | 22 | 26 | 16 |
| C/R 29 (Boz-1) | 11.11 | 4.80 | 45 | 17 | 26 | 12 |
| C/R 29 (Boz-2) | 12.95 | 4.35 | 41 | 21 | 24 | 14 |
| C/R 29 (Hunt) | 11.55 | 4.40 | 43 | 20 | 25 | 13 |
| C/R 56 (Boz-1) | 13.13 | 4.63 | 45 | 22 | 20 | 13 |
| C/R 86 (Boz-2) | 13.39 | 4.30 | 41 | 21 | 24 | 13 |
| C/R 86 (Hunt) | 11.42 | 4.58 | 42 | 19 | 26 | 13 |

[a] C=Carlsberg, C/R=Carlsberg Riso mutant.
[b]Protein = N x 6.25.
[c]Lysine = g/16 g N.
[d]Al/Glo=albumins + globulins, Hord=hordeins, Glu=glutelins, Resi=residue.

Appendix Table 34. CORRELATION COEFFICIENTS OF AMINO ACIDS WITH GAIN, FEED CONSUMPTION, FEED EFFICIENCY AND PROTEIN EFFICIENCY OF RATS FED 23 BARLEYS

| Amino acid | Gain | Feed consumption | Feed/gain ratio | Adjusted PER |
|---|---|---|---|---|
| | r | r | r | r |
| Alanine | -.02 | .11 | .33 | -.09 |
| Arginine | .72[a] | .37 | -.44[b] | .67[a] |
| Aspartic acid | .50[b] | .29 | -.20 | .42[b] |
| Cystine | .07 | -.17 | -.07 | .20 |
| Glutamic acid | -.32 | -.21 | .00 | .27 |
| Glycine | .60[a] | .26 | -.35 | .57[a] |
| Histidine | .17 | .20 | .11 | .12 |
| Isoleucine | -.12 | .28 | .15 | -.01 |
| Leucine | -.50[b] | -.02 | .68[a] | -.51 |
| Lysine | .78[a] | .21 | -.65[a] | .78[a] |
| Methionine | .04 | .24 | .20 | .12 |
| Phenylalanine | -.27 | -.33 | -.01 | -.31 |
| Proline | .32 | -.15 | .05 | -.31 |
| Serine | -.02 | .04 | .08 | .11 |
| Threonine | .56[a] | .18 | -.38 | .64[a] |
| Tryptophan | .38[b] | .02 | -.40 | .34 |
| Tyrosine | -.23 | -.50[b] | -.02 | -.20 |
| Valine | .25 | .15 | -.03 | .15 |

[a] P .01
[b] P .05

Appendix Table 35. CORRELATION COEFFICIENTS OF AMINO ACIDS WITH BIOLOGICAL VALUE (BV), TRUE PROTEIN DIGESTIBILITY (TPD) AND NET PROTEIN UTILIZATION OF RATS FED 23 BARLEYS

| Amino acid | BV | TPD | NPU |
|---|---|---|---|
| Alanine | -.19 | .18 | -.16 |
| Arginine | .53[a] | -.38 | .26 |
| Aspartic acid | .13 | -.06 | .02 |
| Cystine | -.12 | .31 | .26 |
| Glutamic acid | -.08 | .03 | .03 |
| Glycine | .59[a] | -.36 | .41[b] |
| Histidine | -.27 | .31 | -.11 |
| Isoleucine | .18 | -.40 | -.31 |
| Leucine | -.50[b] | .34 | -.43[b] |
| Lysine | .62[a] | -.52[a] | .22 |
| Methionine | .11 | -.16 | -.05 |
| Phenylalanine | -.41[b] | .35 | -.10 |
| Proline | .19 | .18 | .05 |
| Serine | .32 | -.27 | .13 |
| Threonine | .47[b] | -.33 | .25 |
| Tryptophan | .62[a] | -.52[a] | .28 |
| Tyrosine | -.27 | .09 | -.34 |
| Valine | .37 | -.28 | .13 |

[a] P .01
[b] P .05

Appendix Table 36. MULTIPLE R AND $R^2$ OF BARLEY AMINO ACID EFFECT ON GAIN OF RATS (RISO MUTANTS)

| Amino acid | R | $R^2$ |
|---|---|---|
| Lysine | .7814 | .6106 |
| Serine | .8460 | .7157 |
| Threonine | .8652 | .7486 |
| Leucine | .8924 | .7964 |
| Glutamic acid | .9094 | .8270 |
| Proline | .9187 | .8440 |
| Tyrosine | .9249 | .8554 |
| Methionine | .9344 | .8731 |
| Alanine | .9490 | .9006 |
| Phenylalanine | .9554 | .9128 |
| Cystine | .9579 | .9176 |
| Arginine | .9609 | .9233 |
| Tryptophan | .9767 | .9539 |
| Histidine | .9808 | .9620 |
| Glycine | .9843 | .9688 |
| Valine | .9933 | .9866 |
| Aspartic acid | .9964 | .9928 |
| Isoleucine | .9965 | .9930 |

Appendix Table 37. MULTIPLE R AND $R^2$ OF BARLEY AMINO ACID EFFECT ON FEED CONSUMPTION OF RATS (RISO MUTANTS)

| Amino acid | R | $R^2$ |
|---|---|---|
| Tyrosine | .5043 | .2543 |
| Cystine | .5573 | .3106 |
| Histidine | .6140 | .3770 |
| Serine | .6329 | .4006 |
| Methionine | .6696 | .4484 |
| Leucine | .6764 | .4575 |
| Threonine | .6961 | .4846 |
| Phenylalanine | .7077 | .5008 |
| Lysine | .7254 | .5262 |
| Glutamic acid | .7521 | .5657 |
| Valine | .7974 | .6358 |
| Arginine | .8143 | .6631 |
| Aspartic acid | .8779 | .7707 |
| Isoleucine | .8976 | .8057 |
| Tryptophan | .9232 | .8523 |
| Glycine | .9272 | .8597 |
| Alanine | .9272 | .8597 |
| Proline | .9273 | .8599 |

Appendix Table 38. MULTIPLE R AND $R^2$ OF BARLEY AMINO ACID EFFECT ON FEED EFFICIENCY OF RATS (RISO MUTANTS)

| Amino acid | R | $R^2$ |
|---|---|---|
| Leucine | .6780 | .4597 |
| Lysine | .8264 | .6829 |
| Tyrosine | .8913 | .7944 |
| Histidine | .9184 | .8435 |
| Tryptophan | .9261 | .8577 |
| Aspartic acid | .9312 | .8671 |
| Alanine | .9345 | .8733 |
| Isoleucine | .9434 | .8900 |
| Cystine | .9467 | .8962 |
| Proline | .9518 | .9059 |
| Glutamic acid | .9545 | .9111 |
| Glycine | .9652 | .9316 |
| Methionine | .9702 | .9413 |
| Serine | .9743 | .9493 |
| Phenyalanine | .9799 | .9602 |
| Threonine | .9847 | .9696 |
| Valine | .9853 | .9708 |
| Arginine | .9857 | .9716 |

Appendix Table 39. MULTIPLE R AND $R^2$ OF BARLEY AMINO ACID EFFECT ON PROTEIN EFFICIENCY RATIO OF RATS (RISO MUTANTS)

| Amino acid | R | $R^2$ |
|---|---|---|
| Lysine | .7751 | .6008 |
| Leucine | .8294 | .6879 |
| Tryptophan | .8727 | .7616 |
| Cystine | .8912 | .7942 |
| Aspartic acid | .9018 | .8132 |
| Histidine | .9157 | .8385 |
| Valine | .9223 | .8506 |
| Serine | .9273 | .8599 |
| Threonine | .9435 | .8902 |
| Alanine | .9453 | .8936 |
| Isoleucine | .9477 | .8981 |
| Proline | .9509 | .9042 |
| Methionine | .9522 | .9067 |
| Tyrosine | .9570 | .9158 |
| Arginine | .9608 | .9231 |
| Glutamic acid | .9713 | .9434 |
| Phenylalanine | .9842 | .9686 |
| Glycine | .9846 | .9694 |

Appendix Table 40. MULTIPLE R AND $R^2$ OF BARLEY AMINO ACID EFFECT ON BIOLOGICAL VALUE OF RATS (RISO MUTANTS)

| Amino acid | R | $R^2$ |
|---|---|---|
| Lysine | .6199 | .3843 |
| Histidine | .7799 | .6082 |
| Glycine | .8467 | .7169 |
| Valine | .8563 | .7333 |
| Serine | .8681 | .7536 |
| Tryptophan | .8713 | .7592 |
| Tyrosine | .8748 | .7652 |
| Isoleucine | .8853 | .7837 |
| Alanine | .8896 | .7914 |
| Glutamic acid | .8964 | .8036 |
| Phenylalanine | .9059 | .8207 |
| Proline | .9099 | .8279 |
| Cystine | .9142 | .8357 |
| Threonine | .9177 | .8422 |
| Arginine | .9182 | .8430 |
| Methionine | .9184 | .8435 |
| Leucine | .9193 | .8452 |
| Aspartic acid | .9225 | .8510 |

Appendix Table 41. MULTIPLE R AND $R^2$ OF BARLEY AMINO ACID EFFECT ON TRUE PROTEIN DIGESTIBILITY OF RATS (RISO MUTANTS)

| Amino acid | R | $R^2$ |
|---|---|---|
| Tryptophan | .5226 | .2731 |
| Isoleucine | .6453 | .4165 |
| Valine | .7447 | .5546 |
| Tyrosine | .8649 | .7480 |
| Cystine | .9065 | .8218 |
| Leucine | .9420 | .8873 |
| Threonine | .9481 | .8988 |
| Alanine | .9573 | .9164 |
| Glycine | .9609 | .9233 |
| Lysine | .9616 | .9246 |
| Proline | .9644 | .9301 |
| Aspartic acid | .9649 | .9310 |
| Serine | .9651 | .9314 |
| Arginine | .9659 | .9331 |
| Phenylalanine | .9669 | .9348 |
| Glutamic acid | .9671 | .9353 |
| Methionine | .9672 | .9354 |
| Histidine | .9690 | .9390 |

Appendix Table 42. MULTIPLE R AND $R^2$ OF BARLEY AMINO ACID EFFECT ON NET PROTEIN UTILIZATION OF RATS (RISO MUTANTS)

| Amino acid | R | $R^2$ |
|---|---|---|
| Leucine | .4254 | .1810 |
| Glycine | .5620 | .3159 |
| Lysine | .6447 | .4156 |
| Valine | .6950 | .4830 |
| Alanine | .7698 | .5925 |
| Cystine | .7897 | .6236 |
| Tryptophan | .8063 | .6501 |
| Aspartic acid | .8183 | .6696 |
| Methionine | .8518 | .7256 |
| Phenylalanine | .8804 | .7751 |
| Serine | .8883 | .7890 |
| Arginine | .8982 | .8067 |
| Histidine | .9243 | .8544 |
| Isoleucine | .9261 | .8577 |
| Threonine | .9310 | .8667 |
| Tyrosine | .9314 | .8675 |
| Glutamic acid | .9315 | .8676 |
| Proline | .9316 | .8679 |

Appendix Table 43. PHYSICAL CHARACTERIZATION OF CARLSBERG II AND CARLSBERG II DERIVED BARLEYS

| Barley | No. obs. | % plump | % thin | Yield (q/ha)[a] | Test weight (kg/hl)[b] | Kernel weight (mg) |
|---|---|---|---|---|---|---|
| Carlsberg II | 9 | 56.7 | 20.9 | 35.1 | 62.4 | 36.1 |
| Carlsberg Riso 29 | 9 | 32.6 | 40.7 | 32.4 | 57.4 | 33.8 |
| Carlsberg Riso 56 | 8 | 22.3 | 44.5 | 29.4 | 55.8 | 33.6 |
| Carlsberg Riso 86 | 9 | 20.0 | 53.3 | 25.3 | 51.7 | 29.0 |

a quintals per hectare
b kilograms per hectliter

Appendix Table 44. PHYSICAL CHARACTERIZATION OF BOMI AND BOMI DERIVED BARLEYS

| Barley | No. obs. | % plump | % thin | Yield (q/ha)[a] | Test weight (kg/hl)[b] | Kernel weight (mg) |
|---|---|---|---|---|---|---|
| Bomi | 9 | 60.5 | 16.4 | 38.5 | 62.9 | 39.8 |
| Bomi Riso 7 | 8 | 52.0 | 22.5 | 38.4 | 52.3 | 38.7 |
| Bomi Riso 8 | 8 | 14.9 | 58.1 | 31.5 | 53.7 | 30.8 |
| Bomi Riso 9 | 8 | 30.0 | 33.8 | 26.4 | 56.4 | 33.7 |
| Bomi Riso 13 | 8 | 11.1 | 65.1 | 31.4 | 56.0 | 33.1 |
| Bomi Riso 1508 | 9 | 35.0 | 33.8 | 29.0 | 55.7 | 32.0 |

a quintals per hectare
b kilograms per hecliter

Appendix Table 45. Effect of Rate of Nitrogen Fertilizer and Variety on Yield of Barley, Kg/PLOT

| Cultivar | N. Kg/ha | | | Average |
|---|---|---|---|---|
| | 0 | 112.8 | 225.6 | |
| Hiproly | 5.828 | 9.484 | 11.094 | 8.802[c] |
| Hiproly-Normal | 16.167 | 22.918 | 30.168 | 23.084[b] |
| Compana | 25.396 | 30.045 | 31.311 | 28.917[a] |
| Unitan | 26.449 | 32.416 | 32.683 | 30.516[a] |
| Avg. | 18.460[b] | 23.716[a] | 26.314[a] | |

abc means of the sum of cultivars and rate of nitrogen fertilization bearing different superscript letters are significantly different ($P<.01$).

Appendix Table 46. Effect of cultivar and nitrogen fertilization on kernel weight of barley, mg.

| Cultivar | N, Kg/ha 0 | 112.8 | 225.6 | Avg. |
|---|---|---|---|---|
| Hiproly | 39.0 | 35.5 | 35.6 | $36.7^{l}$ |
| Hiproly Normal | 52.7 | 49.5 | 47.1 | $49.8^{j}$ |
| Compana | 55.0 | 51.3 | 46.0 | $50.8^{j}$ |
| Unitan | 44.0 | 41.8 | 39.5 | $41.8^{k}$ |
| Avg | $47.7^{j}$ | $44.5^{k}$ | $42.1^{l}$ | |

a-i etc. - means bearing different superscript letters are significantly different (P .05).

jkl - mean averages for nitrogen fertilizer level and cultivar bearing different superscript letters are significantly different (P<.01).

Appendix Table 47. Effect of variety and nitrogen fertilization on barley test weight Kg/bl.

| Cultivar | N, Kg/bl 0 | 112.8 | 225.6 | Avg. |
|---|---|---|---|---|
| Hiproly | $65.6^{l}$ | $63.1^{e}$ | $61.1^{l}$ | $63.3^{j}$ |
| Hiproly Normal | $75.2^{a}$ | $70.3^{b}$ | $68.9^{c}$ | $71.5^{i}$ |
| Compana | $63.1^{e}$ | $61.1^{f}$ | $58.4^{g}$ | $60.9^{k}$ |
| Unitan | $60.9^{f}$ | $59.1^{g}$ | $56.2^{h}$ | $58.7^{l}$ |
| Avg | $66.2^{i}$ | $63.4^{j}$ | $61.4^{k}$ | |

a-h Means bearing different superscript letters are significantly different (P<.05).

ijk Mean averages for nitrogen fertilizer level and cultivar bearing different superscript letters are significantly different (P<.01).

Appendix Table 48. Effect of Cultivar and Nitrogen Fertilization on % Plump Kernels

| Cultivar | Lbs N kg/ha 0 | 112.8 | 225.6 | Avg. |
|---|---|---|---|---|
| Hiproly | 28.5$^{g}$ | 23.2$^{h}$ | 21.5$^{h}$ | 24.4$^{k}$ |
| Hiproly-Normal | 90.3$^{ab}$ | 78.9$^{de}$ | 74.8$^{ef}$ | 81.3$^{j}$ |
| Compana | 94.0$^{a}$ | 86.7$^{bc}$ | 75.7$^{ef}$ | 85.5$^{i}$ |
| Unitan | 82.8$^{cd}$ | 81.9$^{cd}$ | 72.3$^{f}$ | 79.0$^{i}$ |
| Avg. | 73.9$^{i}$ | 67.7$^{j}$ | 61.1$^{k}$ | |

Appendix Table 49. Effect of Cultivar and Nitrogen Fertilization on % Thin Kernels

| Cultivar | N. Kg/ha 0 | 112.8 | 225.6 | Avg. |
|---|---|---|---|---|
| Hiproly | 34.1$^{a}$ | 38.6$^{ab}$ | 41.0$^{a}$ | 37.9$^{a}$ |
| Hiproly-Normal | 3.3$^{h}$ | 6.1$^{ab}$ | 9.6$^{a}$ | 6.3$^{h}$ |
| Compana | 2.4$^{b}$ | 6.3$^{ab}$ | 13.9$^{a}$ | 7.5$^{b}$ |
| Unitan | 5.2$^{h}$ | 6.9$^{ab}$ | 13.7$^{a}$ | 8.6$^{b}$ |
| Avg. | 11.3$^{b}$ | 14.5$^{ab}$ | 19.6$^{a}$ | |

Appendix Table 50. Effect of Variety and Nitrogen Fertilization on Udy Protein Level of Barley

| Cultivar | N. Kg/ha 0 | 112.8 | 225.6 | Avg. |
|---|---|---|---|---|
| Hiproly | $18.2^{b}$ | $18.1^{b}$ | $18.9^{a}$ | $18.4^{g}$ |
| Hiproly-Normal | $13.4^{d}$ | $14.3^{c}$ | $15.8^{c}$ | $14.5^{h}$ |
| Compana | $8.2^{f}$ | $11.4^{e}$ | $12.8^{d}$ | $10.8^{i}$ |
| Unitan | $8.5^{f}$ | $10.9^{e}$ | $12.8^{d}$ | $10.7^{i}$ |
| Avg. | $12.1^{i}$ | $13.7^{h}$ | $15.1^{g}$ | |

a - f mean bearing different superscript letters are significantly different ($P<.05$).

ghi - mean averages for nitrogen fertilization rate and cultivar bearing different superscript letters are significantly different $P<.01$.

Appendix Table 51. Effect of Variety and Nitrogen Fertilization on Kjeldahl Protein Level of Barley

| Cultivar | N. Kg/ha 0 | 112.8 | 225.6 | Avg. |
|---|---|---|---|---|
| Hiproly | $16.8^{a}$ | $16.1^{b}$ | $17.0^{a}$ | $16.6^{g}$ |
| Hiproly-Normal | $14.2^{c}$ | $14.8^{c}$ | $16.0^{b}$ | $15.0^{h}$ |
| Compana | $9.3^{f}$ | $12.4^{d}$ | $13.7^{c}$ | $11.8^{i}$ |
| Unitan | $9.1^{f}$ | $11.5^{e}$ | $12.5^{d}$ | $11.0^{g}$ |
| Avg. | $12.4^{i}$ | $13.7^{b}$ | $14.8^{g}$ | |

a - e - mean bearing different superscript letters are significantly different ($P<.01$)

ghi - mean average bearing different superscript letters are significantly different ($P<.01$).

Appendix Table 52. Effect of Cultivar and Nitrogen fertilizer on 28 day gain of weanling rats.

| Cultivar | N, Kg/ha 0 | 112.8 | 225.6 | Avg. |
|---|---|---|---|---|
| Hiproly | $67.4^{abc}$ | $64.9^{abc}$ | $64.4^{abcd}$ | $65.6^{g}$ |
| Hiproly Normal | $51.8^{f}$ | $61.4^{abcdef}$ | $58.0^{bcdef}$ | $57.1^{g}$ |
| Compana | $72.9^{a}$ | $60.5^{bcdef}$ | $52.5^{ef}$ | $62.0^{g}$ |
| Unitan | $70.2^{ab}$ | $63.7^{abcde}$ | $56.5^{cdef}$ | $63.4^{g}$ |
| Avg. | $65.6^{g}$ | $62.6^{hi}$ | $57.8^{i}$ | |

a-f means bearing different superscript letters are significantly different ($P < .05$).

ghi -mean averages bearing different superscript letters are significantly different ($P < .05$)

Appendix Table 53. Effect of Cultivar and Nitrogen Fertilizer on 28 day feed Consumption of Rats.

| Cultivar | N, Kg/ha 0 | 112.8 | 225.6 | Avg. |
|---|---|---|---|---|
| Hiproly | 401.5 | 411.0 | 402.1 | 404.9 |
| Hiproly Normal | 361.8 | 393.0 | 406.5 | 387.1 |
| Compana | 413.0 | 381.1 | 358.0 | 384.0 |
| Unitan | 409.1 | 392.7 | 391.1 | 397.6 |
| Avg. | 396.4 | 394.4 | 389.4 | |

Appendix Table 54. Effect of Cultivar and Nitrogen Fertilizer on Feed Efficiency of Rats, 28 Day Growth Trial

| Cultivar | N, Kg/ha 0 | 112.8 | 225.6 | Avg. |
|---|---|---|---|---|
| Hiproly | $6.02^{cde}$ | $6.59^{abc}$ | $6.49^{abcd}$ | $6.37^{b}$ |
| Hiproly Normal | $7.18^{a}$ | $6.56^{abc}$ | $7.17^{a}$ | $6.97^{a}$ |
| Compana | $5.46^{e}$ | $6.38^{bcd}$ | $6.91^{ab}$ | $6.25^{b}$ |
| Unitan | $5.85^{de}$ | $6.20^{cd}$ | $6.92^{ab}$ | $6.32^{b}$ |
| Avg. | $6.13^{c}$ | $6.43^{bc}$ | $6.87^{a}$ | |

a-e Means bearing different superscript letters are significantly different $P<.05$.

Appendix Table 55. Effect of Cultivar and Nitrogen Fertilizer on Adjusted PER of Rats, 28 Day Growth Trial.

| Cultivar | N, Kg/ha 0 | 112.8 | 225. | Avg. |
|---|---|---|---|---|
| Hiproly | $2.10^{abc}$ | $1.94^{cde}$ | $1.99^{cd}$ | $2.01^{f}$ |
| Hiproly Normal | $1.77^{e}$ | $1.93^{cde}$ | $1.78^{de}$ | $1.83^{g}$ |
| Compana | $2.27^{a}$ | $1.96^{cde}$ | $1.87^{de}$ | $2.03^{f}$ |
| Unitan | $2.24^{ab}$ | $2.07^{bcd}$ | $1.88^{de}$ | $2.06^{f}$ |
| Avg. | $2.09^{f}$ | $1.98^{fg}$ | $1.88^{g}$ | |

a-e Means bearing different superscript letters are significantly different ($P<.05$).

fg Mean averages bearing different superscript letters are significantly different ($P<.05$).

Appendix Table 56. Percentage amino acids (g/16g recovered N) in Hiproly, Hiproly Normal, Compana and Unitan Barleys produced at three levels of Nitrogen Fertilization, 0, 112.8 and 225.6 KgN/ha.

| Amino acid | Hiproly | | | Hiproly Normal | | | Compana | | | Unitan | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 112.8 | 225.6 | 0 | 112.8 | 225.6 | 0 | 112.8 | 225.6 | 0 | 112.8 | 225.6 |
| Ala | 3.99 | 4.35 | 4.08 | 3.61 | 3.68 | 3.39 | 4.12 | 3.69 | 3.74 | 4.04 | 3.88 | 3.51 |
| Arg | 4.94 | 5.09 | 4.92 | 4.56 | 4.36 | 4.38 | 5.01 | 4.86 | 4.77 | 5.19 | 4.89 | 4.61 |
| Asp | 6.71 | 6.99 | 6.83 | 5.64 | 6.00 | 5.56 | 6.27 | 5.82 | 5.82 | 3.36 | 6.17 | 5.66 |
| Cys/1 | 1.51 | 1.80 | 1.67 | 2.10 | 2.20 | 1.83 | 2.60 | 2.41 | 2.07 | 2.46 | 2.65 | 2.25 |
| Glu | 24.71 | 23.52 | 24.17 | 27.37 | 26.84 | 27.76 | 24.79 | 26.60 | 27.03 | 25.07 | 26.31 | 25.09 |
| Gly | 3.32 | 3.54 | 3.36 | 3.32 | 3.34 | 3.18 | 3.62 | 3.29 | 3.31 | 3.65 | 3.48 | 3.18 |
| His | 2.31 | 2.38 | 2.26 | 2.21 | 2.30 | 2.21 | 2.41 | 2.36 | 2.35 | 2.42 | 2.37 | 2.20 |
| Iso | 3.74 | 3.81 | 3.76 | 3.62 | 3.61 | 3.57 | 3.78 | 3.72 | 3.79 | 3.71 | 3.68 | 3.48 |
| Leu | 6.93 | 7.02 | 6.87 | 6.95 | 6.84 | 6.81 | 7.12 | 7.06 | 6.98 | 7.10 | 6.96 | 6.56 |
| Lys | 4.05 | 4.33 | 4.08 | 3.06 | 3.42 | 3.18 | 3.78 | 3.33 | 3.31 | 3.74 | 3.51 | 3.25 |
| Met | 1.95 | 1.98 | 1.97 | 1.74 | 1.67 | 1.68 | 1.85 | 1.71 | 1.75 | 1.78 | 1.74 | 1.64 |
| Phe | 5.84 | 5.66 | 5.65 | 5.69 | 5.72 | 5.83 | 5.00 | 5.17 | 5.26 | 4.87 | 4.90 | 4.79 |
| Pro | 11.86 | 11.25 | 11.44 | 12.54 | 12.54 | 13.04 | 10.89 | 11.90 | 11.71 | 10.87 | 11.38 | 11.04 |
| Ser | 4.52 | 4.50 | 4.53 | 4.56 | 4.42 | 4.31 | 4.77 | 4.46 | 4.58 | 4.81 | 4.69 | 4.30 |
| Thr | 3.54 | 3.63 | 3.54 | 3.39 | 3.50 | 3.35 | 3.78 | 3.61 | 3.59 | 3.72 | 3.64 | 3.41 |
| Trp | 2.07 | 2.21 | 2.42 | 2.16 | 1.95 | 1.97 | 2.25 | 2.35 | 2.16 | 2.42 | 1.76 | 1.79 |
| Tyr | 3.30 | 3.16 | 3.17 | 3.18 | 2.94 | 3.18 | 3.11 | 3.23 | 2.98 | 2.93 | 2.98 | 2.77 |
| Val | 5.01 | 5.10 | 5.06 | 4.65 | 4.74 | 4.49 | 5.21 | 4.80 | 4.96 | 5.38 | 5.19 | 4.88 |
| Prot.rec.,% | 14.0 | 12.8 | 13.2 | 11.4 | 11.4 | 12.5 | 7.3 | 10.0 | 11.1 | 6.9 | 8.4 | 10.6 |
| NX 6.25,% | 16.7 | 15.9 | 16.4 | 14.0 | 14.5 | 15.7 | 9.0 | 11.6 | 13.4 | 8.9 | 11.1 | 12.3 |

Appendix Table 57. Correlation of % lysine (g/116g N) and adjusted PER

| Cultivar | 0 N/ha % Lys | 0 N/ha Adj. PER | 112.8 N/ha % Lys | 112.8 N/ha Adj. PER | 225.6 N/ha % Lys | 225.6 N/ha Adj. PER |
|---|---|---|---|---|---|---|
| Hiproly | 2.10 | 4.05 | 1.94 | 4.33 | 1.99 | 4.08 |
| Hiproly Normal | 1.77 | 3.06 | 1.93 | 3.42 | 1.78 | 3.18 |
| Compana | 2.27 | 3.78 | 1.96 | 3.33 | 1.87 | 3.31 |
| Unitan | 2.24 | 3.74 | 2.07 | 3.51 | 1.88 | 3.25 |

r = .59 with Hiproly data, N=12
v = .98 without Hiproly data, N=9

Appendix Table 58. Percentage of Osborn factors in barley protein as affected by Cultivar and Nitrogen Fertilizer.

| Cultivar | N | Total Protein | Recovered Protein | % of Recovered Protein: Albumins& Globulins | Hordein | Glutelin | Residue |
|---|---|---|---|---|---|---|---|
| Hiproly | 0 | 16.7 | 16.43 | 30.92 | 28.54 | 36.64 | 3.90 |
| Hiproly | 112.8 | 15.9 | 15.69 | 34.80 | 26.70 | 33.40 | 5.10 |
| Hiproly | 225.6 | 16.4 | 16.08 | 35.14 | 27.55 | 32.15 | 5.16 |
| HPN | 0 | 14.0 | 13.54 | 26.74 | 38.63 | 29.25 | 5.39 |
| HPN | 112.8 | 14.5 | 14.52 | 28.17 | 37.88 | 28.79 | 5.16 |
| HPN | 225.6 | 15.7 | 15.66 | 27.65 | 38.95 | 28.22 | 5.17 |
| Compana | 0 | 9.0 | 8.52 | 33.57 | 31.34 | 28.29 | 6.81 |
| Compana | 112.8 | 11.6 | 11.47 | 30.25 | 36.53 | 27.72 | 5.49 |
| Compana | 225.6 | 13.4 | 12.95 | 29.81 | 36.22 | 28.65 | 5.33 |
| Unitan | 0 | 8.9 | 8.39 | 33.37 | 25.51 | 31.94 | 9.18 |
| Unitan | 112.8 | 11.1 | 10.86 | 31.12 | 29.74 | 31.95 | 7.18 |
| Unitan | 225.6 | 12.3 | 11.78 | 30.48 | 30.65 | 32.00 | 6.88 |

Appendix Table 59. Lysine content for eight shrunken endosperm mutants.

| Character Measured+ | Betzes seg 1 | Betzes seg 2 | Compana sex 1 | Compana seg 3 | Compana seg 4 | Glacier seg 5 | Ingrid seg 6 | Ingrid seg 7 |
|---|---|---|---|---|---|---|---|---|
| **Kernel Wt (mg)** | | | | | | | | |
| Mutant | 18.8 | | 38.6 | 26.2 | 37.8 | 32.6 | | 26.8 |
| Normal | 34.3 | | 47.6 | 46.9 | 47.8 | 45.9 | | 36.7 |
| Difference | -15.4** | | -9.0** | -10.7** | -10.0** | -13.3** | | -9.9** |
| No. of Observations | 17 | | 8 | 8 | 9 | 7 | | 8 |
| **Percent Protein (Kjeldahl)** | | | | | | | | |
| Mutant | 15.9 | 16.1 | 17.9 | 16.6 | 16.5 | 16.3 | 15.8 | 15.0 |
| Normal | 14.6 | 14.9 | 14.4 | 14.4 | 14.2 | 12.6 | 13.2 | 12.8 |
| Difference | 1.3** | 1.2 | 3.4** | 2.2** | 2.3** | 3.6** | 2.6 | 2.2** |
| No. of Observations | 18 | 2 | 14 | 12 | 10 | 10 | 2 | 11 |
| **Percent Lysine in Protein (microbiological)** | | | | | | | | |
| Mutant | 3.25 | 4.38 | 3.37 | 3.40 | 3.79 | 2.93 | 3.86 | 3.25 |
| Normal | 3.05 | 2.18 | 2.66 | 2.76 | 2.87 | 2.94 | .24 | 3.20 |
| Difference | 0.20** | 2.20 | .71** | .65** | .91** | -0.01 | .85 | 0.05 |
| No. of Observations | 18 | 2 | 14 | 12 | 10 | 10 | 2 | 11 |
| **Percent Lysine in Barley (micro-biological)** | | | | | | | | |
| Mutant | .518 | .704 | .598 | .534 | .624 | .473 | .610 | .488 |
| Normal | .436 | .320 | .379 | .391 | .403 | .369 | .395 | .407 |
| Difference | 0.082** | .384 | .219** | .143** | .221** | .104** | .215 | .081** |
| No. of Observations | 18 | 2 | 14 | 12 | 10 | 10 | 2 | 11 |

\+ Values are means and mean differences
* Significant at p=.05 by paired t test
** Significant at p=.01 by paired t test

Appendix Table 60. The expression of xenia for shrunken endosperm by Bomi, Riso Mutant No. 1508, $F_2$ seed from $F_1$ Plants.

| Normal Varieties used in Crosses with Riso 1508 | No. of Kernels Plump Sex3- | Shrunken sex3sex3 | Total | $X^2$ for 3:1 Ratio | P Level |
|---|---|---|---|---|---|
| Compana | 613 | 182 | 795 | 1.88 | .100-.250 |
| Carlsberg II | 523 | 147 | 670 | 3.34 | .050-.100 |
| Betzes | 503 | 137 | 640 | 4.41 | .025-.050 * |
| Heines Hanna | 445 | 103 | 548 | 11.25 | <.005 * |
| CI4961 | 404 | 104 | 508 | 5.55 | .010-.025 * |
| Hector | 575 | 101 | 676 | 36.48 | <.005 * |
| Steptoe | 401 | 101 | 502 | 6.38 | .010-.025 * |
| Unitan | 276 | 104 | 380 | 1.14 | .250-.500 |
| Piroline | 310 | 101 | 411 | 0.04 | .750-.900 |

* Reject the 3:1 hypotheses.

Note: Heterogeneity $X^2_2$ on above data = 31.41, p<.005.
Heterogeneity $X^2$ on above data without Hector x Riso 1508 = 13.48, p=.100-.050.
$X^2$ on above data without Hector x Riso 1508 for 3:1 ratio = 21.66, p<.005.

Appendix Table 61. The expression of shrunken endosperm by $F_2$ Plants from Bomi, Riso Mutant No. 1508 crosses.

| Normal Varieties used in Crosses with Riso 1508 | No. of $F_2$ Plants Plump Sex3Sex3 | Hetero-zygous Sex3sex3 | Shrunken sex3sex3 | Total | $X^2$ for 1:2:1 Ratio | P Level |
|---|---|---|---|---|---|---|
| Compana | 56 | 138 | 65 | 259 | 1.74 | .250-.500 |
| Carlsberg II | 14 | 29 | 12 | 55 | 0.30 | .750-.900 |
| Betzes | 77 | 126 | 61 | 264 | 2.48 | .250-.500 |
| Heines Hanna | 17 | 20 | 5 | 42 | 6.95 | .025-.050* |
| Hector | 37 | 83 | 25 | 142 | 5.03 | .050-.100 |
| Steptoe | 22 | 67 | 23 | 112 | 4.33 | .100-.250 |
| Unitan | 27 | 71 | 24 | 122 | 3.42 | .100-.250 |
| Erbet | 24 | 40 | 14 | 78 | 2.61 | .250-.500 |
| Piroline | 24 | 100 | 25 | 149 | 17.47 | <.005 * |

*Reject the 1:2:1 hypothesis.

Note: Heterogeneity $X^2_2$ on above data = 29.05, p=.010-.025.
Heterogeneity $X^2$ on above data without Piroline x Riso 1508-11.58, p=.500-.750
$X^2$ on above data without Piroline x Riso 1508 for 1:2:1 ratio = 8.44, p=.010-.025*

Appendix Table 62. Partial $F_3$ Linkage Data for Male Sterile Genes (msg) x Bomi, Riso Mutant No. 1508 Shrunken Endosperm Xenia Mutant (sex3) Crosses.

| Cross, msg x Riso 1508, sex3 | Chromosome location of msg gene | Partial $F_3$ Classification | | | | % Recombination and S.E.+ |
|---|---|---|---|---|---|---|
| | | Msg - SexSex | Msg - Sexsex | Msg - sexsex | msg msg | |
| Compana msg 10 | 1 | 10 | 36 | 8 | 12 | Independent |
| Compana msg 2 | 2 | 8 | 30 | 11 | 20 | Independent |
| Carlsberg II msg 5 | 3 | 14 | 31 | 12 | 24 | Independent |
| Betzes msg 24 | 4 | 14 | 27 | 13 | 17 | Independent |
| Betzes msg 1 | 5 | 18 | 30 | 9 | 24 | Independent |
| Compana msg 1 | 5 | 12 | 20 | 10 | 15 | Independent |
| Heines Hanna msg 6 | 6 | 17 | 21 | 5 | 21 | Independent |
| CI 4961 msg 19 | 7 | 0 | 33 | 12 | 19 | 0.0 + 2.1 |

+ Recombination and S. E. was calculated by the maximum likelihood method (Allard, 1956). Equation no. 17 was used.

Appendix Table 63. Observed Recombination of Male Sterile 19 (msg19) with T-7 translocation Breakpoints, $F_3$ Data.

| Translocation | $F_3$ Classification + | | | | | Recombination and S.E.‡ |
|---|---|---|---|---|---|---|
| | Msg Msg Fertile | Msg msg Fertile | Msg Msg Semi-Sterile | Msg msg Semi-Sterile | Total | |
| T1-7a | 31 | 0 | 0 | 66 | 97 | 0.0 |
| T3-7a | 25 | 0 | 0 | 74 | 99 | 0.0 |
| T4-7b | 22 | 2 | 5 | 71 | 100 | 4.4±1.5 |

+ The Fertiles are translocation homozygotes and semisteriles are translocation heterozygotes.

‡ Recombination and S.E. was calculated by the maximum likelihood method.

Appendix Table 64. Partial $F_3$ Linkage Data for Rachilla Hair Length (s) and Bomi Riso Mutant No. 1508 Shrunken Endosperm Xenia Mutant (sex3), $F_1$ genotype S sex3/s Sex3.

| genotype | Frequency + |
|---|---|
| S- Sex3 Sex3 | 31 |
| S- Sex3 sex3 | 100 |
| S- sex3 sex3 | 54 |
| ss Sex3 Sex3 | 23 |
| ss Sex3 sex3 | 23 |
| ss sex3 sex3 | 2 |
| Total | 233 |
| % Recombination and S.E. | 28.6 ± 3.4 |

+ The S-: ss ratio is 185 : 48 which fits a 3:1 ratio with $X^2 = 2.4048$, $p = .217$
The SexSex:Sexsex:sexsex ratio is 54:123:56 which fits a 1:2:1 ratio with $X^2 = 20.7596$, $p = .690$.
Recombination and S.E. calculation by the maximum likelihood method (Allard, 1956).

Appendix Table 65. Summary of $F_3$ lysine data for Variety x Bomi, Riso Mutant No. 1508 crosses and parents.

| Seed Analyzed | Mean and Confidence Limits (P = .01) | | |
|---|---|---|---|
| | % Protein + (No. of obs.) | % Lysine in Protein (No. of obs.) | % Lysine in Barley (No. of obs.) |
| Riso 1508 parent | 13.10 (1) | 5.65 (1) | .740 (1) |
| $F_3$ shrunken | 13.08±.435 (41) | 5.76±.219 (41) | .756±.018 (62) |
| $F_3$ heterozygous | 14.48±.345 (124) | 3.41±.068 (124) | .493±.010 (130) |
| $F_3$ plump | 14.17±.459 (66) | 3.13±.085 (66) | .441±.010 (71) |
| Parental Varieties ‡ | 13.45±.923 (15) | 3.11±.113 (15) | .418±.023 (15) |

+ Protein determinations were by Neotec Grain Quality Analyzer.
‡ Parental varieties included are Compana, Carlsberg II, Betzes, Heines Hanna, CI 4961, Hector, Steptoe, Unitan, Erbet and Piroline.
§ Lysine in the barley is by modified microbiological assay.

.Appendix

Table 66. 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 67. 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 5½/64 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 68 Protein, Lysine and Agronomic Comparisons Between Glacier and High Amylose Glacier

| Character Measured | Number of Comparisons | Glacier(x) mean | Glacier(x) range | High Amylose Glacier (y) mean | High Amylose Glacier (y) range | Difference + $\bar{x} - \bar{y}$ | byx‡ | $r^2$ § |
|---|---|---|---|---|---|---|---|---|
| Kjeldahl Protein,% | 21 | 12.53 | 8.5-16.2 | 12.60 | 8.4-15.5 | -0.07 | 1.03 | .885** |
| GQA Protein,% | 21 | 12.59 | 10.0-15.2 | 13.21 | 9.0-15.9 | -0.62** | 1.00 | .736** |
| Udy Protein,% | 21 | 11.55 | 7.5-14.5 | 12.44 | 6.8-15.5 | -0.89** | 1.07 | .859** |
| Transmittence,% | 21 | 45.3 | 37.8-64.5 | 46.8 | 37.5-60.5 | -1.5 | 0.46** | .316** |
| Lysine in Barley,% | 21 | .373 | .310-.515 | .430 | .330-.610 | -0.057** | 1.16 | .868** |
| Lysine in Protein,% | 21 | 3.00 | 2.43-3.88 | 3.44 | 2.64-4.51 | -0.44** | 0.95 | .498** |
| Yield, Q/ha | 8 | 34.3 | 16.1-45.3 | 33.6 | 13.3-43.9 | 0.7 | 0.82 | .801** |
| Plump, on 6/64 sieve,% | 20 | 86.3 | 59.8-97.1 | 84.3 | 58.7-97.2 | 2.0 | 0.89 | .655** |
| Thin, thru 5½/64 sieve,% | 20 | 4.2 | 0.7-10.8 | 5.0 | 0.6-21.7 | -0.8 | 1.09 | .490** |
| Kernel Weight, mg | 20 | 49.4 | 42.1-55.6 | 46.9 | 38.3-57.8 | 2.5** | 0.77 | .479** |
| Test Weight, Kg/hl | 8 | 57.6 | 53.3-60.6 | 56.6 | 50.9-60.6 | 1.0 | 0.90 | .647* |
| Plant Height, cm | 7 | 72.2 | 40.64-94.0 | 72.6 | 40.64-101.6 | -0.4 | 1.12 | .973** |
| Date Headed, days from 1/1 | 6 | 170.0 | 169.0-175.0 | 169.8 | 170.0-171.0 | 0.2 | 0.17** | .205 |

+ 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 69. Summary of Yield Performance of Advanced High Lysine Pedigree Lines.

| Lines | % of Shabet | % of Hiproly |
|---|---|---|
| SHABET* | 100 | 286 |
| (1) Betzes/Hiproly, $F_8$ | 83 | 239 |
| (2) Bonus/Hiproly, $F_6$ | 79 | 226 |
| (3) Betzes/Hiproly, $F_8$ | 78 | 224 |
| (4) Bonus/Hiproly, $F_6$ | 73 | 208 |
| (5) Compana/Hiproly, $F_8$ | 71 (78) | 204 |
| (6) Compana/Hiproly, $F_8$ | 68 (75) | 196 |
| (7) Bonus/Hiproly, $F_6$ | 68 | 193 |
| (8) Bonus/Hiproly, $F_6$ | 62 (68) | 178 |
| Hiproly* | 35 (39) | 100 |

* The yield of Shabet is 38.3 Quintals/Ha, of Hiproly is 13.4 Quintals/Ha.

Appendix
Table 70. Correlation and Regression Data for Percent Lysine in Barley of Normal Variety x Hiproly, $F_3$ vs. $F_4$. *

| Normal Variety x Hiproly | n | Mean % Lysine in Grain | Difference $\bar{x} - \bar{y}$ | r | $r^2$ | byx |
|---|---|---|---|---|---|---|
| $F_3$ (x) | 45 | .610±.009 | -.061 | .12 | .015 | .17 |
| $F_4$ (y) | 45 | .671±.013 | | | | |

* All values are non-significant

Appendix
Table 71. Protein evaluation of lines composited to form 75 RSP 15a, a Hiproly hi-lysine population, established 11/75.

| Components+ | No. of lines | Male Sterile Gene | Mean Percent Protein | Lysine in Protein | Lysine in Barley |
|---|---|---|---|---|---|
| Betzes x Hiproly, $F_7$ | 32 | - | 16.7±.2 | 3.44±.14 | .557±.011 |
| Compana x Hiproly, $F_7$ | 16 | msg 10 | 17.9±.2 | 3.23±.07 | .577±.012 |
| Titan x Hiproly, $F_7$ | 20 | msg 1 | 16.0±.2 | 3.50±.07 | .562±.011 |
| Bonus x Hiproly, $F_5$ | 25 | - | 17.1±.9 | 3.42±.10 | .584±.011 |

+ 71 lines were fertile. 21 lines segregated for male sterility. Each fertile line represents 1.05% and each segregating male sterile line represents 1.2% of the composite.

Appendix
Table 72. Protein evaluation of parents of 75 RSP 15a, Hiproly hi-lysine population.

| Variety | Percent Protein | Percent Lysine in Protein | Percent Lysine in Barley |
|---|---|---|---|
| Hiproly | 18.7 | 3.46 | .648 |
| Betzes | 14.6 | 2.96 | .430 |
| Compana | 15.0 | 2.77 | .416 |
| Titan | 14.2 | 2.76 | .390 |

Appendix
Table 73. Sieve size assortment and protein evaluation of 76 RSP 15a, Hiproly hi-lysine population, 1976 harvest, fertile plants only.

| Sieve Size, inch | Sieve size assortment | Percent + Protein | Percent Lysine in Protein | Percent Lysine in Barley |
|---|---|---|---|---|
| on 7/64 | 2.2 | 15.2 | 2.37 | .360 |
| on 6/64 thru 7/64 | 51.5 | 15.7 | 3.30 | .518 |
| on 5.5/64 thru 6/64 | 29.3 | 16.2 | 3.46 | .560 |
| on 5/64 thru 5.5/64 | 8.1 | 15.8 | 3.54 | .560 |
| thru 5/64 | 8.9 | - | - | - |

+ Protein analyses were by the Kjeldahl method.

Appendix
Table 74. Protein evaluation of lines composited to form 76 RSP 15b, Hiproly hi-lysine population, established 5/76

| Components+ | No.of lines | Male Sterile Gene | Protein | Lysine in Protein | Lysine in Barley |
|---|---|---|---|---|---|
| Betzes x Hiproly, $F_8$ | 13 | - | 13.3±.3 | 3.59±.09 | .477±.015 |
| Compana x Hiproly, $F_8$ | 10 | msg 10 | 12.2±.4 | 3.72±.07 | .454±.008 |
| Titan x Hiproly, $F_8$ | 3 | msg 1 | 14.7 | 3.18 | .468 |
| Bonus x Hiproly, $F_6$ | 13 | - | 12.5±.3 | 3.68±.08 | .459±.014 |

+ 36 lines were fertile. 3 lines segregating for male sterility. The composite consists of 50% fertile lines and 50% male sterile segregating lines. The fertile line component includes only seed that remained on top of a 5.5/64 sieve. Before sieving, each fertile line represented 2.7% of the total fertile component. Compana msg 10 x Hiproly represents 30% and Titan msg 1 x Hiproly represents 70% of the male sterile segregating component. The male sterile component was not sieved.

Appendix
Table 75. Sieve size assortment and protein evaluation of 76 RSP 15b, Hiproly hi-lysine population, 1976 harvest, fertile and male sterile plants, in bulk.

| Sieve size | Sieve size assortment | Percent Protein+ | Percent Lysine in Protein | Percent Lysine in Barley |
|---|---|---|---|---|
| on 7/64 | 2.8 | 15.8 | 2.72 | .429 |
| on 6/64 thru 7/64‡ | 49.6 | 16.6-18.4 | 3.37-3.32 | .560-.610 |
| on 5/64 thru 6/64 | 32.5 | 18.7 | 3.53 | .660 |
| thru 5/64 | 15.1 | 19.6 | - | - |

+ Protein analyses were by the Kjeldahl method

‡ The left hand value is representative of plump kernels while that on the right represents dimpled or shrunken kernels.

Appendix
Table 76.76RSP 16 - Components of a male sterile facilitated recurrent selection population homozygous for the shrunken endosperm gene (sex3 sex3) of Bomi, Riso Mutant No. 1508.+

| Variety and msg gene | % germplasm represented | Percent protein ‡ | Percent lysine in protein | Percent lysine in barley |
|---|---|---|---|---|
| Compana msg10 | 3.33 | 12.1 | 6.94 | .840 |
| Compana msg2 | 3.33 | 12.6 | 6.83 | .860 |
| Carlsberg II msg5 | 3.33 | 11.8 | 7.29 | .860 |
| Betzes msg24 | 3.33 | 11.8 | 7.12 | .840 |
| Compana msg1 | 3.33 | 12.1 | 6.94 | .840 |
| Betzes msg1 | 3.33 | 12.1 | 7.27 | .880 |
| Heines Hanna msg6 | 3.33 | 12.1 | 6.61 | .800 |
| CI 4961 msg19 | 3.33 | 13.8 | 6.38 | .880 |
| Hector | 3.33 | 11.0 | 7.56 | .830 |
| Steptoe | 3.33 | 10.6 | 7.51 | .790 |
| Unitan | 3.33 | 11.6 | 6.57 | .760 |
| Betzes | 3.33 | 11.6 | 7.29 | .840 |
| Compana | 3.33 | 11.6 | 7.15 | .860 |
| Erbet | 3.33 | 12.0 | 7.33 | .880 |
| Piroline | 3.33 | 11.6 | 6.72 | .780 |

+ Each component was selected from shrunken endosperm 1st cross $F_1$ plants with Bomi, Riso Mutant 1508. $F_3$ seed was composited, and therefore, about 50% of the germplasm is represented by Bomi.

‡ Protein determination was by the Neotec Grain Quality Analyzer.

Appendix
Table 77. $F_3$ Lysine Data for Variety x Bomi, Riso Mutant No. 1508 Crosses+

| Source of Seed | No. of Observations | Mean: Percent Lysine in Barley | Mean: Difference | |
|---|---|---|---|---|
| $F_3$ shrunken ($X_1$) | 62 | $.755 \pm .007$ | | |
| $F_3$ plump ($X_2$) | 71 | $.441 \pm .004$ | $(\bar{X}_1-\bar{X}_2)$ | .314** |
| Parental Varieties ($X_3$) | 15 | $.418 \pm .008$ | $(\bar{X}_1-\bar{X}_3)$ | .337** |
| Parental Mutant No. 1508 ($X_4$) | 1 | .740 | $(\bar{X}_4-\bar{X}_3)$ | .322** |

+ Varieties included are Compana, Betzes, Carlsberg II, Heines Hanna, C.I. 4961, Hector, Steptoe, Unitan, Erbet, Piroline and Bomi.

** difference significant at the $p > .01$ level

Appendix Table 78. **High Lysine - Male Sterile Stocks Available**

| Variety and High Lysine Mutant | Variety and Male Sterile Mutant | Chromosome of msg gene | Lysine in Barley Range %* | Lysine in Protein Range %** | No. of Lines Available |
|---|---|---|---|---|---|
| Hiproly | Compana msg 10 | 1 | .660-.820 | 4.12-5.10 | 22 |
| Hiproly | Betzes msg 23 | 1 | .600-.780 | 4.03-4.93 | 4 |
| Hiproly | Titan msg 1 | 5 | .600-.700 | 3.57-4.17 | 6 |
| Hiproly | Carlsberg II msg 5 | 3 | .620-.640 | 3.93-405 | 2 |
| Bomi,Riso Mutant #8 | Carlsberg II msg 5 | 3 | .455 | 3.20 | 1 |
| Bomi,Riso Mutant #9 | Carlsberg II msg 5 | 3 | .440 | 3.83 | 1 |
| Bomi,Riso Mutant #13 | Carlsberg II msg 5 | 3 | .620-.640 | 4.70-5.12 | 3 |
| Bomi,Riso Mutant #1508 | Compana msg 10 | 1 | .800-.820 | 6.15-6.26 | 2 |
| Bomi,Riso Mutant #1508 | Compana msg 2 | 2 | .740-.800 | 6.07-6.11 | 2 |
| Bomi,Riso Mutant #1508 | Carlsberg II msg 5 | 3 | .620-.760 | 5.16-6.23 | 3 |
| Bomi,Riso Mutant #1508 | Betzes msg 24 | 4 | .820 | 5.90 | 1 |
| Bomi,Riso Mutant #1508 | Betzes msg 1 | 5 | .720-.740 | 5.56-5.67 | 2 |
| Bomi,Riso Mutant #1508 | Heines Hanna msg 6 | 6 | .700-.780 | 5.43-5.73 | 2 |
| Carlsberg II, Riso Mutant #29 | Carlsberg II msg 5 | 3 | .466-.490 | 3.82-3.92 | 2 |
| Carlsberg II, Riso Mutant #56 | Carlsberg II msg 5 | 3 | .440-.508 | 3.50-3.64 | 2 |
| Carlsberg II, Riso Mutant #86 | Carlsberg II msg 5 | 3 | .508-.542 | 3.82-4.23 | 5 |
| **Variety Checks** | | | | | |
| Compana, msg 10 | | | .402 | 3.14 | |
| Carlsberg II, msg 5 | | | .429 | 2.90 | |
| Compana, msg 2 | | | .402 | 3.09 | |
| Betzes, msg 24 | | | .440 | 3.33 | |
| Betzes, msg 1 | | | .429 | 3.06 | |
| Heines, Hanna msg 6 | | | .466 | 3.13 | |
| Hiproly | | | .760 | 4.58 | |
| Bomi, Riso Mutant #1508 | | | .740 | 5.65 | |

* Lysine Data from Bozeman 1976. Determined by a modified microbiological assay technique

** Based on proteins determined on Neotec Grain Quality Analyzer

Appendix
Table 79. Protein, Agronomic and Malt Quality Comparisons Between Compana (normal endosperm) and Wapana (Waxy endosperm Compana)

| Character Measured | Number of Comparisons | Compana (x) mean | Compana (x) range | Waxy Compana (y) mean | Waxy Compana (y) range | Difference+ $\bar{x} - \bar{y}$ | byx‡ | $r^2$ # |
|---|---|---|---|---|---|---|---|---|
| Yield (q/ha) | 37 | 28.29 | 7.7-49.4 | 26.91 | 9.0-51.2 | 1.39** | .87** | .939** |
| Test wt (k/hl) | 36 | 61.55 | 53.6-69.4 | 60.54 | 53.1-67.0 | 1.01** | .79** | .809** |
| Plant height (cm) | 32 | 60.60 | 33.0-91.4 | 62.64 | 37.3-91.4 | -2.04* | .91 | .893** |
| Heading Date | 28 | 180.68 | 160-208 | 180.53 | 159-198 | .143 | .98 | .987** |
| Plump, on 6/64 sieve, % | 29 | 77.49 | 12.6-98.0 | 73.85 | 10.4-98.0 | 3.64** | 1.03 | .964** |
| Thin, thru 5½/64 sieve, % | 25 | 10.89 | 0.0-38.8 | 12.34 | 0.0-55.6 | -1.45* | 1.06 | .957** |
| Lodging Index | 7 | 52.0 | 11.0-99.0 | 50.0 | 11.0-82.8 | 1.71 | .52 | .474 |
| Shattering % | 3 | .00 | 0.0-0.0 | 5.67 | 2.0-10.0 | -5.67 | .00 | .00 |
| Kernel wt. (mg) | 13 | 45.61 | 34.2-56.4 | 44.58 | 33.3-58.8 | 1.02 | .84 | .660** |
| Protein, KJD % | 13 | 14.21 | 9.3-17.0 | 14.97 | 10.5-16.9 | -.76** | .91* | .978** |
| Protein, GQA % | 13 | 14.08 | 8.6-17.1 | 14.99 | 10.0-17.5 | -.9154** | .83* | .950** |
| Amylose in starch % | 8 | 18.62 | 16.5-20.5 | 1.14 | 0.0-3.1 | 17.49** | -.26** | .109 |
| Particle Size Index (Kans) | 14 | 29.88 | 26.1-37.4 | 30.49 | 24.6-36.1 | -.61 | .30* | .078 |
| | | | USDA Malt Quality Laboratory | | | | | |
| Barley Kernel Wt - mg | 12 | 45.19 | 35.4-52.1 | 42.85 | 32.0-47.9 | 2.34** | .86 | .848** |
| Plump Barley Percent | 12 | 76.09 | 19.2-97.6 | 73.75 | 19.5-97.3 | 2.34 | .97 | .963** |
| Color (Agtron) | 12 | 73.17 | 48-94 | 75.17 | 44-94 | -2.0 | 1.03 | .783** |
| Malt Extract % | 12 | 73.06 | 68.5-78.0 | 72.84 | 69.1-75.1 | .22 | .89 | .951** |
| Extract fine-coarse dif. % | 12 | 4.57 | 3.3-6.0 | 4.41 | 2.3-6.1 | .167 | 1.08 | .798** |
| Wort color | 12 | 1.38 | 1.3-1.5 | 1.39 | 1.3-1.5 | - .01 | .50 | .314 |
| Barley Nitrogen % | 12 | 2.49 | 1.61-2.90 | 2.57 | 1.71-2.96 | - .08* | .93 | .904** |
| Wort Nitrogen % | 12 | .58 | .476-.703 | .61 | .507-.736 | - .03* | .83 | .612** |
| Diastatic Power Degrees Lint. | 12 | 159.83 | 105-190 | 142.17 | 91-186 | 17.67** | .79 | .552** |
| Wort N/Malt N % | 12 | 23.66 | 19.5-29.2 | 24.05 | 19.4-29.6 | - .392 | 1.07 | .766** |
| Alpha Amylase 20 units | 12 | 29.07 | 23.0-42.3 | 29.59 | 20.4-42.3 | - .525 | .88 | .554** |

+ 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 80. Approximate feed analysis of barleys grown in 1975 as "high fat" lines.

Percent composition reported on dry matter basis

| Variety | Ether extract | Protein | Ash | crude fiber | ca | P | hull | ether extract* |
|---|---|---|---|---|---|---|---|---|
| Compana** | 2.7 | 15.5 | 3.5 | 5.9 | .03 | .52 | covered | |
| C.I. 12116 | 2.6 | 14.4 | 2.5 | 2.3 | .03 | .54 | hulless | 4.6 |
| C.I. 14285 | 2.5 | 17.8 | 3.2 | 1.8 | .01 | .51 | " | 3.7 |
| C.I. 5681 | 2.3 | 18.9 | 2.6 | 1.6 | .01 | .56 | " | 4.0 |
| C.I. 14234 | 2.3 | 14.6 | 2.3 | 1.8 | .02 | .51 | " | 3.8 |
| C.I. 14362 | 2.3 | 17.4 | 2.5 | 1.9 | .02 | .53 | " | 3.8 |
| Hiproly | 2.2 | 21.9 | 3.3 | 2.2 | .02 | .61 | " | |
| C.I. 14233 | 2.2 | 14.3 | 2.3 | 2.1 | .01 | .49 | " | 4.1 |
| Nepal | 2.2 | 16.8 | 2.6 | 1.0 | .00 | .50 | " | |
| Sermo | 2.2 | 18.2 | 2.8 | 1.8 | .00 | .49 | " | |
| C.I. 14718 | 2.2 | 19.3 | 3.2 | 1.7 | .02 | .55 | " | 3.7 |
| Ubamer | 2.0 | 17.9 | 2.6 | 0.8 | .02 | .57 | " | |
| Hiproly Normal | 1.9 | 20.1 | 2.7 | 1.8 | .01 | .56 | " | |
| Betzes** | 1.8 | 14.2 | 3.4 | 4.1 | .02 | .50 | covered | |
| Steptoe** | 1.5 | 11.9 | 3.3 | 7.1 | .03 | .50 | covered | |

* as reported by Dr. P. B. Price, So. Dak. State University, personal communication.

** Included as Montana recommended variety checks.

Appendix Table 81. Mean values of absorbance readings for 25 varieties of barley for the presence of alpha-amylose as a measure of gibberellic acid activity[1]

| | | | |
|---|---|---|---|
| Nugopana | .06 a | Svalof 50-103 | .32 ij |
| Heines Flo | .12 b | Steptoe | .33 jk |
| Piroline | .18 c | New Moravian | .36 k |
| Klages | .19 cd | Brunes Wisa | .42 l |
| Betzes | .22 de | Haisa II | .45 l |
| Horn | .23 ef | Firlbecks III | .45 l |
| Unitan | .26 fg | Ingrid | .45 l |
| Munsing | .27 gh | Nupana | .51 m |
| Vantage | .28 gh | Compana | .57 n |
| Hannchen | .29 gh | Dekap | .59 no |
| Heines Hanna | .29 gh | Otis | .62 o |
| Traill | .29 ghi | Freja | .71 p |
| Spartan | .30 hij | | |

[1] Values expressed are an average of 12 observations. Means bearing different letters are significantly different (p .01) as determined by Duncan's Multiple Range test.

Appendix Table 82. Step-wise regression evaluating the association of 20 factors with Gibberellic Acid activity.

| Factors | Rank | R | accumulative $R^2$ |
|---|---|---|---|
| Barley color | 1 | .459 | .21 |
| Barley extract | 2 | .533 | .28 |
| Wort color | 3 | .622 | .39 |
| Test weight | 4 | .660 | .43 |
| Barley diastatic Power | 5 | .666 | .44 |
| Beta amylase | 6 | .699 | .49 |
| Kjeldahl Protein - Bozeman | 7 | .745 | .55 |
| Protein Udy | 8 | .797 | .63 |
| Percent malt nitrogen | 9 | .810 | .66 |
| Kjeldahl protein - Madison | 10 | .848 | .72 |
| Malt extract | 11 | .867 | .75 |
| Barley kernel wt. | 12 | .870 | .76 |
| Malt kernel wt. | 13 | .900 | .81 |
| Wort Malt nitrogen | 14 | .930 | .86 |
| Plumpness score | 15 | .953 | .91 |
| Malt diastatic power | 16 | .974 | .95 |
| Beta/alpha amylase | 17 | .981 | .96 |
| alpha amylase | 18 | .990 | .98 |
| Plump barley | 19 | 1.00 | 1.00 |
| Wort nitrogen | 20 | | no effect |

Appendix Table 83. Water "characteristic" measurements of selected barley varieties

| Variety | Row | Mod. of Elastic e[1] | -3 to -17 Slope[2] | >-17 Slope[3] | Wilting Ψ | 7/14/76 Ψop-PM[5] | 7/14/76 Ψop-AM[6] | 7/14/76 Δop[7] | 8/10/76 Ψop-PM | 8/10/76 Ψop-AM | 8/10/76 Δop | Water remaining in soil at end of season-by indicated depths 2.5'-5.5' | 2.5'-4.0' | 4.0'-5.5' |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Marie | 2 | 41 | 114.52 | 45.94 | -17 | -14.7 | -10.2 | -4.5 | -21.8 | -17.0 | -4.8 | 5.18 | 2.20 | 2.98 |
| Titan | 6 | 178 | 341.43 | 47.22 | -19 | -15.3 | -10.4 | -4.9 | -24.4 | -19.5 | -4.9 | 5.34 | 2.16 | 3.18 |
| Betzes | 2 | 117 | 172.50 | 48.55 | -13.5 | -15.8 | -10.7 | -5.1 | -19.3 | -15.0 | -4.3 | 5.00 | 1.97 | 3.03 |
| Vantage | 6 | 52 | 132.89 | 61.11 | -14.5 | -15.6 | -10.4 | -5.2 | -19.5 | -15.6 | -3.9 | 5.94 | 2.58 | 3.36 |
| Compana | 2 | 159 | 240.00 | 43.27 | -15.5 | -17.0 | -11.3 | -5.7 | -24.4 | -19.3 | -5.1 | 5.09 | 2.08 | 3.01 |
| Glacier | 6 | 107 | 161.65 | 39.50 | -16.5 | -16.7 | -11.0 | -5.0 | -22.9 | -17.5 | -5.4 | 5.14 | 2.15 | 2.99 |
| Dekap | 2 | 110 | 168.52 | 41.14 | -15.5 | -21.2 | -12.2 | -9.0 | -23.8 | -18.7 | -5.1 | 5.19 | 1.98 | 3.21 |
| Traill | 6 | 199 | 312.50 | 50.00 | -16.5 | -14.7 | -10.2 | -4.5 | -24.1 | -19.3 | -4.8 | 5.00 | 1.97 | 3.03 |
| Freja | 2 | 100 | 166.67 | 61.55 | -13 | -16.7 | -11.3 | -5.4 | -19.3 | -15.0 | -4.3 | 4.89 | 1.99 | 2.90 |
| Tropny | 6 | 99 | 166.09 | 59.29 | -21 | -14.4 | - 9.9 | -4.5 | -22.7 | -17.5 | -5.2 | 4.82 | 1.97 | 2.85 |
| Ingrid | 2 | 102 | 170.06 | 44.44 | -13 | -18.0 | -10.4 | -4.6 | -21.0 | -16.7 | -4.3 | 5.07 | 1.97 | 3.10 |
| Larker | 6 | 227 | 337.50 | 98.80 | -16 | -14.1 | - 9.9 | -4.2 | -13.9 | -11.9 | -2.0 | 5.02 | 2.02 | 3.00 |
| NewMoravian | 2 | 107 | 155.00 | 30.02 | -17 | -17.3 | -11.9 | -5.4 | -21.0 | -16.7 | -4.3 | 4.95 | 1.94 | 3.01 |
| Atlas 46 | 6 | 113 | 181.43 | 56.62 | -13 | -14.7 | - 9.9 | -4.8 | -18.4 | -15.0 | -3.4 | 5.67 | 2.42 | 3.25 |
| Piroline | 2 | 113 | 192.31 | 60.66 | -18 | -16.4 | -11.0 | -5.4 | -24.1 | -19.0 | -5.1 | 5.57 | 2.23 | 3.34 |
| Harlan | 6 | 81 | 149.28 | 71.54 | -19 | -14.7 | -10.2 | -4.5 | -21.8 | -17.3 | -4.5 | 5.16 | 2.03 | 3.13 |
| Otis | 2 | 80 | 150.00 | 65.00 | -20 | -18.4 | -12.2 | -6.2 | | | | 5.09 | 2.02 | 3.07 |
| Hiland | 6 | 176 | 258.78 | 24.49 | -22.5 | -13 | - 8.2 | -4.8 | -21.8 | -17.3 | -4.5 | 5.15 | 2.16 | 2.99 |
| Heines Hanna | 2 | 193 | 270.24 | 38.22 | -19 | -15 | -10.4 | -4.6 | -23.8 | -18.7 | -5.1 | 4.88 | 1.93 | 2.95 |
| Frontier | 6 | 134 | 205.34 | 35.64 | -20 | -16.4 | -11.0 | -5.0 | -23.2 | -18.1 | -5.1 | 5.09 | 1.91 | 3.18 |
| Horn | 2 | 159 | 246.05 | 54.65 | -17.5 | -15.6 | -10.7 | -4.9 | | | | 4.93 | 2.02 | 2.91 |
| Trebi | 6 | 145 | 243.10 | 88.97 | -20.5 | -15.8 | -11.0 | -4.8 | -21.2 | -16.7 | -4.5 | 5.21 | 2.11 | 3.10 |
| Haisa II | 2 | 64 | 246.05 | 110.71 | -15 | -14.4 | - 9.9 | -4.5 | -19.5 | -15.6 | -3.9 | 5.29 | 2.16 | 3.13 |
| Gem | 6 | 102 | 165.00 | 43.40 | -17.5 | -16.4 | -11.0 | -5.0 | -20.1 | -15.8 | -4.3 | 5.53 | 2.28 | 3.25 |
| Hannchen | 2 | 209 | 328.81 | 46.15 | -19 | -15.3 | -10.4 | -4.9 | -23.2 | -18.1 | -5.1 | 5.39 | 2.09 | 3.30 |
| Bonneville | 6 | 259 | 450.00 | 76.03 | -16 | - 9.6 | - 7.9 | -1.7 | -23.8 | -18.7 | -5.1 | 4.76 | 1.89 | 2.87 |
| Munsing | 2 | 186 | 277.63 | 44.72 | -18 | -17.3 | -11.9 | -5.4 | -23.2 | -18.1 | -5.1 | 4.90 | 1.97 | 2.93 |
| Spartan | 2 | 160 | 238.57 | 83.42 | -14.0 | -16.7 | -11.3 | -5.4 | | | | 5.86 | 2.45 | 3.41 |
| Beecher | 6 | | 301.69 | 29.59 | -23 | -17.0 | -11.3 | -5.7 | | | | | | |

1. Modulus of elasticity. This is calculated from the measured relationship of total potential vs. relative water content.
2. Slope of the first linear region of the relationship of total potential vs. relative water content.
3. Slope of the second linear region of the relationship of total potential vs. relative water content.
4. The lower inflection point of the relationship of total potential vs. relative water content.
5. Osmotic potential in the afternoon.
6. Osmotic potential in early morning
7. Algebraic difference between the osmotic potential in the afternoon and the morning.

Appendix Table 84. Parental varieties used to develop six 2-row and five 6-row recurrent selection populations, RSP's 4 through 14.

2-row male sterile facilitated recurrent selection populations

| RSP No. : | RSP 4 | RSP 6 | RSP 8 | RSP 9 | RSP 10 | RSP 11 |
|---|---|---|---|---|---|---|
| Male sterile female parent: | Compana | Betzes | Carlsberg II | C.I. 4961 | Shonupana | Compana |
| male sterile gene: | msg 10 | msg 23 | msg 5 | msg 19 | msg 10 | msg 2 |
| chromosome of msg: | 1 | 1? | 3 | 7 | 1 | 2 |

Male 2-row parents used to develop the above RSP's.

1. Herta
2. Ingrid
3. Bruens Wisa
4. Zephyr
5. Erbet
6. Dekap
7. Hector
8. Wapana
9. Union
10. Vireo
11. Summit
12. Maris Mink
13. Nupana
14. Cumhuiyet 50
15. Toonucier

6-row male sterile facilitated recurrent selection populations

| RSP No. : | RSP 5 | RSP 7 | RSP 12 | RSP 13 | RSP 14 |
|---|---|---|---|---|---|
| Male sterile female parent : | Manchuria | Betzes | Carlsberg II | Trebi | WS 471 |
| male sterile gene: | msg 10 | msg 23 | msg 5(6row) | msg 2 | msg 1 |
| chromosome of msg: | 1 | 1? | 3 | 2 | 5 |

Male 6-row parents used to develop the above RSP's

1. Gem
2. Unitan
3. Arimont
4. Watan
5. Nordic
6. Atlas 68
7. Beecher
8. Galt
9. Steptoe
10. Nuvan
11. Nucier
12. Minn. 21
13. Athenais
14. Atsel
15. CM 67 (Calif. Mariout)

Composite of each of the 15 $F_1$'s is bulked and at least one generation of recombination (harvest from male steriles only) is accomplished before distribution.

Appendix
**Table 85.** Seedling reactions of barley cultivars to isolates of net blotch, *Pyrenophora teres*.

| Cultivar | Isolate | | | | |
|---|---|---|---|---|---|
| | Rudyard,MT | Sidney,MT | ES8(Tunisia) | ES9(Tunisia) | ES10(Lebanon) |
| C.I. 5791 | 1* | 1,2 | 1 | 1 | 1 |
| Tifang | 2 | 3,4,2 | 1 | 1 | 2 |
| Oderbrucker | 3,4 | 3,4 | 2 | 1 | 1 |
| C.I. 7584 | 1 | 1,2 | 1 | 1 | --- |
| C.I. 2235 | 2,1 | 1,2 | 1 | 1 | --- |
| C.I. 9776 | 1 | 1 | 1 | 1 | --- |
| C.I. 9819 | 1 | 1 | 1 | 1 | 2 |
| Trebi | 4 | 4 | 4 | 3 | 3 |
| Betzes | 4 | 4 | 4 | 4 | --- |

* 0 = (very resistant) no observable infection
1 = (resistant) pinpoint lesions without chlorosis
2 = (moderately resistant) slightly developed dark brown lesions with no chlorosis
3 = (moderately susceptible) restricted longitudinal brown streaks with slight chlorosis
4 = (susceptible) brown elongated lesions, criss-crossed with dark-colored net-like venation and marked chlorosis

Appendix Table 86. Eight varieties and six associated scald resistant genes crossed onto male sterile plants of RSP 5 (Appendix Table 84) to yield the initial recurrent selection population RSP 5 Rrs

| Variety | Scald resistant genes presents |
|---|---|
| Trebi | Rh |
| Jet | rh5, rh6 |
| Kitchin | Rh 9 |
| Steudelli | rh 5, rh 6 |
| Atlas 46 | Rh |
| Modoc | Rh 2, rh 6 |
| Nigrinudum | rh 8 |
| Turk | Rh, rh 6 |

Appendix
Table 87. Seedling reactions of barley cultivars to isolates of scald, *Rhynchosporium secalis*.

| Cultivar | Isolate | | | |
|---|---|---|---|---|
| | Creston, MT | Lewistown, MT | Lebanon | Turkey |
| Atlas 46 | 0* | 0 | 0,1 | 0 |
| La Mesita | 0 | 0 | 0 | 0 |
| Trebi | 1,2 | 1 | 1,2 | 1 |
| Osiris | 0 | 0 | 0 | 0 |
| Jet | 1 | 1 | 1 | 1 |
| Steudelli | 1 | 1 | 1 | 1 |
| Kitchin | 0,1 | 0 | 0 | 0,1 |
| Modoc | 1 | 1 | 1 | 1 |
| Brier | 0 | 0 | 0 | 0,1 |
| Betzes | 2 | 3 | 3 | 2 |
| Bonus | 2,3 | 3 | 2,3 | 3 |
| Hannchen | 3 | 3 | 3 | 3 |

* 0 = (very resistant) no symptoms observed
1 = (resistant) small brownish lesions on tips or margins of leaves
2 = (intermediate) marginal lesions extended in length and/or well-developed "scald" lesions
3 = (susceptible) leaves collapse and wilt.

Appendix Table 88. Scald reaction class frequencies of $F_2$ seedlings of the Betzes primary trisomics x Kitchin.

| Trisomic | Reaction Class Frequencies 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 |

+ (0,1,2):(3)

** significant at 1% confidence level

Appendix Table 89. Scald reaction class frequencies of $F_2$ seedlings of the Betzes primary trisomics x Jet.

| Trisomic | Reaction Class Frequencies 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 | 396 | 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 |

+ (0,1):(2,3)

** Significant at 1% confidence level

Appendix 90. Net blotch reaction class frequencies of $F_2$ seedlings of the Betzes primary trisomics X Tifang.

| Trisomic | Reaction Class Frequencies 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 |

+ (0,1,2,3):(4)

** Significant at 1% confidence level

Appendix Table 91. Net blotch reaction class frequencies of $F_2$ seedlings of the Betzes primary trisomics X C.I. 7548

| Trisomic | Reaction Class Frequencies 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 |

+ (o,1,2,3):(4)

** Significant at 1% confidence level

Appendix Table 92. Net blotch reaction class frequencies of $F_2$ seedlings of the Betzes primary trisomics X C.I. 9819

| Trisomic | Reaction Class Frequencies 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‡ |
| 6 | 159 | 108 | 21 | 288 | .533 |
| 7 | 90 | 91 | 16 | 197 | 1.178 |

+ (0,1,2,3:(4)

‡ P = .05-.10

** significant at 1% confidence level

Appendix Table 93. Scald reactions of $F_3$ lines of crosses between T3 translocations and scald resistant cultivars (fertile plants).

| Dross | No. of $F_3$ lines homozygous resistant | segregating | homozygous susceptible | Total |
|---|---|---|---|---|
| T1-3c x Modoc | 19 | 9 | 22 | 50 |
| T1-3e x Atlas 46 | 12 | 3 | 18 | 33 |
| T1-3f x Osiris | 17 | 4 | 27 | 48 |
| T1-3k x Atlas 46 | 23 | 1 | 26 | 50 |
| T2-3e x Modoc | 23 | 4 | 23 | 50 |
| T2-3f x Atlas 46 | 20 | 4 | 25 | 49 |
| T3-4d x Atlas 46 | 21 | 2 | 26 | 49 |
| T3-6c x Modoc | 16 | 5 | 29 | 50 |
| T3-7d x Atlas 46 | 43 | 1 | 6 | 50 |

Appendix Table 94. Progress in inducing lethals in the intersticial segment of a number of translocations.

| male sterile x Translocation cross | Number of Potential Lines | | | |
|---|---|---|---|---|
| | Translocation Homo-zygote lethal | Haplo-viable | Apomictics ? | Other Genetic Materials |
| msg 10 x T 1-3e | 7 | | | |
| " 1-4e | 4 | 3 | | |
| " 1-5f | 8 | 3 | | 4 |
| " 1-6a | 8 | 6 | 1 | 4 |
| " 1-6e | 6 | 3 | 1 | 1 |
| " 1-6j | 3 | 6 | 1 | 5 |
| " 1-7c | 9 | 5 | | 3 |
| " 1-7i | 4 | 1 | | 1 |
| " 1-7k | 13 | | | 3 |
| msg 2 x T 2-4a | 9 | 3 | 1 | 6 |
| " 2-4d | 20 | 13 | | 9 |
| " 2-5a | 6 | 3 | 9 | 2 |
| " 2-5e | 7 | 2 | 3 | 5 |
| msg 5 x T 3-4b | 5 | 3 | 1 | 2 |
| msg 1 x T 4-5e | 7 | 9 | 1 | 15 |
| " 5-6d | 7 | 6 | 5 | 3 |
| " 5-7g | 16 | 1 | | 3 |
| msg19 x T 4-7b | 6 | 2 | 2 | |
| msg 6 x T 6-7c | 13 | 6 | 1 | 3 |

Appendix 95. Reaction of two broad-based populations to three diseases

| Population | Reaction | Stem Rust | Scald | Net Blotch |
|---|---|---|---|---|
| CC XXX-F | Resistant | 4.5% | 34.5 | 16.9 |
| | Intermediate | 5.2 | 7.6 | 30.5 |
| | Susceptible | 90.2 | 57.9 | 52.6 |
| World Collection (spring) | Resistant | 5.8 | 20.3 | 20.0 |
| | Intermediate | 4.2 | 14.3 | 39.3 |
| | Susceptible | 90.0 | 65.4 | 40.8 |

Appendix
Table 96. Seedling reaction to several diseases of entries in the Elite Barley Yield Trial (EBYT, Early), 1976.

| Entry | Variety | Stem Rust | Leaf Rust | Scald | Net Blotch | Pseudomonas | Stripe Rust | BSMV seed contam. |
|---|---|---|---|---|---|---|---|---|
| 1. | CM-67-11016.2 | MS | R | S | R | S | R | O |
| 2. | 11016.2-Weeah | S | MR | S | I | S | R | O |
| 3. | Por x Ds-Apro/CM67-Dwg2 | S | S | S | MR | S | R | O |
| 4. | CM67-U. Sask. 1800 x Pro-CM67 | S | MR | S | R | S | R | O |
| 5. | Porvenir | S | MR | S | MR | S | R | O |
| 6. | Apam-Godiva | MS | R | S | I | S | R | O |
| 7. | Mona-Arivat | S | MR | I | I | S | R | O |
| 8. | Apam-RL x Apam - Dwarf II-1Y | MR | R | S | I | S | R | O |
| 9. | Candelilla "S" | I | R | S | I | S | R | O |
| 10. | 11012.2 | S | I | S | I | S | R | O |
| 11. | M66.95-M66.123 x BGS 0252 | R | R | S | I | S | R | O |
| 12. | Hja C4715 x Olli - M64.69 | MR | R | S | MS | S | R | O |
| 13. | Hja C4715 x Olli - M64.69 | MR | MR | S | S | S | R | O |
| 14. | M66.83 - Larker L.S. x Apam-RL | MR | R | S | MR | S | R | O |
| 15. | Mona | S | R | S | S | MS | R | O |
| 16. | M66.83 - Larker L.S. x Apam-RL | MR | R | S | MR | S | R | O |
| 17. | Apam-RL x Kristina | MR | R | S | MR | S | R | O |
| 18. | Mari - Coho | R | R | S | S | S | R | O |
| 19. | M65.167-M66.69.1 x Mona | MR | R | S | MS | MS | R | O |
| 20. | S. Precoz (2h) | S | I | S | S | S | R | O |
| 21 | CR115-Por x S. Precoz (6h) | I | R | S | MS | S | R | O |
| 22. | ER-Apam | S | I | S | I | S | R | O |
| 23. | ER-Apam | S | MS | S | MR | S | R | O |
| 24. | M69.69 x Apam-RL | S | S | S | MS | S | R | O |

R = resistant
MR = moderately resistant
I = intermediate
MS = moderately susceptible
S = susceptible
O = no BSMV seed contamination

Table 97. Inheritance of barley stripe mosaic resistance in a Modoc x Vantage cross and the reciprocal.
$F_2$ genotype determinations from $F_3$ family data.

| Cross | Ratio tested | Observed frequency | | P for fit |
|---|---|---|---|---|
| | | Seed transmission | No seed transmission | |
| MSV | 3:1 | 910 | 307 | .80-.95 |
| VXM | 3:1 | 280 | 122 | .05-.01 |

Trip Report: VISIT TO CIMMYT - MEXICO D. F. MEXICO

Date: June 28, 1976

Name of people, title:

Charles F. McGuire, Associate Professor of Agronomy
C. W. Newman, Professor of Animal Science

Period of Travel: June 11-17, 1976

Itinerary: Bozeman - Denver - Mexico City
Return by the same route

Purpose:

Discuss with biochemist in charge, Dr. Eva Villegas, the microbiological assay of barley for its lysine content. We further were to discuss with Dr. Villegas and her group the results of animal nutrition studies being conducted at MSU. A third objective of our visit was to coordinate communications with barley workers at CIMMYT in the planning and execution of an International Barley Improvement Workshop in 1977 somewhere in the Near East.

Persons contacted: At CIMMYT we visited extensively with:

Dr. Eva Villegas
Dr. Arnold Amaya
Dr. Glenn Anderson
Dr. Reinald Bauer
Enrique Ortega
Jese Angel Guarez
Juan Luis Juarez
Jaime L. Cessati
Rigoberto Valenzuela

Informally we met and visited with Dr. Santiago Fuentes, a wheat plant pathologist at CIMMYT and Dr. Uriel Maldonado who is Assistant Director of Extension Service for Mexico. We paid courtesy calls on Dr. Keith W. Finley, Deputy Director Outreach & Special Programs, Dr. Robert D. Ostler, Deputy Director Resident Programs.

Results of our trip:

We did introduce the microbiological assay by use of a slide series. Good relationships were established that will allow a free exchange of information and samples relative to lysine work being conducted by MSU and CIMMYT. A procedure for measuring Tryptophan was obtained from Dr. Villegas which will be of value in Dr. Newman's nutrition studies.

Discussions were held with Dr. R. Glenn Anderson, Associate Director of Wheat Headquarters Staff pertaining to the proposed International Barley Improvement Workshop. His recommendations were to get the people involved who are in the target region. Be sure they are

participants on the program and active in the planning for the workshop. Obtain names and addresses of all professionals active in barley improvement in target countries so they may be invited to participate.

Follow up and action required:

We should extend to Dr. Villegas a formal invitation to visit our campus. She should be invited to come and observe first hand the operation of the microbiological assay. While here she should be invited to present seminars to staff and students in Plant & Soil Science and in Animal Science. The topics should be methodology for lysine screening at CIMMYT.

We need to supply Dr. Villegas with detailed costs of materials used in the microbiological assay so that some estimate of the cost per sample can be computed. The major advantages and disadvantages of procedure compared to the chemical method for lysine assay now in use at CIMMYT need to be prepared for Dr. Villegas. We have enumerated the advantages of the microbiological assay as compared to the Amino Acid Analysis. The accuracy and precision of the microbiolical assay need to be documented for Dr. Villegas.

Planning for the International Barley Improvement Workshop should be done relying heavily on J. P. Srivastava - ICARDA, Cairo. He knows the workers in the area and can be of great help. Follow up on the selection of a suitable location for the workshop should be done, possibly Syria, Iraq or Tunisia.

Comments on discussions with Dr. Glenn Anderson:

Dr. Anderson listed areas of the world where some barley improvement efforts are under way. In North Africa: Morocco, Algeria, Tunisia, and Lybia. Some work is being done in Turkey, Syria and Jordan. Very little work in E. Africa. Some in Kenya and Ethiopia. In South America work is being done in Ecuador, Bolivia, and Peru. These nations are in addition to those listed in the "Proposed Program". Dr. K. B. L. Jain considered an authority on Barley in India should be included.

Dr. Anderson recommended that the conference be in English. C. W. Cho would thus be a questionable participant because of lack of English. A possible replacement would be Choi, an economist from Korea, who is Omar Kelly's counterpart.

Site Selection:

Cairo and Teheran are both in a very critical situation for hotel accommodations. Both cities have absorbed many people from Beirut. Even reservations made six months ahead may not be honored.

Dr. Anderson questioned his participation on the workshop program. He is convinced that more positive results will come from more active local participation.

# REPORT ON TRAVEL AND VISITS IN THE MIDDLE EAST REGARDING THE IMPROVEMENT OF THE NUTRITIVE QUALITY AND PRODUCTIVITY OF BARLEY FOR SEMIARID REGIONS

AID/ta - C - 1094

February 25 - March 24, 1977

Dr. T. W. Carroll, Professor of Plant Pathology, Department of Plant Pathology, Montana State University

Dr. E. A. Hockett, Research Agronomist (Barley Breeder and Geneticist), USDA, ARS, Department of Plant and Soil Science, Montana State University.

ITINERARY:

Depart Bozeman, February 25, overnight Billings.
Depart Billings, February 26, arrive in Minneapolis, February 26.
Depart Minneapolis, February 26, arrive in New York, February 26.
Depart New York, February 26, arrive in Casablanca, February 27.
In Morocco, February 27 - March 3.
Depart Casablanca, March 3, two hour layover in Madrid.
Depart Madrid, March 3, arrive Rome.
In Italy, March 3 - March 6.
Depart Rome, March 6 and arrive in Tunis, March 6.
In Tunisia, March 6 - March 9.
Depart Tunis, March 9, overnight in Rome.
Depart Rome, March 10, arrive in Cairo, March 10.
In Egypt, March 10 - March 14.
Depart Cairo, March 14, arrive in Damascus, March 14.
In Syria, March 14 - March 17.
Depart Damascus, March 17, arrive in Istanbul, March 17.
Depart Istanbul March 17, arrive in Ankara, March 17.
In Turkey, March 17 - March 23.
Leave Ankara, March 23, overnight in Frankfurt.
Depart Frankfurt, March 24, arrive Bozeman, March 24.

PURPOSE OF THE TRIP:

1. To make germplasm and technical knowledge available.
2. Determine, in so far as possible, the current status of barley research in the developing countries.
3. To increase the awareness of the barley project among overseas barley workers and administrators.
4. Evaluate the barley plant disease situation and collect specific plant pathogens from areas not previously visited by scientists on this project. Special emphasis to be placed on barley stripe mosaic virus and barley yellow dwarf virus and their diagnosis and control.
5. Evaluate the male sterile-facilitated recurrent selection population, $76RSP\text{-}5RrsF_2AF_2$ for resistance to scald.
6. To acquaint the breeders and data analysis personnel with the Montana-ARS regression analysis program for variety evaluation and recommendation.

## ORGANIZATIONS AND PERSONS CONTACTED:

### Morocco

1. Institut Agronomique et Veterinaire Hassan II, Rabat.

   Dr. John Caddel, Asst. Prof., Dept. of Agronomy and Plant Genetics, Univ. of Minnesota on USAID contract to Morocco.

2. Ecole Nationale d'Agriculture, Meknes.

   Mr. Mohammed Boulif, Instructor (conducting some research on Helminthosporium gramineum).

3. Ministere de l'Agriculture, Station Experimentale, Merchouch (office, Rabat).

4. AID -- Rabat.

   Dr. G. (Jerry) Neptune, Agricultural Development Officer.
   Mr. Mohammed Hanafi, Assistant to Dr. Neptune.

### Rome

1. FAO, Plant Protection Service, Plant Production and Protection Division.

   Dr. Luigi Chiarappa, Senior Plant Pathologist.
   Dr. Alex Bozzini, Chief Crops and Grassland Protection Service.
   Mr. H. Al Jibouri, Senior Officer for Field Food Crops.

### Tunisia

1. AID - Tunis.

   Dr. Carl E. Ferguson, Agricultural Development Officer.
   Mr. Salah Mahjoub, Assistant to Dr. Ferguson.

2. Office of Cereals -- Tunis.

   Mr. Tousti, Head, Technical Division.

3. INRAT, Tunis.

   Mr. Stomrad, Director.
   Mr. Allala Ghodbane, Wheat Pathologist, Field Survey.
   Mr. Mahmoud Deghais, Barley Breeder until M. Harabi returns from OSU.

4. INRAT, Tunis.

   Dr. M. Djerbi -- Plant Pathologist.
   Dr. Habib Ketata - Head, Genetics Laboratory (Wheat breeder).
   Mr. Hub Stoetzer - Dutchman working with Djerbi on the FAO Horizontal Resistance Project for Wheat Rusts.

Tunisia - Continued

5. Mateur Lycee Agricultural High School, Mateur.

6. Fretissa Pilot Farm, near Mateur.

   Mr. Rondia, European Chef de Station.
   Mr. Mustaphe Ghabli, Tunisian Chef de Station de Fretissa.

7. Beja Experiment Station, Beja.

8. Tunisian Government Cooperative Farm - near El Fahs (Cospos).

9. Hindi Zitoun Experiment Station - Agricultural Engineering (Irrigated Station), near Kairouan.

Egypt

1. ICARDA, Cairo - Aleppo, Syria.

   Dr. Jit P. Srivastava, Breeder, Winter Cereals.
   Dr. Owen L. Brough, Assistant Director, ICARDA.

2. Ford Foundation, Cairo

   Dr. Gordon MacClean, Director
   Dr. Pearl Bronzi, Agric. Prod. Officer for Middle East.

3. Egyptian Ministry of Agriculture, Agricultural Research Station, Giza.

   Mr. N. Farid, Director, Field Crops Research.
   Dr. T. A. Hak, Director, Plant Pathology.
   Dr. Abdul S. Gomaa, Director Wheat Research.
   Dr. Ahmod Mansour, Director Barley Research.
   Dr. E. Ghobrial, Senior Plant Pathologist.
   Dr. M. I. Khalifa, Barley Plant Pathologist.
   Dr. A. H. Kamel, Director, Wheat Disease Research.
   Professor H. M. El Said, Head, Dept. of Agricultural Botany, Faculty of Agriculture, Zagazig University, Zagazig. (Plant Virologist).
   Mr. Abdul Hafiz, Project Manager, Regional Project Field Food Crops, FAO.

4. Bahteem Experiment Station, Central Station.

   Dr. Imail E. Darrag, Director (Plant Pathologist).

5. Sakha Experiment Station, Sakha.

   Dr. Bishr, Director Maize Breeder.
   Mr. Farid Azer, Barley Breeder-Assistant.
   Mr. Khalid Mostafa, Barley Breeder-Assistant.
   Mr. Abdrabboh Abdelaziz, Barley Breeder-Assistant.

Syria

1. AID, Damascus.

   Dr. Nassib Hemaidan, Chief, Office of Technical Assistance.

2. The Arabe Center, The League of Arab States, (ACSAD--Arab Center for Semi-Arid Development) Douma (near Damascus).

   Dr. Iamil A. Quhaiwi, Director of Plant Sciences (to be replaced by Dr. S. N. Dessouki (Egyptian) in June, 1977).
   Dr. Mohammed Loulou Roushdi Morsi, Barley breeder.

3. Syrian Ministry of Agriculture, Agricultural Research Center, Douma (near Damascus).

   Mr. Walid Malik, Deputy Director for Agricultural Research.

4. ICARDA, Barley Workshop Nurseries and Germplasm, Muslimieh (near Aleppo).

   Dr. Shawki Barghouti, Mass Communication Officer.
   Mr. Omar Jarikji, Research Assistant to Srivastava.
   Mr. Midami, working with Barghouti to set up ICARDA in Syria.
   Mr. Ghassan Avis, Assist. on Winter Cereals.

Turkey

1. Aegaen Regional Research Centers, Menenmen, Izmir.

   Mr. Kasif Temiz, Director.
   Mr. Fikret Demirkan, Barley Breeder.
   Dr. Alpaslan Kircalioglu, Statistician and Programmer.
   Dr. Serife Ince, Barley Pathologist.
   Mrs. Sena Uraz, Barley Pathologist.
   Mrs. Inci Baydan, Barley Pathologist - Agronomist.
   Mr. Suleyman Güzel - Barley Breeder and Geneticist.

2. Eskisehir Regional Research Center, Eskisehir.

   Mr. M. Nuri Taysi, Director, Wheat Breeder.
   Mr. Bahattin Erginel, Barley Breeder.
   Dr. Fahri Altay, Cereal Pathologist.

3. National Directorate of Agriculture, Ankara.

   Dr. Mehmet Kiroglu, Director
   Mr. Alpaslan Pehlivanturk, Assistant Director
   Mr. Mümin Kara, Economist
   Mr. Basri Devecioglu, Director Wheat Program

4. Wheat Research and Training Center, Rockefeller Foundation, Ankara.

   Dr. Bill C. Wright, National Program Director.
   Mr. Ali Bayraktar, Principal Wheat Breeder.

Turkey - Continued

5. Haymana Experiment Station, near Ankara

## PLANT DISEASE SUMMARY:

### Morocco

In visits to farmers' fields and experimental plots, the prevalent diseases noted were: net blotch, scald, Helminthosporium stripe, and powdery mildew. Other diseases seen were: loose smut, spot blotch, Septoria leaf blotch, leaf rust, and barley yellow dwarf.

### Tunisia

The principal diseases observed in barley plots in Tunisia were: net blotch, Helminthosporium stripe, barley stripe mosaic, scald, and powdery mildew. These same diseases and loose smut, covered smut, leaf rust, and barley yellow dwarf occurred in commercial plantings of barley.

### Egypt

Diseases present in experimental nurseries included net blotch, leaf rust, powdery mildew, covered smut, barley stripe mosaic, Helminthosporium stripe, and barley yellow dwarf. Trace amounts of stem and stripe rust were also visible.

### Syria

In the nurseries and germplasm plots at Muslimieh, near Aleppo, powdery mildew, scald, spot blotch, Helminthosporium stripe, and an unidentified crown rotting disease were evident.

### Turkey

Powdery mildew, scald, spot blotch, and leaf rust were the diseases seen in b ley plots and farmers' fields in the Aegean Coastal Region near Izmir. Spot blotch, and scald were present in both experimental and commercial plantings of barley in the Eskisehir Region. Scald was the only disease of any consequence found in experimental nurseries at Haymana Station near Ankara.

Sixty-one plant pathogen samples were collected under APHIS permit from the above countries for isolation and for identification. Distribution of the samples based on origin was as follows:

Morocco - 39
Tunisia - 12
Egypt - 7
Syria - 1
Turkey - 2

Results of the isolation and identification of pathogens from these samples to date are listed below:

Net blotch fungus - 12
Helminthosporium stripe fungus - 9
Scald fungus - 7
Leaf rust fungus - 5
Septoria tritici fungus - 1
Barley stripe mosaic virus - 6 (2 from Tunisia and 4 from Egypt).

## PLANT BREEDING SUMMARY

The principal agronomic problems needing attention were as follows:

### Morocco

Since barley is grown mostly in drier regions, greater drought resistance either through earliness or tolerance is needed. In some higher rainfall areas the land varieties grown need greater lodging resistance and shorter height. Higher nutritional value would be desirable, although this question needs further investigation since the barley is probably eaten mixed with wheat flour in bread or is used as pulverized grain in stews (mixed with meat, vegetables and/or food legumes). Hulless barley may be desirable for the latter use. Better agronomic practices are necessary in some regions before high yield can be obtained with any variety.

### Tunisia

Drought resistance is needed since the bread wheats are pushing the durum wheats into drier areas and the durum wheat is pushing the barley into the driest marginal rainfall areas. Salty land is another area where barley is grown so better varieties for this use are needed. A better brewing variety is also needed.

### Egypt

Varieties for the irrigated areas need higher yield potential, straw stiffness and salt tolerance. In the rainfed area along the coast drought resistance and salt tolerance are the major problems. Varieties more tolerant of animal grazing would be of value in both areas. More work could be expended on an adapted malting variety.

### Syria

The major needs in barley varieties are drought resistance (they said earliness) and salt tolerance for the arid zones. Since they import the malting barley used an adapted brewing barley would be useful.

### Turkey

In the coastal areas where spring types are grown in the winter, the major needs are higher yield combined with easy threshing and straw strength. The central plateau where the winter barley is grown could

use varieties with better hardiness, lodging resistance, drought resistance, and higher yield potential when fertilized. If a high yielding malting variety was developed this might lead to increased export of barley.

## IMPRESSIONS AND RECOMMENDATIONS - PLANT DISEASES

It appears that the best approach to the control of barley diseases in North Africa and the Middle East would be through the vehicle of CIMMYT and ICARDA. National barley programs in the LDC's and the barley improvement projects of Montana State University, the Arab League FAO, CIMMYT, and ICARDA, could interact to produce and distribute disease resistant selections. Immediate emphasis should be placed on developing resistance to net blotch, scald, Helminthosporium stripe, powdery mildew, leaf rust, and barley yellow dwarf. Control of barley stripe mosaic virus could be accomplished mainly by planting virus-free seed. Roguing to eliminate symptomatic plants from breeding stock in field plots could be done on a national program basis and at ICARDA, and serodiagnosis of seed lots could be performed in some central clearing laboratory which could be established at either CIMMYT or ICARDA.

## IMPRESSIONS AND RECOMMENDATIONS - PLANT BREEDING

In these developing countries the breeder will have to breed varieties for the conditions as they are now or are likely to be in the near future, not for conditions as he thinks they should be to attain maximum yield. There are many social or economic reasons why the farmers farm as they do, such as lack of capital, lack of knowledge, size of farm, population density, etc. If these conditions are improved the breeding program may need to produce another type of barley adapted to large fields, intensive application of fertilizer and herbicides, and mechanical harvesting.

Some possible improvements which could be made at this time in individual countries are:

1. Train more scientists in breeding, pathology, agronomy, soils, physiology, nutrition, etc. for a team approach.
2. Adjust personnel payment system so best scientists can continue to work on breeding program and not go into administration or international programs to advance.
3. Full time barley breeders should be hired not utilize wheat breeders part time.

As well as improvement in the agronomic characteristics mentioned disease resistance needs to be incorporated in all new barley varieties. Therefore a barley breeder will have to be half plant pathologist or better yet, closely associated with a plant pathologist in a team effort. The international programs now concerned with barley improvement in these developing countries should cooperate more fully and cease duplication of effort. Each individual country could best accomplish its long term goals through cooperation with International Center for Agricultural Research in Dry Areas (ICARDA). Technical input could be made by: Montana AID, CIMMYT, European, and other developed countries assistance programs - through ICARDA.