



ORGANIC FARMING RESEARCH FOUNDATION

Organic farming research project report submitted to the Organic Farming Research Foundation:

Project Title:

Small Grain Cultivar Selection for Organic Systems

FINAL PROJECT REPORT

OFRF project number: 01-f-19

Submitted: June 2003

Principal investigator:

Patrick Carr
North Dakota State University
1089 State Avenue
Dickinson, SD 58601
tel. (701) 483-2581
pcarr@ndsu.nodak.edu

Co-investigators:

Brad Brummond, Walsh County Extension Educator, Park River, ND
Tonya R. Haigh
Herman J. Kandel, Extension Educator, Red Lake Falls, MN
Paul M. Porter, Associate Professor, Dept. of Agronomy and Plant Genetics, University of Minnesota
Steve F. Zwinger, Research Specialist, Carrington Research Extension Center, Carrington, ND

Funding provided by OFRF: \$7,706

Project period: 2002

Organic Farming Research Foundation

P.O. Box 440
Santa Cruz, CA 95061
tel. 831-426-6606
email research@ofrf.org
web www.ofrf.org

SUMMARY

The current selection criteria used for the development of modern small-grain cultivars is based on performance in environments where synthetic fertilizers and pesticides are applied to minimize nutrient deficiencies and pests. Cultivar performance in these environments may not be applicable to organic environments where only approved inputs and mechanical weed control are used. Our objective was to identify hard red spring wheat (*Triticum aestivum* L. emend. Thell.), barley (*Hordeum vulgare* L.), and oat (*Avena sativa* L.) cultivars that are adapted to environments managed organically in the northern Great Plains. Thirteen spring wheat and 10 oat cultivars representing a diverse pedigree were included in adaptation studies at two Minnesota (MN) and two North Dakota (ND) on-farm locations in 2002. Seed lots produced under both conventional and organic management were included for two wheat cultivars at all four locations and for two oat cultivars at two locations. Five barley cultivars also were compared at one ND location. Wheat grain production ranged from 13 to 31 bu/acre across cultivars and locations ($P < 0.05$). Oat yield ranged from 38 to 64 bu/acre. There was a significant interaction between location and cultivar for most crop traits measured, including grain yield. Yield ranged from 38 to 47 bu/acre among cultivars at the single location in ND where barley cultivars were compared. Grain yield and quality of modern small-grain cultivars were better than or equal to grain yield and quality of older cultivars at each location. Crop performance differed when two seed lots of the same cultivar were compared for both wheat and oats. Results of this preliminary study support the hypothesis that grain yield and quality may be maximized when modern rather than older commercial cultivars are grown in organic environments. The value of using high-quality seed lots for superior small-grain crop performance also was reinforced in this project.

INTRODUCTION

North Dakota leads the nation in planted acreage of organic grain crops, including spring wheat and oats. Almost 64,000 acres were devoted to organic production of grain crops in the state in 2001 (ERS, 2002). In addition, almost 46,000 acres were planted to grains managed organically in Montana and about 42,000 acres in MN. These production data demonstrate the preeminence of the northern Great Plains among agro-climatic zones within the USA for organic grain crop production. More importantly, organic acreage of cereals continues to increase in ND and neighboring states.

The development and selection of modern small-grain cultivars generally occurs in environments where synthetic fertilizer and pesticides are used to minimize nutrient deficiencies and pests. Many organic producers of small-grain crops would prefer to have access to modern cultivars that have been selected specifically for organic environments, but such cultivars are not available (B. Schmaltz, personal communication, 2003). Some organic agriculturists grow cultivars developed prior to the widespread use of synthetic agri-chemicals. These agriculturists believe that older cultivars are adapted better to organic environments than modern cultivars, even though results from adaptation studies in conventional environments indicate that old cultivars generally do not perform as well as modern cultivars (P.M. Carr, unpublished data).

Organic agriculturists expressed the need for adaptation studies to land grant scientists at North Dakota State University (NDSU), beginning in 2000. In response, a limited number of modern spring wheat and oat cultivars were compared in MN and ND in 2001. Funds provided by the Organic Farming Research Foundation and the Wheat Subcommittee of the North Dakota State Board of Agricultural Research and Education allowed expansion of this effort in 2002.

OBJECTIVES STATEMENT

The objectives of this project were to:

- i. Determine if modern spring wheat, oats, and barley cultivars are better adapted than old cultivars to organic environments.
- ii. Determine if natural adaptation occurs after small-grain cultivars are introduced into organic environments.
- iii. Identify growth traits and agronomic characteristics that result in superior cultivar performance in organic environments.

MATERIALS AND METHODS

Fourteen to 18 cultivars of hard red spring wheat were included in field experiments in certified organic fields on commercial farms near Comstock (46° 40' N, 96° 45' W, elevation: 930 ft) and Fertile (47° 32' N, 96° 17' W, elevation: 1144 ft) in western MN, and Fullerton (46° 10' N, 98° 26' W, elevation: 1455 ft) and Richardton (46° 53' N, 102° 19' W, elevation: 2470 ft) in south central and southwestern ND. Thirteen of the cultivar entries occurred in each field experiment. The cultivars represented both private and public breeding programs active in the region, were developed and released over several decades, and varied in selected crop traits (Table 1). Three of the cultivars were released prior to 1970 and were considered old cultivars for purposes of this study; the remaining 10 cultivars were classified as modern. Similarly, 10 to 13 oat cultivars were included in field experiments at the four locations and 10 of the cultivars occurred in each of the experiments. The oat cultivars differed in place of origin, year of release, and selected crop traits (Table 2), although not to the extent as with the wheat cultivars. For example, no oat cultivars released prior to 1970 were included because seed lots of older cultivars in the amounts needed for inclusion in the field experiments could not be obtained. Five barley cultivars were compared in a field experiment at the Richardton, ND location (Table 3). As with oat entries, barley cultivars released prior to 1970 were not included because seed lots of older cultivars were unavailable.

The same seed lot was used for a cultivar entry at all locations included in the project, although various sources were relied upon to provide the seed lots that were used. Most of the wheat seed lots were provided by certified organic agriculturists, although the conventional seed lot along with the organic seed lot were included for the wheat cultivars Parshall and Stoa. Conversely, most of the oat seed lots included in the field studies were produced under conventional management because sources of organic seed lots of cultivars

generally were not yet available. However, organic seed lots of two oat cultivars (Hytest and Otana) were acquired and were included in field studies along with conventional seed lots of these same two cultivars at the two ND locations. All of the barley seed lots included in the field experiment were produced under conventional management. The conventional seed lots of wheat, oat, and barley cultivars were provided by the Foundation Seedstocks Programs at NDSU, the MN Crop Improvement Association, certified seed growers, and from plant breeders at the land grant institutions in MN, ND, and South Dakota.

Seed beds were prepared by cooperating organic agriculturists following standard practices on each farm and varied by location. A 3 ton/acre application of turkey manure was applied at Fertile, MN and 900 lb/acre of 'cluck' (4-4-2) was applied at Comstock, MN prior to cultivating fields with a chisel plow in the fall of 2001. A light cultivation to firm and level the seedbeds preceded planting in the spring at both locations, followed by two light, post-plant harrowing operations to control early-emerging weeds. Soybean (*Glycine max* L.) was grown the preceding year at both locations in MN. Oats and yellow-flowered sweetclover (*Melilotus officinalis* Lam.) were green manured at Fullerton and Richardton, respectively, in North Dakota. Seedbeds were firmed and leveled with a light cultivation the following spring just prior to planting. No post-plant harrowing occurred at either location in North Dakota after the field experiments were established.

Cultivar treatments were established by sowing wheat and barley entries at 1.6 million pure live seed (PLS)/acre. A 1.6 million PLS/acre sowing rate was used to establish oat cultivar treatments at both MN locations and at Fullerton. Oat cultivar treatments were established using a 1.4 million PLS/acre sowing rate at the Richardton site. The field experiments were established on 17 May at Comstock, 27 May at Fertile, 14 May at Fullerton, and 15 May at Richardton. Individual plots dimensions were at least 4 by 20 ft and consisted of seven to nine rows. Plots were arranged in a randomized complete block with cultivar treatments replicated four times.

Emerged small-grain seedlings were counted at three of the four locations and seedling vigor was rated (1 to 9 scale; 1 = low vigor and 9 = high vigor) at all four locations for wheat and oats at around 15 days in each plot. Small-grain seedlings were counted and seedling vigor was rated in all plots for barley at Richardton. Plant height at physiological maturity was determined in each plot at all four locations for wheat, at two of the four locations for oat, and for barley.

Yield was determined by harvesting grain from all rows in each plot with a small-plot research combine. Grain test weight was determined from sub-samples. Grain protein concentration was determined from separate sub-samples by near-infrared spectroscopy. Grain was harvested from plots on 19 August at Comstock, 23 August at Fertile, 14 August at Fullerton, and 13 August at Richardton.

Additional data were collected in wheat, oat, and barley field experiments including days to crop emergence, plant height at various growth stages, and dry matter of small-grain crops and weeds. Rating systems were used to evaluate plant canopy development, weed growth,

and disease pressure within plots. However, these data were not collected at a majority of locations and so are not discussed in this report.

Data were analyzed across locations by means of the GLM procedure available from SAS (SAS Institute, 2001). Cultivar treatments were considered fixed effects while locations and blocks were considered random. Mean comparisons using a protected LSD were made to separate cultivar treatments where *F*-tests indicated that significant differences existed ($P < 0.05$). Data were analyzed within each location for any factor when the location by cultivar interaction was significant, or for all factors with barley since only one field experiment occurred.

RESULTS

Wheat

Cultivars differed in agronomic traits across the four locations included in this project (Table 4). Plant stand ranged from 18 to 33 seedlings/ft², seedling vigor rating from 2 to 8, plant height from 26 to 34 inches, grain yield from 13 to 31 bu/acre, grain protein concentration from 15 to 18%, and grain test weight from 54 to 59 lb/bu among cultivars (Table 5). Cultivar comparisons across locations were confounded by the presence of a location H cultivar interaction for vegetative and reproductive growth traits. Therefore, cultivars were compared within each of the four locations.

A consistent trend between the era of cultivar development and crop seedling numbers did not occur within the three locations where seedlings were counted. For example, fewer seedlings occurred for the old cultivar Red Fife compared with many modern cultivars at Fertile (Table 6). However, more seedlings occurred for Red Fife than for the modern cultivars Glupro and Reeder Richardton, along with Stoa when the conventional seed lot was used. 'Waldron' had equal or greater numbers of seedlings compared with other cultivars at each of the three locations. These data suggest that seedlings can be as numerous when seed lots of old cultivars are used as when seed lots of modern cultivars are sown.

Differences did not exist in seedling numbers when the organic and conventional seed lots of the cultivar Parshall were sown (Table 6). However, more seedlings resulted when the organic seed lot of Stoa was used compared with the conventional seed lot at all locations. These data demonstrate the impact that seed lot quality may have on seedling establishment.

Seedling vigor was equal or greater for the modern cultivar Gunner compared with other cultivars at each of the four locations, along with Parshall when the organic seed lot was used (Table 6). Seedling vigor of these two cultivars generally was superior to seedling vigor of the old cultivar Red Fife. However, differences in seedling vigor generally were not detected between Gunner and Parshall and the old cultivar Waldron. Moreover, vigor of Waldron seedlings was superior to the seedling vigor of the modern cultivar Glupro at three locations. These data demonstrate that a consistent trend on seedling vigor was not detected by the eras of cultivar development represented in this study.

Seedling vigor was greater when the organic seed lot of Parshall was used compared with the conventional seed lot of Parshall at only one of the four locations (Table 6). In contrast, greater seedling vigor occurred when the organic seed lot of Stoa was used compared with the conventional seed lot at three of four locations. These data indicate that seedling vigor may be affected by the seed lot of a particular cultivar being evaluated.

A consistent trend in plant height for the era of cultivar development was not detected for cultivars considered to be tall statured (Table 1). For example, differences in height between plants of Red Fife and the modern cultivar Glupro were not detected at three of four locations (Table 6). Likewise, height differences between plants of Glupro and of the old cultivar Chris were detected at only one location.

Chris, Red Fife, and Glupro are classified as tall statured cultivars (Table 1). Waldron also is classified as tall statured, but plants of Waldron were shorter than plants of Red Fife at three of the four locations (Table 6). Similarly, taller plants occurred for 'Ingot' compared with plants of 'Alsen', 'Reeder', and 'Walworth' at three of four locations, even though all four cultivars are classified as semi-dwarf in stature (Table 1). These data indicate that plant stature classification of cultivars may not be consistent in all environments.

Differences in plant height were not detected between plants using different seed lots of the same cultivar (Table 6). For example, plant heights were similar for the cultivar Parshall established using the organic seed lot and the conventional seed lot. Similarly, differences in plant height were not detected when Stoa was established using the organic seed lot and the conventional seed lot. These data suggest that plant stature may be less sensitive to differences in seed lot quality than the other agronomic traits considered in this project.

Highest grain yields generally occurred with modern cultivars compared with old cultivars (Table 7). For example, Parshall produced more grain than other cultivars at Comstock when the organic seed lot of Parshall was used, except for Ingot and Walworth. All three cultivars were released during or after 1999 (Table 1). Walworth produced more grain than other cultivars except for Parshall at Fertile (Table 7). Stoa produced higher yields than other cultivars at Richardton when the organic seed lot was used, with two exceptions. Parshall and Reeder produced a grain yield similar to Stoa when using the organic seed lot of Stoa. Conversely, the old cultivars Chris, Waldron, and particularly Red Fife produced low yields relative to some of the modern cultivars at these three locations. The range in yield was more compressed among cultivars at Fullerton because of the lower yields that occurred at this site. Still, yields of Red Fife were lower than those of most modern cultivars at Fullerton.

Yield differences were not detected where Parshall was established with the organic seed lot compared with the conventional seed lot at three of the four locations (Table 7). More grain was produced when the organic seed lot was used at the Comstock site. Similarly, more grain was produced when the organic seed lot of Stoa was used compared with the conventional seed lot at both Comstock and Richardton. These data indicate the

importance that seed lot selection can have for grain yield of a cultivar, even when other agronomic factors like plant stature may not be affected.

Protein was of equal or greater concentration in grain of Glupro compared with grain of other cultivars at all four locations (Table 7). Glupro was released by the Agricultural Experiment Station at NDSU in 1995 because of the very high protein concentration of grain compared with other cultivars. Protein concentrations of grain produced by old cultivars were comparable to concentrations of grain produced by several modern cultivars at each location included in this study. Similarly, differences in grain protein concentration were not detected between organic and conventional seed lots for both Parshall and Stoa.

Differences in grain test weight were detected among cultivars at each of the four locations (Table 7). However, consistent differences in grain test weight were not detected between the eras of cultivar development that were represented. For example, test weight was heavier for grain produced by the modern cultivar BacUp compared with the old cultivar Red Fife at three of four locations, but grain test weight was heavier at one site and never was lighter for Red Fife compared with grain produced by the modern cultivar Glupro.

Differences were not detected in grain test weight when the organic seed lot of Parshall was used compared with the conventional seed lot (Table 7). However, heavier test weights occurred at two locations when the organic seed lot of Stoa was used rather than the conventional seed lot. These data indicate the importance that seed lots may have on grain test weight of a cultivar in some instances.

Oats

Oat cultivars differed in agronomic traits across the four locations included in this study, except for seedling vigor (Table 8). Mean seedling numbers ranged from 25 to 32 seedlings/ft², plant height from 31 to 37 inches, grain yield from 38 to 64 bu/acre, and grain test weight from 27 to 40 lb/bu when averaged across locations (Table 9). A location H cultivar interaction occurred for all measured crop traits so cultivars were compared within each location.

Seedling numbers of the cultivars Hytest and Wabasha were equal or greater than seedling numbers of other cultivars at all four locations (Table 10). Seedling vigor also was equal or greater for Hytest compared with other cultivars, except at Richardton where ‘Buff’ and ‘Richard’ seedlings were more vigorous. These data indicate the importance that environmental differences can have on the response of selected agronomic traits among cultivars. Consistent trends in seedling numbers and vigor were not detected between organic and conventional seed lots of oat cultivars at the two locations where comparisons were made (data not presented).

Plant height was equal or greater for ‘Youngs’ compared with other cultivars at each of the four locations (Table 10), even though Youngs is rated as only having medium plant stature (Table 2). Conversely, shorter plants occurred for Ebeltoft than for Youngs at all four locations (Table 10), even though Ebeltoft is considered a tall cultivar (Table 2). These data suggest that the relative height differences between oat cultivars can be affected by

environmental factors. Plant height differences generally were not detected between plants established with organic and conventional seed lots of the same cultivar (data not presented).

Grain yield was equal or greater for ‘Leonard’ compared with other oat cultivars at three of four locations, including both sites in ND (Table 11). Morton produced equal or greater amounts of grain than other cultivars at three locations, including both sites in MN. Leonard produced less grain than Morton at Fertile, even though Leonard was released by the Agricultural Experiment Station at the University of Minnesota while Morton was released by the Agricultural Experiment Station at NDSU. Conversely, Leonard produced more grain than Morton at Richardton. Lowest grain yields were produced by the hull-less cultivar Buff at both locations in North Dakota. Buff also produced lower grain yields than other cultivars at Comstock, except for Youngs.

Differences generally were not detected for grain yield when using the organic seed lot compared with the conventional seed lot of the same cultivar (data not presented). Higher yields did occur when the conventional seed lot rather than the organic seed lot of Otana was used at one of the two locations where both seed lots were compared. No yields differences were detected using organic and conventional seed lots of Otana at the other location, nor were differences in yield detected when using organic and conventional seed lots of Hytest and either location.

Grain test weight was heaviest for Buff at all four locations (Table 11). Grain test weight of hull-less oat cultivars generally is heavier than the test weight of grain produced by hulled oat cultivars. Hytest generally produces grain with a heavier test weight compared with other hulled oat cultivars, but differences in test weight were not detected between Hytest and some other hulled cultivars at each of the four locations. For example, test weights were similar for grain produced by Ebeltoft and Hytest at Comstock, and test weight was heavier for grain produced by Ebeltoft at Fertile. Likewise, test weights were comparable for grain produced by Hytest and Wabasha at both locations in ND. Differences in test weight were not detected when using organic and conventional seed lots of the same cultivar at locations where different seed lots were compared (data not presented).

Barley

Seedling numbers were greater for the two-rowed cultivar Conlon than for six-rowed cultivars, except Lacey and Robust (Table 12). Seedlings of Conlon also were more vigorous than seedlings of ‘Drummond’ and ‘Legacy’. No differences in height were detected between cultivars even though Conlon generally is shorter in stature than the other cultivars included in the study (Table 3). Grain yields were similar between Conlon, Lacey, Robust, and Drummond. Less grain was produced by Legacy than by Conlon, Lacey, and Robust. Test weight was heavier for grain produced by Conlon compared with the other four cultivars. Test weight generally is heavier for grain produced by two-rowed cultivars compared with six-rowed cultivars.

CONCLUSIONS AND DISCUSSION

Consistent trends in agronomic traits were not detected among spring wheat cultivars developed during different eras that were represented in this project, except for grain yield. Greatest amounts of grain were produced by wheat cultivars released on or after 1999 at both MN locations. Differences in yield trends were not as distinct between old and modern cultivars at the ND locations, although at least one modern cultivar produced a grain yield that was equal or greater than yields of other cultivars at both locations. Conversely, the old cultivar Red Fife generally produced low yields. These preliminary data do not support the hypothesis that old cultivars are better adapted than modern cultivars in organic environments.

The old cultivars Chris and Waldron were released over 40 years ago but not before agriculturists had begun to use synthetic pesticides to manage pests in cultivar adaptation trials. Seed lots for cultivars released prior to 1960 were unavailable at the quantities needed for this project, except for Red Fife. Field studies that include cultivars developed prior to 1960 in addition to Red Fife are needed to verify our preliminary observations that agronomic performance is equal or superior for modern wheat cultivars compared with old cultivars in organic environments.

Organic and conventional seed lots of two wheat cultivars and two oat cultivars were included in this study. A consistent trend in agronomic traits with the type of seed lot used was not detected across cultivars for both wheat and oats. For example, agronomic traits for plants generally were similar between the organic and conventional seed lots for the wheat cultivar Parshall and the oat cultivars Otana and Hystest. Conversely, agronomic traits generally were superior when the organic seed lot was used compared with the conventional seed lot for the wheat cultivar Stoa.

Plants that developed from the organic seed lot of Stoa may represent a population that is better adapted to organic environments than plants that resulted using the conventional seed lot, since Stoa is heterogeneous in genetic composition compared with many other modern spring wheat cultivars (S.S. Jones, personal communication, 2003). Hwu and Allan (1992) demonstrated that natural adaptation in wheat populations can occur when heterogeneous populations develop under different production strategies. However, attributing the differences in agronomic traits to genetic heterogeneity in Stoa is confounded by the differences in quality between seed lots that were observed. Kernels were larger and more vitreous in the organic seed lot compared with the conventional seed lot, probably because of environmental differences between sites where the two seed lots were produced. Additional field experiments should be conducted to determine if agronomic traits of Stoa generally are superior when organic seed lots are used compared with conventional seed lots in environments managed organically and, if so, why.

A consistent impact of crop seedling numbers, seedling vigor, and plant height on grain yield was not detected in this project for wheat, oats, or barley. Similarly, additional growth traits considered at some but not a majority of locations (e.g., plant canopy development) failed to impact grain yield consistently across cultivars and crops (data not presented). Results of this preliminary project suggest that additional growth traits and

combinations of various traits should be considered in field work to identify those factors that affect agronomic performance of small-grain cultivars in organic environments. This knowledge then can be used to guide development and selection of small-grain cultivars for organic farming systems.

OUTREACH

Site tours were provided to organic growers and others interested in the project at all four locations during the growing season in 2002 (<http://www.npsas.org/Images/Trialsflier.pdf> [verified 26 September, 2003]). Results of the project were summarized by cooperating scientists at both NDSU and the University of Minnesota and can be accessed for the Fullerton and Richardton sites on the WEB (Fullerton: http://www.ag.ndsu.nodak.edu/carringt/02data/2002_ohrsw.pdf [verified 26 September, 2003]; Richardton: <http://www.ag.ndsu.nodak.edu/dickins/research/2002/agron02h.htm> [verified 26 September, 2003]). A preliminary summary of the 2002 field experiments was presented at the 2003 winter annual meeting of the Northern Plains Sustainable Agriculture Society (NPSAS) in late January and early February in Aberdeen, South Dakota. Results of the project will be presented as an invited paper during the Organic Symposium at the American Society of Agronomy's annual meeting in Denver in early November, and published in the Proceedings from the symposium.

Successful execution of this project provided data and a demonstration of the commitment of scientists at NDSU and the University of Minnesota to identify small grain cultivars that are adapted to organic farming systems. Results of this project were used to obtain NCR-SARE funding to continue and expand this effort during both 2003 and 2004. The summer annual meeting of NPSAS and OCIA #1 included stops at the Richardton site in 2003. Over 50 organic producers as well as others interested in the project attended the event. Similar visits were made to both MN sites. Results of the field experiments in 2003 and 2004 will be published in refereed journals.

REFERENCES

- ERS, 2002. Certified organic acreage, selected crops, by state, 2001 [Online]. Available at <http://www.ers.usda.gov/Data/organic/data/selectcropsstate01.xls> (verified 16 Sept. 2003)
- Hwu, K., and R.E. Allan. 1992. Natural selection effects in wheat populations grown under contrasting tillage systems. *Crop Sci.* 32:605-611.
- SAS Institute. 2001. The SAS system for Windows. Release 8.2. SAS Inst., Cary, NC.

ADDENDA

Table 1. Development and selected traits for hard red spring wheat cultivars included in adaptation trials in fields managed organically at four locations in 2002.

| Cultivar | Origin | Year of release | Plant stature | Maturity |
|----------|-------------------|-----------------|---------------|------------------|
| Alsen | NDSU ^H | 2000 | semi-dwarf | moderately early |
| BacUp | UM | 1996 | medium | early |
| Chris | UM | 1965 | tall | moderately late |
| Coteau | NDSU | 1978 | medium | medium |
| Glupro | NDSU | 1995 | tall | moderately late |
| Gunner | AgriPro | 1995 | medium | medium |
| Ingot | SDSU | 1998 | semi-dwarf | early |
| Parshall | NDSU | 1999 | medium | moderately early |
| Red Fife | Canada | 1840s | tall | moderately late |
| Reeder | NDSU | 1999 | semi-dwarf | moderately early |
| Stoa | NDSU | 1984 | medium | moderately early |
| Waldron | NDSU | 1969 | tall | medium |
| Walworth | SDSU | 2001 | semi-dwarf | moderately early |

^HNDSU = North Dakota State University Agricultural Experiment Station (AES); UM = University of Minnesota AES; SDSU = South Dakota State University AES; AgriPro = AgriPro Seeds, Inc.; written sources suggest Red Fife was first produced commercially in Canada.

Table 2. Development and selected traits for oat cultivars included in adaptation trials in fields managed organically at four locations during 2002.

| Cultivar | Origin | Year of release | Plant stature | Maturity |
|-------------------|-------------------|-----------------|-----------------|----------------|
| Buff ^H | SDSU ^I | 2002 | medium | medium |
| Ebeltoft | NDSU | 1999 | tall | very late |
| HiFi | NDSU | 2001 | tall | late |
| Hyttest | SDSU | 1986 | tall | early |
| Leonard | UM | 2002 | medium | medium to late |
| Morton | NDSU | 2001 | tall | late |
| Richard | UM | 2000 | tall | medium |
| Sesqui | UM | 2001 | moderately tall | late |
| Wabasha | UM | 2001 | tall | medium |
| Youngs | NDSU | 2001 | medium | medium |

^HHull-less or naked oat.

^ISDSU = South Dakota State University Agricultural Experiment Station (AES); NDSU = North Dakota State University AES; UM = University of Minnesota AES.

Table 3. Development and selected traits for barley cultivars included in an adaptation field trial managed organically near Richardton, ND during 2002.

| Cultivar | Origin | Year of release | Plant stature | Maturity |
|---------------------|-------------------|-----------------|------------------|----------------|
| Conlon ^H | NDSU ^I | 1996 | moderately short | early |
| Drummond | NDSU | 2000 | medium | medium |
| Lacey | UM | 1999 | medium | medium |
| Legacy | BARI | 2000 | medium | medium to late |
| Robust | MN | 1983 | medium | medium |

^Htwo-rowed cultivar.

^INDSU = North Dakota State University Agricultural Experiment Station (AES); UM = University of Minnesota AES; BARI = Busch Agricultural Resources, Inc.

Table 4. Mean squares^H from the analyses of variance for plant stand, seedling vigor, plant height, grain yield, grain crude protein concentration (CP), and grain test weight (TW) of thirteen hard red spring wheat cultivar in fields managed organically at four locations in 2002.

| | Plant | | Seedling | Plant | Grain | | | |
|-------------------|-----------------------------|---------------------|----------|-------|------------|-------------|--------|-----------|
| | df | Stand | | | df | vigor | height | Yield |
| | --- no./ft ² --- | | | | - inches - | - bu/acre - | - % - | - lb/bu - |
| Location | 2 | 317.7* ^I | 3 | 1.7 | 1703.1* | 2665.5* | 44.3* | 268.7* |
| Rep[Location] | 9 | 9.5 | 12 | 2.7 | 2.2 | 21.4 | 0.7 | 5.3 |
| Cultivar | 14 | 136.8* | 14 | 33.5* | 91.1* | 452.5* | 5.7* | 44.4* |
| Location cultivar | 28 | 27.2* | 42 | 3.3* | 4.3* | 64.1* | 1.4* | 4.0* |
| Residual | 126 | 10.4 | 168 | 0.9 | 2.7 | 9.7 | 0.5 | 2.4 |

^HSAS statement for the F-test for location was: TEST H = Location E = Rep[Location]; for cultivar the SAS statement was: TEST H = Cultivar E = Location cultivar; the residual error was used to test the location cultivar interaction.

^I* = significant at the 0.05 probability level.

Table 5. Plant stand (Stand), seedling vigor (Vigor), mature plant height (Height), grain yield (Yield), grain crude protein concentration (CP), and grain test weight (TW) for thirteen hard red spring wheat cultivars in fields managed organically in 2002.

| Factor | Stand --no./ft ² -- | Vigor ^H | Height - inches - | Yield - bu/acre - | CP - % - | TW - lb/bu - |
|-------------------------|-----------------------------------|--------------------|----------------------|----------------------|-------------|-----------------|
| <u>Location</u> | | | | | | |
| Comstock, MN | -- | 6 | 35 | 26 | 16 | 54 |
| Fertile, MN | 26 | 5 | 32 | 29 | 15 | 55 |
| Fullerton, ND | 30 | 5 | 24 | 14 | 17 | 58 |
| Richardton, ND | 25 | 5 | 25 | 26 | 15 | 58 |
| Mean | 27 | 5 | 29 | 24 | 16 | 56 |
| LSD _{0.05} | 1.3 | NS | 1 | 2 | 0.3 | 1 |
| <u>Cultivar</u> | | | | | | |
| Alsen | 27 | 6 | 26 | 26 | 16 | 57 |
| BacUp | 29 | 5 | 27 | 22 | 16 | 58 |
| Chris | 26 | 4 | 32 | 20 | 16 | 56 |
| Coteau | 29 | 6 | 29 | 19 | 16 | 55 |
| Glupro | 23 | 3 | 32 | 16 | 18 | 54 |
| Gunner | 29 | 7 | 28 | 23 | 16 | 58 |
| Ingot | 27 | 6 | 29 | 27 | 15 | 58 |
| Parshall-C ^I | 28 | 6 | 29 | 28 | 15 | 58 |
| Parshall-O ^I | 29 | 8 | 27 | 30 | 15 | 59 |
| Red Fife | 26 | 4 | 34 | 13 | 15 | 55 |
| Reeder | 25 | 5 | 26 | 27 | 15 | 56 |
| Stoa-C ^I | 18 | 2 | 30 | 21 | 15 | 54 |
| Stoa-O ^I | 30 | 5 | 30 | 29 | 15 | 56 |
| Waldron | 33 | 7 | 31 | 24 | 16 | 55 |
| Walworth | 27 | 6 | 26 | 31 | 16 | 56 |
| Mean | 27 | 5 | 29 | 24 | 16 | 56 |
| LSD _{0.05} | 4 | 1 | 2 | 6 | 1 | 1 |

^HPoor seedling vigor = 1; very vigorous seedlings = 9.

^IC = conventional seed lot; O = organic seed lot.

Table 6. Plant stand, vigor, and height for thirteen hard red spring wheat cultivars in fields managed organically near Comstock, MN (Com), Fertile, MN (Fer), Fullerton, ND (Ful), and Richardton, ND (Ric) during 2002.

| Factor | Wheat plant seedlings | | | | | | | | Mature wheat plants | | | |
|-------------------------|-----------------------|-----|-----|-----|-------|-----|-----|-----|---------------------|-----|-----|-----|
| | Stand | | | | Vigor | | | | Height | | | |
| | Com | Fer | Ful | Ric | Com | Fer | Ful | Ric | Com | Fer | Ful | Ric |
| | no./ft ² | | | | | | | | in | | | |
| <u>Cultivar</u> | | | | | | | | | | | | |
| Alsen | -- | 28 | 29 | 23 | 6 | 6 | 6 | 5 | 30 | 29 | 23 | 22 |
| BacUp | -- | 27 | 33 | 27 | 5 | 4 | 5 | 5 | 34 | 29 | 24 | 23 |
| Chris | -- | 20 | 33 | 24 | 4 | 3 | 6 | 4 | 38 | 34 | 27 | 28 |
| Coteau | -- | 28 | 30 | 29 | 8 | 5 | 6 | 7 | 37 | 33 | 23 | 24 |
| Glupro | -- | 25 | 24 | 21 | 3 | 5 | 2 | 4 | 40 | 36 | 26 | 28 |
| Gunner | -- | 30 | 32 | 26 | 7 | 8 | 7 | 6 | 33 | 32 | 23 | 25 |
| Ingot | -- | 29 | 28 | 24 | 6 | 7 | 6 | 5 | 34 | 33 | 25 | 25 |
| Parshall-C ^I | -- | 27 | 29 | 29 | 6 | 6 | 8 | 6 | 34 | 32 | 24 | 24 |
| Parshall-O ^I | -- | 27 | 33 | 27 | 8 | 8 | 9 | 6 | 33 | 30 | 22 | 24 |
| Red Fife | -- | 22 | 28 | 27 | 4 | 4 | 5 | 5 | 41 | 36 | 30 | 30 |
| Reeder | -- | 26 | 28 | 20 | 5 | 5 | 6 | 5 | 32 | 29 | 21 | 22 |
| Stoa-C ^I | -- | 20 | 20 | 15 | 2 | 3 | 1 | 2 | 36 | 33 | 25 | 25 |
| Stoa-O ^I | -- | 28 | 30 | 31 | 6 | 4 | 5 | 6 | 37 | 34 | 26 | 26 |
| Waldron | -- | 28 | 37 | 33 | 6 | 7 | 8 | 6 | 38 | 35 | 26 | 27 |
| Walworth | -- | 27 | 30 | 23 | 7 | 6 | 5 | 6 | 31 | 30 | 24 | 22 |
| Mean | -- | 26 | 30 | 25 | 6 | 5 | 6 | 5 | 35 | 32 | 25 | 25 |
| CV(%) | -- | 10 | 11 | 15 | 17 | 20 | 22 | 11 | 3 | 5 | 10 | 5 |
| LSD _{0.05} | -- | 4 | 5 | 5 | 1 | 2 | 2 | 1 | 1 | 2 | 3 | 2 |

^H1 = poor seedling vigor; 9 = very vigorous seedling growth.

^IC = conventional seed lot; O = organic seed lot.

Table 7. Grain yield, crude protein concentration (CP), and test weight (TW) for thirteen hard red spring wheat cultivars managed organically near Comstock, MN (Com), Fertile, MN (Fer), Fullerton, ND (Ful), and Richardton, ND (Ric) during 2002.

| Factor | Grain | | | | | | | | | | | |
|-------------------------|---------------------|-----|-----|-----|---------------|-----|-----|-----|-------------------|-----|-----|-----|
| | Yield | | | | CP | | | | TW | | | |
| | Com | Fer | Ful | Ric | Com | Fer | Ful | Ric | Com | Fer | Ful | Ric |
| | ----- bu/acre ----- | | | | ----- % ----- | | | | ----- lb/bu ----- | | | |
| <u>Cultivar</u> | | | | | | | | | | | | |
| Alsen | 29 | 31 | 15 | 28 | 16 | 15 | 17 | 16 | 56 | 55 | 59 | 60 |
| BacUp | 26 | 26 | 14 | 21 | 16 | 15 | 18 | 16 | 57 | 56 | 60 | 61 |
| Chris | 18 | 23 | 15 | 23 | 16 | 14 | 17 | 15 | 54 | 57 | 57 | 58 |
| Coteau | 18 | 24 | 10 | 25 | 16 | 14 | 17 | 16 | 52 | 54 | 56 | 56 |
| Glupro | 16 | 20 | 8 | 18 | 16 | 16 | 19 | 19 | 52 | 52 | 55 | 55 |
| Gunner | 25 | 22 | 16 | 28 | 16 | 15 | 17 | 15 | 54 | 56 | 59 | 61 |
| Ingot | 35 | 31 | 14 | 27 | 15 | 15 | 17 | 15 | 56 | 55 | 60 | 61 |
| Parshall-C ^H | 33 | 36 | 14 | 30 | 16 | 14 | 16 | 15 | 56 | 57 | 59 | 61 |
| Parshall-O ^H | 38 | 38 | 16 | 29 | 16 | 15 | 16 | 15 | 56 | 56 | 61 | 61 |
| Red Fife | 8 | 12 | 11 | 20 | 16 | 13 | 16 | 14 | 53 | 56 | 55 | 56 |
| Reeder | 33 | 30 | 16 | 29 | 16 | 14 | 16 | 15 | 54 | 54 | 59 | 59 |
| Stoa-C ^H | 17 | 32 | 12 | 23 | 17 | 15 | 16 | 14 | 51 | 54 | 57 | 54 |
| Stoa-O ^H | 33 | 35 | 17 | 32 | 16 | 14 | 16 | 15 | 55 | 54 | 57 | 58 |
| Waldron | 29 | 31 | 12 | 27 | 16 | 15 | 17 | 14 | 54 | 54 | 56 | 58 |
| Walworth | 35 | 41 | 19 | 28 | 16 | 14 | 17 | 16 | 55 | 54 | 59 | 58 |
| Mean | 26 | 29 | 14 | 26 | 16 | 15 | 17 | 15 | 54 | 55 | 58 | 58 |
| CV(%) | 9 | 14 | 25 | 8 | 6 | 4 | 4 | 4 | 4 | 3 | 2 | 1 |
| LSD _{0.05} | 3 | 5 | 5 | 3 | NS | 1 | 1 | 1 | 3 | 2 | 2 | 1 |

^HC = conventional seed lot; O = organic seed lot.

Table 8. Mean squares^H from the analyses of variance for plant stand, seedling vigor, plant height, grain yield and grain test weight (TW) of 10 oat cultivars in fields managed organically at four locations in 2002.

| | Plant | | df | Seedling vigor | Plant height | Grain | |
|-------------------|-----------------------------|-------|----------------|-------------------|-----------------|-------------|-----------|
| | df | Stand | | | | Yield | TW |
| | --- no./ft ² --- | | | | - inches - | - bu/acre - | - lb/bu - |
| Location | 2 | 111 | 3 ^I | 76*' | 1703.1* | 8042* | 502* |
| Rep[Location] | 9 | 46 | 12 | 6 | 2.2 | 420 | 5 |
| Cultivar | 9 | 49* | 9 | 5 | 91.1* | 868* | 228* |
| Location cultivar | 18 | 20* | 27 | 5* | 4.3* | 174* | 25* |
| Residual | 81 | 23 | 108 | 1 | 2.7 | 41 | 2 |

^HSAS statement for the F-test for location was: TEST H = Location E = Rep[Location] and for cultivar was: TEST H = Cultivar E = Location cultivar; residual error was used to test the location cultivar interaction.

^IFewer df were associated with plant height at Fullerton than is indicated.

'* = significant at the 0.05 probability level.

Table 9. Plant stand (Stand), seedling vigor (Vigor), mature plant height (Height), grain yield (Yield), grain crude protein concentration (CP), and grain test weight (TW) of 10 oat cultivars in fields managed organically at four locations in 2002.

| Factor | Stand | Vigor ^H | Height | Yield | TW |
|---------------------|--------------------------|--------------------|--------------|-------------|-----------|
| | --no./ft ² -- | | - inches - | - bu/acre - | - lb/bu - |
| <u>Location</u> | | | | | |
| Comstock, MN | -- | 6 | 42 | 72 | 28 |
| Fertile, MN | 28 | 5 | 25 | 59 | 34 |
| Fullerton, ND | 30 | 5 | 40 | 39 | 26 |
| Richardton, ND | 28 | 3 | 25 | 48 | 33 |
| Mean | 29 | 5 | 33 | 55 | 30 |
| LSD _{0.05} | NS | 1 | ^I | 10 | 1 |
| <u>Cultivar</u> | | | | | |
| Buff ^I | 26 | 4 | 31 | 38 | 40 |
| Ebeltoft | 28 | 4 | 32 | 55 | 28 |
| HiFi | 27 | 5 | 34 | 58 | 27 |
| Hyttest | 32 | 6 | 35 | 48 | 33 |
| Leonard | 30 | 4 | 34 | 58 | 29 |
| Morton | 28 | 5 | 36 | 64 | 29 |
| Richard | 25 | 5 | 34 | 61 | 29 |
| Sesqui | 29 | 5 | 32 | 59 | 31 |
| Wabasha | 30 | 4 | 32 | 54 | 31 |
| Youngs | 28 | 4 | 37 | 51 | 27 |
| Mean | 28 | 5 | 34 | 55 | 30 |
| LSD _{0.05} | 3.8 | NS | ^I | 10 | 4 |

^H1 = poor seedling vigor; 9 = very vigorous seedling growth.

^IHeights were not measured in the plots of all replications at all locations so only treatment means are provided.

Table 10. Plant stand, vigor, and height for ten oat cultivars in fields managed organically near Comstock, MN (Com), Fertile, MN (Fer), Fullerton, ND (Ful), and Richardson, ND (Ric) during 2002.

| Factor | Oat plant seedlings | | | | | | | | Mature oat plants | | | |
|---------------------|---------------------------------|-----|-----|-----|---------------------|-----|-----|-----|-------------------|-----|-----|-----|
| | Stand | | | | Vigor ^H | | | | Height | | | |
| | Com | Fer | Ful | Ric | Com | Fer | Ful | Ric | Com | Fer | Ful | Ric |
| | ----- no./ft ² ----- | | | | ----- bu/acre ----- | | | | ----- % ----- | | | |
| <u>Cultivar</u> | | | | | | | | | | | | |
| Buff ^I | -- | 26 | 28 | 25 | 6 | 5 | 2 | 4 | 40 | 37 | 24 | 23 |
| Ebeltoft | -- | 24 | 29 | 31 | 7 | 4 | 5 | 3 | 39 | 38 | 26 | 22 |
| Hifi | -- | 27 | 28 | 28 | 6 | 5 | 4 | 3 | 43 | 40 | 28 | 25 |
| Hyttest | -- | 32 | 31 | 33 | 8 | 6 | 9 | 2 | 43 | 40 | 27 | 27 |
| Leonard | -- | 27 | 33 | 32 | 6 | 5 | 4 | 3 | 43 | 39 | 26 | 25 |
| Morton | -- | 27 | 30 | 27 | 5 | 6 | 6 | 3 | 46 | 41 | 30 | 27 |
| Richard | -- | 25 | 28 | 22 | 7 | 4 | 5 | 4 | 44 | 40 | 26 | 25 |
| Sesqui | -- | 26 | 35 | 25 | 6 | 4 | 5 | 3 | 42 | 38 | 24 | 24 |
| Wabasha | -- | 29 | 32 | 29 | 7 | 5 | 3 | 3 | 40 | 37 | 25 | 24 |
| Youngs | -- | 26 | 29 | 29 | 7 | 4 | 5 | 3 | 45 | 46 | 31 | 26 |
| Mean | -- | 27 | 30 | 28 | 7 | 5 | 5 | 3 | 43 | 40 | 27 | 25 |
| CV (%) | -- | 8 | 12 | 12 | 16 | 23 | 30 | 18 | 2 | 3 | 5 | 4 |
| LSD _{0.05} | -- | 3 | NS | 5 | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 1 |

^HPoor seedling vigor = 1; very vigorous seedlings = 9.

^IHull-less or naked cultivar.

Table 11. Grain yield, and test weight (TW) for ten oat cultivars managed organically near Comstock, MN (Com), Fertile, MN (Fer), Fullerton, ND (Ful), and Richardton, ND (Ric) during 2002.

| Factor | Grain | | | | | | | |
|---------------------|---------------------|-----|-----|-----|-------------------|-----|-----|-----|
| | Yield | | | | TW | | | |
| | Com | Fer | Ful | Ric | Com | Fer | Ful | Ric |
| | ----- bu/acre ----- | | | | ----- lb/bu ----- | | | |
| <u>Cultivar</u> | | | | | | | | |
| Buff ^H | 50 | 53 | 15 | 34 | 40 | 41 | 33 | 46 |
| Ebeltoft | 76 | 51 | 45 | 49 | 29 | 35 | 23 | 27 |
| HiFi | 83 | 65 | 38 | 45 | 27 | 34 | 23 | 26 |
| Hytest | 67 | 52 | 29 | 46 | 31 | 33 | 29 | 37 |
| Leonard | 76 | 50 | 50 | 56 | 23 | 30 | 28 | 33 |
| Morton | 87 | 75 | 44 | 48 | 29 | 33 | 24 | 31 |
| Richard | 79 | 65 | 47 | 55 | 27 | 32 | 24 | 32 |
| Sesqui | 73 | 61 | 49 | 52 | 28 | 33 | 30 | 34 |
| Wabasha | 71 | 63 | 34 | 49 | 27 | 33 | 28 | 35 |
| Youngs | 59 | 56 | 39 | 51 | 24 | 33 | 21 | 29 |
| Mean | 72 | 59 | 39 | 49 | 29 | 34 | 26 | 33 |
| CV(%) | 12 | 13 | 13 | 6 | 5 | 2 | 6 | 4 |
| LSD _{0.05} | 12 | 11 | 7 | 5 | 2 | 1 | 2 | 2 |

^HNaked or hull-less cultivar.

Table 12. Plant stand, vigor, height, grain yield and grain test weight of five barley cultivars in an adaptation trial under organic management during 2002 near Richardton, ND.

| Cultivar | Barley seedlings | | | Grain | |
|---------------------|---------------------|--------------------|---------------------|---------|-------------|
| | Plant stand | Vigor ^H | Mature plant height | Yield | Test weight |
| | no./ft ² | | inches | bu/acre | lb/bu |
| Conlon ^I | 31 | 9 | 19 | 47 | 43 |
| Drummond | 21 | 4 | 20 | 43 | 40 |
| Lacey | 27 | 9 | 19 | 47 | 37 |
| Legacy | 24 | 4 | 19 | 38 | 40 |
| Robust | 26 | 5 | 20 | 46 | 39 |
| Mean | 26 | 6 | 19 | 44 | 40 |
| CV (%) | 16 | 21 | 4 | 9 | 3 |
| LSD _{0.05} | 6 | 1 | NS | 6 | 2 |

^HPoor seedling vigor = 1; very vigorous seedlings = 9.

^ITwo-rowed cultivar; others are six-rowed cultivars.