Small-Grain Cultivar Selection for Organic Systems

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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 yield 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 ND location 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 old cultivars at each location. Crop performance differed when two seed lots of the same cultivar were compared for both wheat and oats. Preliminary results of this project support the hypothesis that grain yield and quality may be maximized when modern rather than old 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 grain production 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).

Studies comparing small-grain cultivars have been conducted for several years in Europe. For example, nine spring wheat cultivars were compared in Poland from 1989 through 1991 in fields where synthetic agri-chemicals were used and in fields managed organically (Poutala et al., 1993). No differences in yield occurred among the cultivars when managed organically, while yields were different between some of the cultivars when managed using synthetic agri-chemicals (i.e., conventionally). Results of this study suggested that management system (organic and conventional) may affect cultivar performance. However, cultivar selection was unaffected by management system since the highest yielding cultivars under conventional management also were among the highest yielding cultivars under organic management.

Six oat cultivars were compared for grain yield and other traits in a field transitioning to organic management in Scotland during 1987 (Richards, 1988). The ranking of the cultivars for yield was similar to the ranking in fields managed conventionally, with one exception. Yield of the shortest and possibly least-competitive cultivar was lower relative to the yield of other varieties when grown under organic management than when grown conventionally.

Efforts are underway to develop small-grain cultivars which show enhanced resistant to common bunt (*Tilletia tritici* (Bjerk.) Wint. and *T. laevis* Kuhn) and loose smut (*Ustilago tritici* (Pers.) Rostr.) in European environments managed organically (K.J. Mueller, personal communication, 2003). Other workers are dedicated to identifying cultivars capable of producing high quality grain in relatively low-N environments. In spite of these and other efforts, European agriculturists continue to identify the lack of suitable cultivars as a major obstacle to successful organic production of small-grain crops (Gooding, 2003). Similar concerns about the availability of small-grain cultivars that are adapted to growing conditions in the northern Great Plains have been expressed by organic agriculturists (B. Schmaltz, personal communication, 2002).

Few attempts have been made to compare small-grain cultivars for agronomic performance in environments managed organically in North America. Five hard red spring wheat cultivars were compared in a field experiment managed organically during 2001 in Alberta, Canada (T. Lea, personal communication, 2003). The cultivar Red Fife, first named and grown in the 1840s, produced more grain than the modern cultivars AC Barrie, AC Michael, and CDC Teal. Conversely, AC Barrie and CDC Teal produced more grain than Red Fife and many other old cultivars in field experiments at three of four locations in 2002. The field experiments were discontinued in 2003. Results of the 2001-2002 field experiments have been summarized but not published.

A project supported by a West Region SARE grant (SW 96-032) included an evaluation of 10 winter wheat cultivars under organic management. The project also compared different organic soil amendments on winter wheat yield. The winter wheat cultivar Golden Spike was released in part because of agronomic performance in field experiments managed organically. Stukenholtz et al. (2002) reported on results of the soil amendment comparisons, but results of the cultivar comparisons included in the study have not been published (D.J. Hole, personal communication, 2003).

The objective of this study was to identify wheat, oat, and barley cultivars that are adapted to environments managed organically in the northern Great Plains of North America. We also wanted to determine if evidence exists suggesting that old cultivars are better adapted than modern cultivars to organic environments, and if there is evidence that natural adaptation occurs after small-grain cultivars are introduced into organic environments. Finally, we wanted to 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^{o} 40’ N, 96^{o} 45’ W, elevation: 930 ft) and Fertile (47^{o} 32’ N, 96^{o} 17’ W, elevation: 1144 ft) in western MN, and Fullerton (46^{o} 10’ N, 98^{o} 26’ W, elevation: 1455 ft) and Richardton (46^{o} 53’ N, 102^{o} 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 a 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 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 in 2001 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 after seeding 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 oats, 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 including days to crop emergence, plant height at various growth stages, and dry matter of small-grain crops and weeds were collected in wheat, barley, and oat experiments at some locations. Rating systems were used to evaluate plant canopy development, weed growth, and disease pressure within plots at one or two of the locations.

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. Data also were analyzed within each location for any factor that was not included at all locations.

Results

Wheat

Cultivars differed in agronomic traits across the four locations included in this study (Table 4). Plant stand ranged from 18 to 33 seedlings/ft^2, 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 at Richardton, along with Stoa when the conventional seed lot was used. Waldron had equal or greater numbers of seedlings compared with modern 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 each location. 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.

The old cultivars Chris, Red Fife, and Waldron are classified as tall statured, as is the modern cultivar Glupro (Table 1). Plant height was similar between Chris, Red Fife, and Glupro at three of four locations (Table 6). However, 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 when 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 study.

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 1998 (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 and particularly Red Fife produced low yields relative to some of the modern cultivars at these three locations. Likewise, at least one modern cultivar produced more grain than the old cultivar Waldron. 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 when 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.

Severity of leaf rust (*Puccinia recondite* f. sp. Tritici) infection was greater for the old cultivar Red Fife than for other cultivars at the Comstock location (Table 8). Similarly, scab (*Fusarium graminearum* Schwabe) infection tended to be more severe for Red Fife along with Chris than other cultivars at Comstock, except for Glupro, Gunner, and Waldron. Similar data were not collected at the other locations because of labor constraints (Fertile and Fullerton) or because disease pressure was limited (Richardton).

Oats

Oat cultivars differed in agronomic traits across the four locations included in this study, except for seedling vigor (Table 9). Mean seedling numbers ranged from 25 to 32 seedlings/ft^2, 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 10). 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 each of the locations where seedlings were counted (Table 11). 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 11), 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 11), 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. 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 12). 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 one MN location (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 one ND location (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 12). 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, Morton, and Hytest at Comstock, and test weight was heavier for grain produced by Ebeltoft than Hytest 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 the six-rowed cultivars Drummond and Legacy (Table 13). Seedlings of Conlon also were more vigorous than seedlings of Drummond and Legacy. No differences in plant 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.

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 1998 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 released since 1999 produced a grain yield that was equal or greater than yields of old 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.

Agriculturists have identified disease resistance as an important consideration when selecting small-grain cultivars for production in environments managed organically (Gooding, 2003). Disease incidence tended to be greatest for the oldest cultivar included in our project at the single location where disease severity data were collected. Conversely, scab severity generally was less for modern cultivars compared with old cultivars. Efforts should be made to evaluate disease severity when modern and old cultivars are compared in organic environments where disease symptoms are expressed. These data could be used to identify cultivars that are adapted to organic environments where disease pressure is severe, and to help explain the relative performance of cultivars with good disease resistance and cultivars with poor disease resistance in environments were severe disease pressure exists.

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 Hytest. 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 was 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.

Conclusions

Hard red spring wheat, oat, and barley cultivars were identified that are adapted to environments managed organically in the northern Great Plains. Modern cultivars generally were superior to old cultivars when grain yield was the criterion used to determine how well adapted small-grain cultivars were to organic environments. Agronomic performance differed for some traits when cultivar entries were compared that were grown from organic seed lots compared with conventional seed lots. There was no evidence that natural adaptation occurs after a small-grain cultivar is introduced into organic environments when the cultivar is comprised of a population that is genetically homogeneous, and limited evidence that natural adaptation may occur when the population is genetically heterogeneous. We were unable to identify plant growth traits that resulted in superior cultivar performance in organic environments.

This project included field experiments for wheat and oats at four locations and a field experiment for barley at one location during 2002. Still, results generated by this project should be considered preliminary and additional field experiments are needed before cultivar recommendations can be made for organic production of small-grain crops in the northern Great Plains. Expanded versions of the wheat and oat cultivar studies described in the manuscript were conducted at two locations in MN and two locations in ND in 2003 and will be repeated at four locations in 2004. Results of this 2-yr effort will be published after a summary of the data analyses are completed following the 2003-2004 growing season.

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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†	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

†NDSU = 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†	SDSU‡	2002	medium	medium
Ebeltoft	NDSU	1999	tall	very late
HiFi	NDSU	2001	tall	late
Hytest	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

†Hull-less or naked oat.

‡SDSU = 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†	NDSU‡	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

†two-rowed cultivar.

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

Table 4. Mean squares[†] 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.

	df	Plant stand	df	Seedling vigor	Plant height	Grain Yield	Grain CP	Grain TW
		--- no./ft^2 ---			- inches -	- bu/acre -	- % -	- lb/bu -
Location	2	317.7*[‡]	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 H 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

[†]SAS 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 H cultivar; the residual error was used to test the location H cultivar interaction.

[‡]* = 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	Vigor†	Height	Yield	CP	TW
	--no./ft^2 --		- inches -	- bu/acre -	- % -	- lb/bu -
Location						
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
Cultivar						
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‡	28	6	29	28	15	58
Parshall-O‡	29	8	27	30	15	59
Red Fife	26	4	34	13	15	55
Reeder	25	5	26	27	15	56
Stoa-C‡	18	2	30	21	15	54
Stoa-O‡	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

†Poor seedling vigor = 1; very vigorous seedlings = 9.

‡C = 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.

	Wheat plant seedlings								Mature wheat plants			
	Stand				Vigor				Height			
Factor	Com	Fer	Ful	Ric	Com	Fer	Ful	Ric	Com	Fer	Ful	Ric
	-------- no./ft^2 --------								----------- in -----------			
Cultivar												
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‡	--	27	29	29	6	6	8	6	34	32	24	24
Parshall-O‡	--	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‡	--	20	20	15	2	3	1	2	36	33	25	25
Stoa-O‡	--	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

†1 = poor seedling vigor; 9 = very vigorous seedling growth.

‡C = 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.

	Grain											
	Yield				CP				TW			
Factor	Com	Fer	Ful	Ric	Com	Fer	Ful	Ric	Com	Fer	Ful	Ric
	-------- bu/acre --------				----------- % -----------				---------- lb/bu ----------			
Cultivar												
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†	33	36	14	30	16	14	16	15	56	57	59	61
Parshall-O†	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†	17	32	12	23	17	15	16	14	51	54	57	54
Stoa-O†	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

† C = conventional seed lot; O = organic seed lot.

Table 8. Scab rating and leaf rust incidence on the flag leaf of 13 hard red spring wheat cultivars managed organically during 2002 at Comstock, MN.

Cultivar	Scab score†	Leaf rust
		----------- % -----------
Alsen	0.8	6
BacUp	0.6	8
Chris	2.5	11
Coteau	1.5	14
Glupro	2.5	15
Gunner	1.8	19
Ingot	1.0	18
Parshall-C‡	0.3	5
Parshall-O‡	0.8	4
Red Fife	2.4	28
Reeder	1.1	7
Stoa-C‡	1.5	11
Stoa-O‡	1.1	13
Waldron	2.0	14
Walworth	0.5	14
Mean	1.4	12
$LSD_{0.05}$	0.8	7.0

†0 = no scab; 3 = severe scab recorded two weeks before harvest.

‡ C = conventional seed lot; O = organic seed lot.

Table 9. Mean squares[†] 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		Seedling	Plant	Grain	
	df	Stand	df	vigor	height	Yield	TW
		--- no./ft^2 ---			- inches -	- bu/acre -	- lb/bu -
Location	2	111	3[‡]	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

[†]SAS 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.

[‡]Fewer df were associated with plant height at Fullerton than is indicated.

[§]* = significant at the 0.05 probability level.

Table 10. 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†	Height	Yield	TW
	--no./ft^2 --		- inches -	- bu/acre -	- lb/bu -
Location					
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	‡	10	1
Cultivar					
Buff‡	26	4	31	38	40
Ebeltoft	28	4	32	55	28
HiFi	27	5	34	58	27
Hytest	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	‡	10	4

†1 = poor seedling vigor; 9 = very vigorous seedling growth.

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

Table 11. Plant stand, vigor, and height for ten oat cultivars in fields managed organically near Comstock, MN (Com), Fertile, MN (Fer), Fullerton, ND (Ful), and Richardton, ND (Ric) during 2002.

	Oat plant seedlings								Mature oat plants			
	Stand				Vigor[†]				Height			
Factor	Com	Fer	Ful	Ric	Com	Fer	Ful	Ric	Com	Fer	Ful	Ric
	-------- no./ft^2 --------				-------- bu/acre --------				---------- % ----------			
Cultivar												
Buff[‡]	--	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
Hytest	--	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

[†]Poor seedling vigor = 1; very vigorous seedlings = 9.

[‡]Hull-less or naked cultivar.

Table 12. 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.

	Grain							
	Yield				TW			
Factor	Com	Fer	Ful	Ric	Com	Fer	Ful	Ric
	-------- bu/acre --------				---------- lb/bu ----------			
Cultivar								
Buff[†]	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

[†]Naked or hull-less cultivar.

Table 13. 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†	Mature plant height	Yield	Test weight
	no./ft^2		inches	bu/acre	lb/bu
Conlon‡	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

†Poor seedling vigor = 1; very vigorous seedlings = 9.

‡Two-rowed cultivar; others are six-rowed cultivars.