



PRODUCING MILLING OATS IN WESTERN WASHINGTON: GUIDE TO GRAIN QUALITY OPTIMIZATION AND MARKETING

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PRODUCING MILLING OATS IN WESTERN WASHINGTON: GUIDE TO GRAIN QUALITY OPTIMIZATION AND MARKETING

By

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Abstract

Oats, like wheat and barley, are a small grain which agricultural producers in western Washington can incorporate into their rotations to disrupt pest and disease cycles and contribute to soil quality. Oats are physiologically well adapted to the region's cool climate and high rainfall. However, oats have not been studied in western Washington during recent generations, and there is a lack of information about value-added markets for the crop, optimal production practices, and variety choice. This publication takes a first step towards rebuilding a regional knowledge-base for oats, focusing on the production of food oats for the milling industry. We introduce milling oat quality specifications and describe how the crop's performance can be managed to meet them, both in the field and after harvest. Results are presented from two years of variety trials carried out in four western Washington counties which identified several oat varieties with consistent yield and quality performance. Production data from these trials are analyzed together with regional market prices to provide an indication of the revenue potential of milling oats grown in western Washington. Comparison of revenues with those of other small grains show that oats can be economically competitive. Oats represent an interesting opportunity for producers in western Washington both to diversify their rotations and strengthen local food systems.

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Producing Milling Oats in Western Washington: Guide to Grain Quality Optimization and Marketing

Introduction

West of the Cascade mountain range, where a cool maritime climate prevails, the most widely grown crops include specialty potatoes, berries, and hybrid brassica seed. The relatively high returns commanded by these crops are crucial to farm businesses under economic pressure as urban expansion makes farmland increasingly scarce and more expensive. At the same time, continuous monocropping of high value crops is unsustainable owing to the buildup of pest and disease pressures, so small grains are used by many farmers as rotation crops.

Oats and other small grains are not susceptible to major diseases of crops typically grown in western Washington, such as white mold (caused by *Sclerotinia sclerotiorum*) and verticillium wilt (caused by *Verticillium dahliae*). In addition to disrupting pest and disease cycles of beans, peas, sunflower, brassicas, carrots, and potatoes, small grains can contribute to a robust local food system. Work has been underway in recent years to develop markets which can add value to wheat and barley crops in western Washington, such as the breadmaking market for wheat (Hills et al. 2012) and the craft malting market for barley (Stayton 2014). Similarly, there are opportunities to add value to oats (*Avena sativa* L.) by marketing their grain to the human food market. Oats for human food are known as milling quality oats, referred to hereafter as **milling oats** (note that in the grain trade, milling oats are differentiated from feed oats in terms of grain quality only, not production practices).

Oats represent a practical option for western Washington farmers already growing wheat or barley, and a way to add further diversity to their rotations. Oats have a lower disease susceptibility than other small grains (Forsberg and Reeves 1995). Field equipment is interchangeable between oat, wheat, and barley crops. The same grain-cleaning equipment can also be used, though different sieve sizes might be required. For region-appropriate guidance on small grains equipment, see Miles et al. 2009.

Among the small grains, oats are particularly well suited to production in western Washington. Oats germinate well in cold, wet soil and produce their best yields and test weights when spring temperatures are cool and there is ample water supply (Forsberg and Reeves 1995). Indeed, oats have a higher water requirement than other small grains (Briggs and Shantz 1913). The Puget Sound region used to produce some of the world's highest yielding oat crops (Shands and Chapman 1961). Oats disappeared from western Washington in the late

twentieth century along with the region's milling industry as farmers sought higher margin crops (Winkler et al. 2016), but with the 1986 opening of the Grain Millers facility in Eugene, OR, a commercial-scale regional oatmeal mill is now available again.

Because oats have been largely overlooked in western Washington cropping systems during recent generations, there is a lack of up-to-date information about the practical and economic considerations of producing milling oats in the region. This publication addresses the gap by providing guidance on how to understand and meet modern milling oat quality criteria; it also estimates revenue potential using milling oat variety trial data collected in 2014 and 2015 from Whatcom, Skagit, Island, and Thurston Counties.

Marketing Milling Oats in Western Washington

Major milling companies use hulled oats for food oat production rather than hullless oats (a variant of *Avena sativa* L.). One reason for this is the protection offered by the hull during transport and storage of the grain. Oat **groats** (the name used for the oat kernel inside the hull) are high in lipids and vulnerable to rancidification, which speeds up on contact with the air. Owing to the high lipid concentration, oat groats are also soft and easily broken during handling. Additionally, there are relatively few hullless oat varieties available on the US seed market at the time of this publication, and the agronomic performance of the best hullless oat varieties does not yet equal that of the best hulled varieties. In this publication, discussion of grain quality criteria refers solely to hulled oats.

The processing of hulled oats for food requires cleaning, heat treatment to inactivate lipid-degrading enzymes, removal of the tough hull, toasting to develop flavor, and moisture adjustment followed by flaking or grinding (Girardet and Webster 2011; North American Millers' Association 2016). The high capital intensity of oat processing accounts for the relatively small number of oatmeal mills in the US. Most facilities are located in the Midwest (North American Millers' Association n.d.). The largest scale facility accessible to farmers of the coastal Pacific Northwest is that operated by Grain Millers, Inc. in Eugene, OR. This facility processes 50,000 tons per year of oats. Much of the intake is currently imported from Canada owing to lack of local production, but local sources of grain are sought and the mill is able to collect from farms throughout the coastal Pacific Northwest. Because the Grain Millers facility is likely to remain an accessible

Table 1. Example of milling oat quality specifications

	Target ^a	Min/Max ^b	Spec ^c
Quality			
Test weight	40 lb/bu	36 lb/bu	38 lb/bu
Moisture	13%	10–14%	13.50%
Thin kernels (thins)	5%	20%	12%
De-hulled groats	6%	12%	8%
Foreign material (FM)			
FM, conventional	1%	3%	2%
FM, organic	2%	5%	3%
Legumes	0%	1%	0.5%
Oil seeds	0%	1%	0.5%
Barley	0%	2%	1%
Wheat	0%	2%	1%
Total other	0%	2%	2%
Wild oats	0%	2.5%	2%
Ergot	0%	0.02%	0.02%
Damage			
Frost	0%	2%	0%
Sprouted grains	0%	2%	0%
Green seeds	0%	1%	0%
Total of above	0%	3%	2%
Fusarium mycotoxins	0%	1.0 ppm	0.1 ppm
Heated seed	0%	0.10%	0.10%

Source: Grain Millers, Inc. (2016)

^aIndicates ideal specifications; consignments meeting ‘Target’ do not receive a price premium, but in years with ample supply, they will be prioritized for purchase over consignments meeting ‘Spec’.

^bIndicates threshold for rejection of consignment.

^cIndicates required specifications for full purchase price.

option for marketing milling oats grown in western Washington, its quality specifications, purchase process, and prices are used as a reference in this publication. Growers may be able to identify other buyers in the region, and one tool to help with this is Washington State University’s [online bulletin board](#) of organic small grain sales.

In a typical purchase process, the grower first submits a subsample (approximately 2 lb) of harvested and cleaned grain to the mill. This sample can be sent by mail. The mill inspects the sample according to its quality specifications (see the section on Producing for the Milling Market; Table 1). The consignment may be rejected if minimum specifications are not met. If minimum specifications are met but optimum specifications are not met, a reduced purchase price may be offered. In the words of the grain trade, the purchase price is docked (**dockage** refers to that part of the consignment weight which is deemed to be foreign or low quality oat material and therefore not paid for). Rules of price reduction are described in the buyer’s discount schedule (see the section on Producing for the Milling Market; Table 2), but terms may vary according to the market situation.

There are many ways in which the grower can manage grain quality of their oat crop and to anticipate the likely influence of environmental factors on grain quality. These are discussed in the following section.

Table 2. Example of milling oat discount schedule^a

	Conventional oats	Organic oats
Test weight	Discounts apply 38–36 lb \$0.01 per 1/2 lb Reject under 36 lb	Discounts apply 38–36 lb \$0.015 per 1/2 lb Reject under 36 lb
Moisture	Discounts apply 13.5–14.0% \$0.01 per 1/10% Reject over 14%	Discounts apply 13.5–14.0% \$0.02 per 1/10% Reject over 14%
Thins	Discounts apply 12–20% \$0.01 for every 1% Reject over 20%	Discounts apply 12–20% \$0.02 for every 1% Reject over 20%
Wild oats	Discounts apply 1.0–2.5% \$0.02 per 1/2% Reject over 2.5%	Discounts apply 1.0–2.5% \$0.05 per 1/2% Reject over 2.5%
Wheat	Discounts apply to 1.0–2.0% \$0.02 per 1/2% Reject over 2.0%	Discounts apply 1.0–2.0% \$0.04 per 1/2% Reject over 2.0%
Barley	Discounts apply 1.0–2.0% \$0.05 per 1/2% Reject over 2.0%	Discounts apply 1.0–2.0% \$0.08 per 1/2% Reject over 2.0%
Foreign material (FM)	All FM is deducted as dockage	All FM is deducted as dockage

Source: Grain Millers, Inc. (2016)

^aDiscounts are applied on a bushel basis. One bushel of oats is defined as 32 lb by US Grain Inspection, Packers and Stockyards Administration.

Producing for the Milling Market

Quality Criteria

Buyers of food grade oats each set their own quality specifications for a range of criteria, though they are largely similar across organizations. The purchase price of mill intake is contingent upon meeting specifications. As an example, specifications of Grain Millers, Inc. are presented in Table 1. The ideal sample has high test weight, freedom from damage and foreign material, plump kernels of uniform size with bright, light-colored hulls, and low moisture content. Perhaps the most important criteria that the grower can actively manage through variety choice and agronomic management decisions are thins and test weight. These are both assessed on harvested and cleaned grain.

Thins

Percent **thins** is defined as the fraction of oat kernels which pass through a screen with slots measuring $5/64 \times 3/4$ in. These kernels are too small to be processed in the mill and are lost to byproduct streams such as animal feed (Girardet and Webster 2011). The maximum accepted standard is generally 20%, with discounts applied over 12% (Tables 1 and 2).

In general, factors which depress average **kernel weight** (weight of the hull and groat together) in oats tend to increase percent thins. High soil fertility and warmer temperatures can both cause oats to produce more kernels per plant, which can result in higher yields but at the expense of the optimum kernel size profile. In a Canadian study of no-till oat production, 107 lb/ac of nitrogen caused a significant increase in percent thins relative to rates up to 71 lb/ac (Lafond et al. 2013). A second Canadian study observed a linear decrease in kernel weight with increasing nitrogen application (May et al. 2004). Research in Finland has shown a negative relationship between available phosphorus and oat kernel weight, which the author also attributed to the formation of more kernels on plants in more intensively fertilized plots (Saastamoinen 1998).

Smaller kernels can also be understood to result from a shortened grain fill period under unfavorable growing conditions in early summer. Nutrient or water limitation both interfere with grain fill, and oats are also very vulnerable to heat stress. In a growth chamber experiment, Hellewell et al. (1996) observed a 27% longer grain fill period in oat plants grown under a 59°F day/59°F night regime relative to oats grown in a warmer regime of 88°F day/59°F night, and the longer grain fill was associated with 51% higher kernel weight. Exposure to higher temperatures during grain fill is a likely explanation for research showing that later seeding dates increase percent thins in spring oat crops (May et al. 2004).

Test Weight

Test weight (bushel weight) quantifies bulk density of the grain and is obtained by converting the measured weight of a known volume of grain to the weight of one bushel (e.g., multiply the weight in pounds of one quart of grain by 32 to obtain the bushel weight of the sample), standardizing to 14% grain moisture content.

From the buyer's perspective, test weight is an indicator of grain quality and efficiency of transport and storage (Ames et al. 2013), so the highest possible value is desired. The absolute minimum accepted test weight for milling oats is generally 36 lb/bu, with a general specification for a full price of 38 and a target of 40 lb/bu (Tables 1 and 2). Growers should be aware that consignments with a 36 lb/bu test weight are unlikely to be accepted unless there is a widespread shortage of higher test weight oats in that year.

Some research suggests that the majority (60%) of variation in test weight is explained by genetics, i.e., variety choice (Peterson et al. 2005), while other research suggests equal effects of genetics and environment (Doehlert et al. 2001). Results depend on which varieties are included in a given study and the type of environmental variation they are exposed to in the field.

Similar to percent thins, test weight is related to kernel weight. The relationship is often positive (Peterson et al. 2005), but not always. Seed shape is one confounding factor: rounder oat grains tend to have higher test weight (Doehlert et al. 2006). Elongated, thin kernels may be a product of variety genetics, or may be caused by environmental stressors such as disease or water or nutrient deficiency during grain filling; kernel length is already determined at anthesis, but kernel width can vary according to the degree of grain fill (Ames et al. 2013). Like percent thins, test weight can also be negatively affected by high fertility situations which stimulate the oat plant to form a large number of grain sites among which it must later distribute a finite quantity of photosynthate. High nitrogen early in the growing season is particularly problematic in this regard (Forsberg and Reeves 1995).

Another factor contributing to test weight is **kernel content**, also known as groat percent or groat proportion, defined as the weight of the groat relative to the weight of the grain including the hull. The oat groat is denser than the hull, so a higher kernel content generally gives rise to higher test weight (Doehlert et al. 2006; Doehlert et al. 2009; Peterson et al. 2005). The relationship between kernel size and kernel content is not smoothly linear because an empty space exists between the groat and the hull, and the size of this space can vary under both genetic and environmental influence (Doehlert et al. 2006).

If the grower is aiming to maximize the quality of harvested grain over yield, wind strength (fan speed) can be adjusted upwards on the combine harvester and/or grain cleaning equipment to try and eliminate the lightest fraction of seed.

Moisture Content

Grain moisture content of mill intake is generally specified between 12% and 14% (Tables 1 and 2). Grain should be dried if harvest occurs before it has reached this level, but drying above 110°F can cause **heated seed** damage and should be avoided. In western Washington, early or mid-season varieties are more likely to mature in time to be harvested dry before fall rains begin. Particularly in years when spring rains delay planting, growers should prioritize shorter days to maturity as a criterion when choosing which variety to grow.

Other Criteria

Upper limits may be set by buyers of milling oats for the presence of **Fusarium-infected grain**. Fusarium head blight (FHB) is known as a disease of wheat and barley but has become a problem in oat crops during the last two decades (Tekauz et al. 2004). It is caused by several strains of fungus in the genus *Fusarium* including *F. graminearum*, *F. poae*, and *F. sporotrichioides*. In the field, infection can be recognized by pink or tan shading at the base of the glume which proceeds to cover the whole glume (Figure 1; Grain Millers, Inc. 2016). FHB can lead to the accumulation of deoxynivalenol (DON, also known as vomitoxin) in grain, though the visible symptoms of FHB in the field are not a reliable indicator of how much DON will accumulate on the grain (Tekauz et al. 2004). DON is detrimental to human health. US Food & Drug Administration guidelines set a maximum limit of one part per million for the presence of DON in food products (FDA 2016), which may be reflected in buyer standards and is established by the buyer in a laboratory test of grain samples.

There are a number of management options growers can deploy to minimize the severity of FHB infection, which are well summarized by McMullen et al. (2008). They include rotation of small grains with broadleaf crops, burial of small grain residue through tillage, use of high quality, clean seed for planting, and the application of triazole fungicides at early flowering. FHB is too recent a problem in oats for plant breeders to have responded with resistant genotypes, but work in this area has begun. Growers should also be aware that lodging can increase levels of DON mycotoxin (Tekauz et al. 2004).

Foreign material such as insects, weed seeds, and grains other than oats will also lead to discounts or rejection. Similar specifications are encountered in any food quality grain market. Contamination with foreign material is related to



Figure 1. Fusarium-infected oat floret. Photograph by Janet Lewis, CIMMYT.

physical handling (harvest, cleaning, and storage) of the grain in addition to field management.

Dehulled oats in a consignment are considered undesirable because they will rancidify quickly and will be further damaged during the mill's dehulling process. Dehulled oats can arise from hull breakage in the combine harvester and can be addressed by widening the concave and reducing cylinder speed. Oat hulls are more fragile in hot, dry summers, so it may be wise to reduce cylinder speed on the combine during harvest in such years.

Grain samples may also be inspected for **frost damage** to kernels, which refers to frosts occurring when the crop is mature and is unlikely to affect oats grown in western Washington. **Preharvest sprouting** is also unlikely to particularly affect oat kernels, which are somewhat protected from moisture by their lignified hulls; but it is unwise to leave a mature crop standing in the field for long periods, particularly if there is the risk of rain. **Green seed** may be observed in harvested grain if there are a lot of secondary tillers in the crop, resulting from (1) severe stressors early in the season, (2) the use of a particularly late-maturing variety, or (3) overapplication of nitrogen.

White, cream, or yellow **hull colors** tend to be preferred for food oat applications because damage to the grain can be more clearly detected than with darker colored hulls. Hull color is influenced primarily by variety and secondarily by environmental conditions. Adequate crop nutrition and warm, sunny weather are required for full expression of the variety's natural hull color. Cool, wet, or humid weather near harvest or moisture in storage encourage growth of mold on the hull and dark staining. Figure 2 shows the oat variety Furlong grown at Thurston and Island counties in 2015. The plants at Thurston were less stressed and developed a more intense hull color



Figure 2. Oat variety Furlong grown at Thurston (left) and Island (right) in 2015, showing effects of local climate on weathering and hull color. Photographs by Louisa Winkler.

during the course of the season; they were also more affected by preharvest mold growth owing to the accumulation of 2.5 in of rain in the two weeks prior to harvest. Severe discoloration of hulls can be cause for rejection of oats at the mill.

Finally, kernel content of 75% or more is preferred. This is generally achieved with varieties bred for use as milling oats. Hulling degree describes the proportion of grains successfully dehulled during milling, while hullability describes the ease of hull removal from the groat (Browne et al. 2002). Though millers care about these characteristics, there are currently no standardized tests which can be used to measure them. Millers may specify preferred varieties of oat which are known to perform well in these respects.

Agronomic Factors Influencing Grain Quality

Grain quality traits vary not just according to the genetics of a particular variety, but also according to agronomic management. Oats are thought of as a resilient species of small grain which grow well under conditions suboptimal for other cereals; indeed, high fertility conditions can be detrimental to seed quality. Nonetheless, oat seed quality does suffer equally under excessive exposure to environmental stressors including nutrient limitation (Ames et al. 2013), so growers must manage sensitively to strike the right balance.

Good practical references for management of milling oat crops are published by Grain Millers, Inc. (2011) and Senova (2011). Senova markets the most widely grown oat varieties in the UK and its guide is written for UK growers, who primarily grow winter oats; but most of the concepts and practices discussed are transferrable to spring oat crops (note that test weight is known as “specific weight” in the UK). In the following section, locally specific guidelines and research findings are presented.

Planting Date

Spring oat crops in western Washington can be planted as soon as the ground is sufficiently dry. Oats can germinate in soil temperatures of 37–41°F, and early planting minimizes damage to the crop from high temperatures and drought in spring and summer (Forsberg and Reeves 1995). This is an important consideration as western Washington progresses on a trend towards warmer and drier spring and summer weather.

Later planting of oats results in accelerated development of the crop and a smaller total number of days in the growing season. In the absence of agronomically significant diseases such as crown rust (caused by *Puccinia coronata* f. sp. *Avenae*; see the section on Disease and Insect Control), planting date is unlikely to have a strong growing effect on quality characteristics. If any effect is observed, it is likely to be a reduction in yield and test weight (Ciha 1983; May et al. 2004) and/or reduction in kernel weight (Frey 1959a), observed at later planting dates.

If cultivation is being used as the primary method of weed control, earlier planting dates may give rise to higher levels of weed seed contamination in harvested grain because less time is available for cultivation before planting (May et al. 2004).

Seeding Rate

Marshall et al. (1987) obtained higher test weight in two oat varieties by increasing the seeding rate from 60 to 119 lb/ac, but denser planting caused earlier maturity and lodging. Guitard et al. (1961) tested three oat varieties in nine environments at seeding rates of 48–128 lb/ac and reported no change in thousand-kernel weight but a yield increase between rates of 48 to 80 lb/ac, which thereafter levelled off. They showed that as plants per acre increased, panicles per plant and kernels per panicle both decreased. Ciha (1983) tested oats at Pullman in eastern Washington and found that

raising oat seeding rates from 36 to 98 lb/ac improved crop yield when seeding date was early; however, it had no effect when seeding date was late.

While seeding rates in the literature are often reported as weight per unit area, oat varieties can differ widely in average kernel weight. Variety thousand-kernel weights obtained in eight site-years in western Washington spring oat variety trials ranged between 24.9 and 48.9 g (see the Appendix). Targeting 23 plants per square foot and assuming 80% germination rate, these thousand-kernel weight values yield seeding rates of 69 and 136 lb/ac respectively. This large range illustrates the value of calculating seeding rates by using a kernel weight measurement and targeting a specified number of seeds per unit area rather than a specified number of pounds. The general recommendation for spring oats is to aim for a live plant population of 18–25 per square foot (Wade 2011; Grain Millers, Inc. 2016).

Crop Nutrition

Fertilizer management decisions should take account of soil type, organic matter content, cropping history, and previous inputs, which can influence soil nutrient supply. An oat crop planted after legumes may not need additional fertilizer applications at all. Soil tests to determine soil nutrient status prior to fertilizer application are well worth the expense.

Research into nitrogen (N) needs of oats has suggested that, as a rough guide, growers should provide 1.3 lb per acre of available soil N for each bushel per acre of yield sought (Forsberg and Reeves 1995). (A standard oat bushel is set at 32 lb by the Grain Inspection, Packers and Stockyards Administration.) For a yield of 180 bu/ac (5,760 lb/ac), a reasonable target in western Washington, the grower would thus aim for 234 lb/ac of available N, constituted from N present in the soil plus added fertilizer.

Several studies have shown that higher rates of available N early in the season increase plant height, panicle density, and lodging in spring oat crops (Frey 1959b; Brinkman and Rho 1984; Marshall et al. 1987; May et al. 2004). Increased grain yield associated with N application arises from the higher number of seeds per plant (Frey 1959b); as noted (see the section on Thins), the impact on grain quality tends to be negative, in particular at later seeding dates (May et al. 2004). N applications after mid-booting stage (Zadoks 43-47, Feekes 9-10) mainly serve to increase grain protein (Forsberg and Reeves 1995).

Mohr et al. (2007) reported that, similar to N application, application of phosphorus (P) and potassium (K) fertilizer to spring oat crops at seeding stimulated changes in plant height

and panicle density, though of smaller magnitude.

Nonetheless, application of both P and K is worthwhile if they are deficient in the soil, as both are crucial to the oat plant's physiological function from its earliest growth stages and the plant is quicker to show stress symptoms without them (Forsberg and Reeves 1995; Grant et al. 2001). Also, P is considered the most important plant nutrient for lodging prevention.

Influence of fertilization on oat grain quality depends on the oat variety, planting date, soil nutrient status, and weather. The susceptibility to lodging of a given variety is a function of both its height and its stem strength; as with other small grains, shorter oat varieties are generally able to withstand higher fertility conditions without lodging. Growers should examine plant height and lodging in variety tests as a consideration in variety choice and fertility management.

A final factor in crop nutrition for oat crops in western Washington is manganese (Mn) deficiency, known as gray speck. Oat plants have a relatively high Mn requirement, and gray speck has been observed in many western Washington oat variety tests. Soil conditions inhibiting Mn availability include: (1) neutral to high pH; (2) recent liming; (3) high organic matter; and (4) high iron content (Schulte and Kelling 1999; Hong et al. 2010). Such conditions are observed at many locations in western Washington and gray speck can probably be expected to occur commonly in oat crops. Symptoms begin as gray, oval spots of dying leaf tissue on the edge of new seedling leaves which spread as the plant grows and can eventually cause some leaves to distort and collapse (Figure 3). Observations from variety tests suggest that cultivars differ in their susceptibility to gray speck, but unless the deficiency is extremely severe, it is probably not a yield limiting factor.

Weed Control

Oats are quick to establish and develop a dense canopy and are therefore good competitors of weeds. They are also able to withstand tine-weeding at the two- or three-leaf stage, which can be a very effective method of weed control in organic crops. For best effectiveness, tine-weeding should be done when the soil is dry and weed seedlings are at the 'white-thread' stage (Lundkvist 2009). For organically grown spring oat crops, a cover crop sown the preceding fall can offer effective weed control; in choosing what species or variety to use, consideration should be given to how the cover crop will be terminated (Singh 2012). Researchers have had success controlling weeds in organic small grains by sowing the seed in two perpendicular passes to distribute it more uniformly or by sowing at wider row spacing and performing inter-row cultivation (Kolb et al. 2010). Intercropping oats with peas is a nonchemical weed control strategy with an excellent track



Figure 3. Gray speck symptoms on spring oat leaves. Photograph by Louisa Winkler.

record (Gronle et al. 2015), but one that unfortunately cannot be used in milling oat production on account of the risk of contaminating grain with foreign matter.

Growers considering the use of herbicides should be aware that oats are more sensitive to herbicides than wheat or barley. Added to the fact that certain herbicides used in wheat or barley are not labeled for oats, rate and timing of application are generally more critical in oats than in other small grains (Forsberg and Reeves 1995). Herbicides 2,4-D, bromoxynil, MCPA amine, diuron, thifensulfuron-methyl, and tribenuron-methyl are all used for weed control in oat crops in the coastal Pacific Northwest. The Oats section of the PNW Weed Management Handbook (Morishita 2016) provides further information about the application of herbicides to oat crops at various stages.

Disease and Insect Control

A major advantage of western Washington as an oat production region is that it appears to be free of crown rust, caused by the fungus *Puccinia coronata* f. sp. *avenae*. Crown rust is a major disease of oats present in most other regions where the crop is grown (Martinelli 2004) and causes major impairments to grain yield and quality (Simons et al. 1979; Martinelli 2004; May et al. 2014). In northwest Oregon, likewise, growers do not encounter crown rust and do not make fungicide applications to oats (Nicole Anderson, Oregon State University, personal communication).

Oats grown in western Washington are, however, affected by barley yellow dwarf (BYD) virus, an increasingly common disease of small grain crops in the region (O’Connell 2016). BYD is spread by many species of aphid, primarily the oat bird-cherry aphid (*Rhopalosiphum padi*) and the English grain aphid (*Sitobion avenae*; Figure 4).



Figure 4. English grain aphid (left) and oat bird-cherry aphid (right). Photographs by Magnus Gammelgaard Nielsen, Aarhus University.

Infected oat plants show reddening of the leaves and reduced leaf size, followed by reduced grain set (Figure 5). Spring grain crops are generally less affected than winter crops by BYD because their main growth stages take place after aphid flight has peaked. According to the PNW Insect Management Handbook, control measures taken against an already-established aphid population are unlikely to reduce BYD incidence (Rinehold 2016). A pre-emptive strategy is an insecticidal seed treatment. Neonicotinoid chemicals imidacloprid (Gaucho) and thiamethoxam (Cruiser) have shown control of aphid activity up to 150 days after crop emergence, i.e., the full growing season for most spring oat crops (Rinehold 2016), and are labeled for oats. Both organic and conventional oat growers can benefit from choosing oat varieties with BYD tolerance such as Rockford, Tack, and Saber. Tolerant varieties may exhibit some of the symptoms of infection but are less likely to suffer yield loss.

Cereal leaf beetle, *Oulema melanopus*, is a pest of oat crops in western Washington. The adult insect and its larvae strip green material off the leaf and reduce its photosynthetic area. Populations can build up quickly and cause yield loss. Cereal leaf beetle is also considered a serious pest of oats in northwest Oregon, where growers spray Mustang Maxx insecticide to control it (Nicole Anderson, personal communication). Mustang Maxx is registered for use in Washington State. Some spinosad products can be used in organic certified crops (Rinehold 2016) under conditions specified in the Crop Pest, Weed, and Disease Management section (205.206e) of the USDA organic standards. A biological alternative is introduction of parasitoid wasps (*Tetrastichus julis* and *Anaphes flavipes*) by WSU agents or APHIS (Rinehold 2016).



Figure 5. Oat plants with yellow or red discoloration at leaf tips indicative of BYD virus infection. Photograph by Louisa Winkler.

Weather

Oat crops generally perform best in terms of yield and quality under relatively cool conditions. In oats, as in wheat and barley, research has shown that high temperatures after anthesis can cause reduced seed size, increasing the tendency for higher thins proportion (Brouwer and Flood 1995). Taylor (1967) compared a “warm” regime of 84°F day/59°F night to a “control” regime of 65°F day/47°F night and found that oats undergoing tiller differentiation in the “warm” regime developed fewer panicles but drastically increased the number of seeds per panicle, resulting in much lower seed weights. In contrast, oat plants exposed to a “cool” regime of 49°F day/35°F night during tiller differentiation developed fewer seeds per panicle, resulting in lower total grain yield per plant but higher individual seed weight than normal.

Reviewing experimental findings regarding the influence of water availability on oat crop development, Brouwer and Flood (1995) report that water limitation (drought stress) can interfere with photosynthesis and the translocation of assimilates, reducing grain fill and ultimately crop yield. Waterlogging early in the growing season negatively impacts tillering, but oat plants are able to compensate later in the season by increasing grain weight.

Oat crown rust is favored by humid conditions, explaining why oat test weight in many reports is negatively correlated with precipitation (Doehlert et al. 2001), while in western Washington, where crown rust is absent, precipitation generally enhances oat test weight (see the section on Disease and Insect Control).

These findings may explain why western Washington’s climate has historically been considered uniquely well suited to the production of high quality oats. However, the current trend is for the region to experience warmer and drier weather in spring and summer (Elsman and Ekrem 2012), and oat variety tests reported in this publication (see the Case Study and the Appendix) demonstrate the negative influence of such weather on oat crop yield and quality. If the current trend continues, it will represent a challenge to oat growers targeting the quality market. One possible upside is the finding that high temperatures at anthesis suppress plant height (Taylor 1967), which could help to control lodging in oat crops.

Variety Choice

To generate information about the performance of modern US oat varieties in western Washington and assess which ones would be most suited to use as milling oat varieties in the region, variety trials of spring oats were conducted at four locations during the growing seasons of 2014 and 2015. In-field and postharvest data collection included heading date, plant height, lodging rate, yield, test weight, kernel weight, and thin kernels. Locations were in Whatcom, Skagit, Thurston, and Island Counties. A subset of varieties was omitted from the Whatcom trial in 2014 and hence was only tested at seven environments total; these varieties are identified along with the full report of trial results in the Appendix.

The spring oat nurseries faced challenges in many of the test environments. Abundant spring and summer rain in Skagit 2014 caused lush vegetative growth and severe lodging; a late application of 2,4-D herbicide in Island 2014 caused plant injury and reduced grain quality; a bird infestation reduced yields and grain quality in Island 2015, and the nursery faced severe weed pressure in Thurston 2014. Four of the eight trials were on certified organic land. All test locations in 2015 experienced abnormally high spring temperatures and low rainfall, which showed strong influence on yield (whole-trial average yield in 2014 was 4,889 lb/ac, whereas in 2015 it was 3,025 lb/ac) and grain fill (Figure 6). In view of the challenges faced, results with respect to yield and grain quality performance were encouraging for the potential of milling oat production in western Washington.

Those varieties which delivered the most impressive individual results were not necessarily those which performed with the greatest consistency. Across four locations and two years of

data collection, the maximum observed yield was obtained with Pinnacle at Skagit in 2014 (8,667 bu/ac), but Pinnacle was mid-ranked for average yield across all environments (Table 3). The maximum observed test weight was obtained with Buckskin at Island in 2014 (44.9 lb/bu), but Buckskin also set the record for the highest percent thins at Island in 2015 (28%). For the most reliable prediction of future performance, growers may wish to focus on consistency of past performance when selecting a variety to grow. Table 3 displays the frequency (percentage of seven or eight trial environments at which varieties were tested) with which each variety met milling quality specifications for thins (minimum 20%, optimum 12%) and test weight (minimum 36 lb/bu, optimum 38 lb/bu). While no variety met specifications at every test environment, several had high success rates. Rockford and Tack both attained optimum specifications at 75% of test environments and minimum specifications at 88% of environments.

In addition to varieties recently tested in western Washington, oat growers may also consider milling oat varieties showing promise in tests in other regions. Examples include Shelby 427 and Hayden, released by South Dakota State University; and Betagene and Badger, released by the University of Wisconsin (Gailans and Carlson 2015; Wiersma et al. 2015; Ransom et al. 2016; Lang and Pecinovsky 2014).

Storage and Handling Factors Influencing Grain Quality

In most of the variety trials described in this manual, oats were harvested using a combine harvester with cylinder speed set to 1350 RPM and concave width set to 5 mm at the front and



Figure 6. Oat variety test plots at WSU NW Washington Research & Extension Center, Skagit County, in mid-June of 2014 (left) and 2015 (right), showing the effects of an extremely dry growing season in 2015. Photographs by Louisa Winkler.

Table 3. Results from spring oat variety trials carried out in 2014 and 2015 at four locations in western Washington: mean yield across eight environments and the percentage of environments in which each variety met minimum or optimum milling specifications for thins and test weight.^a

Variety	Mean yield, lb/ac ^b	% test environments meeting milling standards	
		Optimum ^c	Minimum ^d
AC Morgan	4,617	25	63
Kaufmann	4,530	71	71
Jordan	4,434	0	38
ProLeaf 234	4,405	25	50
Horsepower	4,333	63	88
AC Lu	4,329	43	71
Tack	4,152	75	88
Furlong	4,120	50	75
Rodeo	4,045	29	71
Summit	4,022	57	86
Rockford	4,011	75	88
Saber	4,005	43	71
UC 125	4,002	50	63
Pinnacle	3,990	29	57
NZA293,111	3,920	29	71
Viking	3,886	38	63
Esker	3,850	57	71
Chaps	3,766	29	57
Leggett	3,702	43	71
Excel	3,700	57	86
Robust	3,654	71	71
Souris	3,639	50	63
Ronald	3,621	57	86
Buckskin	3,579	38	88
Jim	3,570	71	71
IL06-5465	3,564	75	88
Ogle	3,529	29	43
Jay	3,430	57	86
HiFi	3,376	43	71
Spurs	3,246	57	86

^aFull trial results are presented in the Appendix.

^bAveraged across eight environments.

^cOptimum standards are taken as more than 38 lb/bu test weight and less than 12% thin kernels.

^dMinimum standards are taken as more than 36 lb/bu test weight and less than 20% thin kernels.

1 mm at the back. Optimum harvest settings can vary depending on year, location, and variety, so growers are generally advised to check performance and re-adjust equipment at each harvest. More detailed guidance on small grains equipment appropriate to western Washington is given by Miles et al. (2009).

Oat grain is cleaned on intake at the mill, and a large percentage of mill intake is field-run; but growers are more likely to avoid dockage or rejection for foreign material, heated seed, and weed seed presence if they are able to clean their own grain after harvest. Oats can be cleaned effectively using the same equipment as that used for other small grains, such as a Clipper (A.T. Ferrell Company, Inc., Bluffton, IN), though different sieve sizes may be needed. It is especially important to clean out unripe weed seeds and other green matter after harvest, as the oats will absorb their moisture during storage. Growers may wish to consider the option of custom cleaning as a last resort to improve test weight of harvested grain. If grain is to be cleaned before sending to the mill, the subsample for advance inspection (see the section on Marketing Milling Oats in Western Washington) should be taken after cleaning.

Moisture and temperature are the most important considerations in storage of food grade oats. Recommendations state that oats should be stored between 40°F and 70°F at no more than 13% grain moisture (Ganssman and Vorwerck 1995). Grain should be dried before storage to achieve ≤13% moisture, though drying temperatures should not exceed 110°F (see the section on Moisture Content) to avoid downgrading at the mill for heated seed.

Summary of Production Information

In western Washington, early planting dates for spring oats are likely to favor high grain quality. Early planting can also help to limit negative impacts on yield and quality arising from spring and summer heat and drought. Fertility for milling oat crops should be adequate but not too high, a rule of thumb being 234 lb/ac available N for expected yield of 180 bu/ac. It may be possible to increase test weight and yield by increasing seeding rate from a baseline of 18 plants per square foot, but at the risk of increased lodging. Growers using higher fertility and planting densities should be especially careful to choose varieties with short plant height and high lodging resistance (e.g., Horsepower, Jay, and Spurs). In general, absence of fungal disease affecting oats in western Washington gives growers a lot of flexibility in variety choice. Growers should be cautious in applying herbicides on oats and should probably avoid doing so after stem elongation has begun. Choosing early maturing varieties (e.g., Buckskin, Excel, and Horsepower) will help to ensure that grain moisture drops as low as possible by harvest; grain should be dried to 13% moisture before storage.

Case Study: Revenue Potential of Milling Oats in Western Washington

The revenue potential of milling oats in western Washington depends not only on the buyer and their purchase price but also on performance of the oat variety at the location where it is grown. Here, we use data from western Washington spring milling oat variety tests conducted in 2014 and 2015 (see the Appendix) to estimate gross returns obtained at four locations in the region using each of four oat varieties. The varieties Esker, Horsepower, Rockford, and Tack were chosen because they are some of the most readily available on the commercial seed market, in addition to being known as relatively reliable milling oat varieties. To represent price of conventional grain, we used Grain Millers, Inc. annual average purchase prices for grain delivered to the mill in Eugene, OR (Perry Anderson, personal communication). Organic grain prices were reported to be 1.5–2 times higher than conventional prices in 2014 and 2015 (Perry Anderson, Grain Millers, Inc., personal communication), so we used a conservative organic grain price estimate of 1.5 times the conventional price for each year.

Gross revenue figures given in the case study take account only of dockage assessed for test weight and thin kernels. Dockage is also assessed for the presence of foreign material and high grain moisture (see the section on Marketing Milling Oats in Western Washington; Tables 1 and 2). These factors reflect aspects of field management and grain handling that we were not able to make assumptions about based on variety trial data.

Over the 32 variety-environment combinations examined, milling oats earned between \$331.92 and \$1,113.22/ac. The highest price was earned by Rockford grown at Thurston in 2015, partly because the premium paid for organic grain from that location offset the lower yields. Across all 32 tests, organically grown grain grossed \$622.26/ac on average and conventionally grown grain grossed \$594.37/ac.

Failure of grain to meet test weight specifications at five of 16 variety-environment combinations in 2015 reflects the negative impact of heat and drought on grain quality during the growing season. In variety tests, all grain was harvested using the same combine settings. It is possible for growers to improve test weight by adjusting combine fan settings upwards at harvest, although some yield is sacrificed. Similarly, postharvest cleaning can help to improve test weight.

Also partly attributable to heat and drought in 2015 were lower yields than in 2014, which were not fully offset by higher prices paid for grain that year: average revenue per acre from

acceptable harvests were \$636.55 in 2014 and \$567.27 in 2015. Particularly low yields in Island County may have been related to bird damage (see the Appendix).

Using information from regional buyers and western Washington small grain variety trials, it is possible to draw some comparisons between the revenue potential of spring milling oats and that of other small grains grown and marketed in the coastal Pacific Northwest. Prices for organic hullless barley rose to \$850/ton during 2014, considerably more than millers are reported to pay for oats. Hullless spring barley varieties tested in Skagit County organic trials in 2014 yielded 2,561 to 3,183 lb/ac (Brouwer 2014). At \$850/ton, organic hullless spring barley in Skagit County would have grossed \$1,094 to \$1,353/ac. Also in 2014, conventional hullless barley fetched up to \$440/ton in regional markets. Hullless varieties grown conventionally in Skagit County yielded 1,055 to 3,805 lb/ac (see Appendix E in Brouwer 2015), grossing \$232 to \$837/ac.

Prices for organic spring feed barley have reached \$380/ton in the past. In 2014 variety trials in Skagit County, organically grown spring barley varieties yielded between 2,180 and 4,993 lb/ac (Brouwer 2014), translating to gross revenue of \$414 to \$949/ac. Conventional soft white spring wheat in the same location-year yielded 1,302 to 5,598 lb/ac. At a market price of \$260/ton typical of that year, the wheat would have grossed \$169 to \$728/ac. These revenues compare with \$675 to \$846/ac for conventional spring oats grown in the same location (Table 4).

In 2015, hard spring wheat tested in Skagit County yielded 2,100 to 4,632 lb/ac (Lyon 2015). At an estimated purchase price of \$250/ton for conventional hard spring wheat that year, these yields would have grossed \$263 to \$579/ac, in comparison with \$344 to \$372/ac for the three out of four conventional oats grown at the same location that met milling specifications (Table 5). Western Washington barley variety trial data from 2015 was not available at the time of writing, nor were yield data from other locations in the region.

Markets for different grains fluctuate somewhat independently of each other, as does performance of different grains and even different varieties within grain types. For these reasons, the comparisons above should be regarded as very approximate. What they do clearly show is that small grain revenues can fluctuate widely, and it may be difficult to identify a single option which performs consistently better than others. Also, they suggest that revenue potential of milling oats in western Washington is, over time, likely to compare favorably with that of other small grains.

Table 4. Revenue potential of four oat varieties grown at four western Washington locations in 2014

Location ^a	Yield, bu/ac ^b	Test weight, lb/bu	Test weight dockage, \$/bu	Thins, %	Thins dockage, \$/bu	Total dockage, \$/bu	Gross revenue per acre, \$
Esker							
Island C	127.2	41.0	0.00	2	0.00	0.00	\$ 459.86
Skagit C	234.0	39.9	0.00	2	0.00	0.00	\$ 846.31
Thurston O	91.1	38.1	0.00	5	0.00	0.00	\$ 494.14
Whatcom C ^c	—	—	—	—	—	—	—
Horsepower							
Island C	166.6	44.2	0.00	2	0.00	0.00	\$ 602.51
Skagit C	228.1	42.6	0.00	2	0.00	0.00	\$ 824.67
Thurston O	102.9	38.2	0.00	16	0.08	0.08	\$ 549.67
Whatcom C	216.1	41.6	0.00	7	0.00	0.00	\$ 781.33
Rockford							
Island C	91.8	39.0	0.00	6	0.00	0.00	\$ 331.92
Skagit C	196.8	43.5	0.00	3	0.00	0.00	\$ 711.53
Thurston O	109.7	39.4	0.00	12	0.00	0.00	\$ 595.07
Whatcom C	204.0	42.7	0.00	12	0.00	0.00	\$ 737.53
Tack							
Island C	136.5	44.7	0.00	3	0.00	0.00	\$ 493.56
Skagit C	186.7	43.2	0.00	4	0.00	0.00	\$ 675.18
Thurston O	128.9	40.7	0.00	10	0.00	0.00	\$ 699.08
Whatcom C	206.3	44.0	0.00	6	0.00	0.00	\$ 745.95

^aC indicates conventional farm, O indicates organic. Assumed purchase price per bushel is \$3.62 conventional, \$5.42 organic; per ton is 226.25 conventional, \$338.89 organic.

^bYield figures represent the cleaned weight of grain standardized to 14% moisture.

^cEsker was not tested at Whatcom in 2014.

Table 5. Revenue potential of four oat varieties grown at four western Washington locations in 2015

Location ^a	Yield, bu/ac ^b	Test weight, lb/bu	Test weight dockage, \$/bu	Thins, %	Thins dockage, \$/bu	Total dockage, \$/bu	Gross revenue per acre, \$
Esker							
Island O	60.2	29.0	0.27	14	0.04	0.31	Rejected
Skagit C	103.9	33.7	0.09	6	0.00	0.09	Rejected
Thurston O	79.7	39.6	0.00	1	0.00	0.00	\$ 481.94
Whatcom O	146.6	36.8	0.03	5	0.00	0.03	\$ 882.15
Horsepower							
Island O	68.3	32.9	0.15	14	0.04	0.19	Rejected
Skagit C	93.0	36.3	0.03	11	0.00	0.03	\$ 372.28
Thurston O	61.9	39.6	0.00	4	0.00	0.00	\$ 374.61
Whatcom O	147.0	39.2	0.00	7	0.00	0.00	\$ 531.62
Rockford							
Island O	46.2	29.6	0.26	24	0.24	0.50	Rejected
Skagit C	98.7	36.2	0.04	11	0.00	0.04	\$ 394.07
Thurston O	72.1	41.3	0.00	6	0.00	0.00	\$ 435.92
Whatcom O	184.1	40.4	0.00	2	0.00	0.00	\$ 1,113.22
Tack							
Island O	58.2	32.5	0.17	18	0.12	0.29	Rejected
Skagit C	86.1	36.3	0.03	10	0.00	0.03	\$ 344.46
Thurston O	83.2	39.8	0.00	3	0.00	0.00	\$ 503.36
Whatcom O	133.3	39.1	0.00	9	0.00	0.00	\$ 806.41

^aC indicates conventional farm, O indicates organic. Assumed purchase price per bushel is \$4.03 conventional, \$6.05 organic; per ton is \$251.88 conventional, \$378.13 organic.

^bYield figures represent the cleaned weight of grain standardized to 14% moisture.

Seed Sourcing

The variety tests reported in this publication included some experimental lines which are not commercially available. These are identified in the trial report in the Appendix. Many other varieties included in the test are available from commercial seed companies, though availability changes from year to year. Because milling oat production is not well established in western Washington, it is difficult to find regional seed sources for milling varieties; many of our regional seed companies are focused on forage or hay varieties such as Montezuma or Cayuse. Similarly, oat varieties available through companies in California or the South are often bred for forage. Growers of milling oats may need to ship seed from suppliers located in milling oat production areas of the Midwest (ND, SD, MN, WI, and IA are the leading producers).

Targeting certified seed is the most reliable way to ensure high quality. Certified seed is thoroughly inspected by the Crop Improvement Association of the state where it is produced and is verified as having a high germination rate and being free of weed seed and seedborne disease. In addition, the inspectors

ensure that the seed is genetically pure and representative of its variety.

Organic growers may be interested in obtaining seed which is not only certified by the Crop Improvement Association but is also certified organic. Such seed is known as “double certified.” There are few companies producing double certified oats. Examples known to the authors are Albert Lea Seed Company (Albert Lea, MN) and DKG Seed Farms LLC (Orville, OH).

Glossary

dehulled oats. Oat kernels where the hull has been cracked and is partly or entirely missing. A quality concern in food oats.

dockage. A grain trade term for reduction assessed on the purchased weight of grain in a consignment on account of foreign material, damaged seed, and other factors that contribute to not meeting optimum specifications.

foreign material. Material such as ergot, stones, or seeds of weed, wheat, barley or rye in an oat grain consignment. A quality concern in food oats.

frost damage. Damage to grain arising from exposure of the plant to frost during grain development; unlikely to affect oat crops in western Washington.

Fusarium-infected grain. Grain with a high load of mycotoxins produced by *Fusarium* fungal pathogens (only detectable through laboratory tests). A quality concern in food oats.

green seed. Seeds whose hulls have not yet matured enough to lose their chlorophyll and moisture, turn white or brown, and harden. Green seed is a quality issue in food oats.

groat. The edible oat kernel inside the tough outer hull.

heated seed. Seed with physical damage such as cracks in the hull, discoloration, and shrinkage; caused by exposure to excessive heat (over 110°F).

hull color. Each oat variety has its own distinctive hull (lemma) color. Hull color in oats may be white, yellow, tan, grey, red, or black, but white, tan, and yellow are generally preferred for milling oats. Hull color is also influenced by weather conditions.

kernel content. The weight of the groat relative to the weight of the, grain including the hull.

kernel weight. The weight of the hull and groat together.

milling oats. Oats for human food are known as milling quality oats, or milling oats.

preharvest sprouting. Initiation of the germination process in seeds of a standing crop. If advanced enough, sprouting may result in a visible white root and green cotyledon. Preharvest sprouting is a quality concern in food oats.

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Appendix

Milling Oat Variety Tests in Western Washington

Spring oat variety tests were conducted in 2014 and 2015 at the WSU NW Washington Research & Extension Center in Skagit County, WA and on commercial farms in Whatcom, Island, and Thurston Counties.

Table A1. Variety information

Variety	Breeding origin	Year of release or registration	Kernel color
AC Lu	Agriculture and Agri-Food Canada	2004	White
AC Morgan	Agriculture and Agri-Food Canada	2000	Yellow
Buckskin	University of Illinois	2008	Tan
Chaps	University of Illinois	1996	Yellow
Esker	University of Wisconsin	2005	Yellow
Excel	Purdue University	2007	Yellow
Furlong	Agriculture and Agri-Food Canada	2003	Tan
HiFi	North Dakota State University	2004	White
Horsepower	South Dakota State University	2013	White
IL06-5465	University of Illinois	NA ^a	Yellow
Jay	Purdue University	2001	Light tan
Jim	University of Minnesota	1996	Yellow
Jordan	Agriculture and Agri-Food Canada	2006	White to yellow
Kaufmann	Agriculture and Agri-Food Canada	2003	Yellow to white
Leggett	Agriculture and Agri-Food Canada	2005	White to cream
NZA293,111	Progene LLC	NA ^a	Yellow
Ogle	University of Illinois	1983	Yellow
Pinnacle	Agriculture and Agri-Food Canada	2002	White
ProLeaf234	Progene LLC	2015	White
Robust	Purdue University	2005	Light tan
Rockford	North Dakota State University	2008	Yellow
Rodeo	University of Illinois	1997	Yellow
Ronald	Agriculture and Agri-Food Canada	2002	White
Saber	University of Illinois	2012	Light yellow
Souris	North Dakota State University	2006	White
Spurs	University of Illinois	2003	Tan
Summit	Agriculture and Agri-Food Canada	2011	White
Tack	University of Illinois	2008	Tan
UC 125	University of California	2010	Light red
Viking	Progene LLC	2011	White

^aUnreleased breeding material, not commercially available.

Table A2. 2014 weather and management data

	Location			
	Island	Skagit	Thurston	Whatcom ^a
	48.195N, -122.695W	48.440N, -122.388W	46.806N, -123.081W	48.996N, -122.450W
Planted	4/9/2014	4/7/2014	5/15/2014	4/2/2014
Harvested	8/26/2014	8/28/2014	9/9/2014	8/8/2014
	Growing season air temp., °F			
Min.	34	35	32	34
Mean	55	57	57	57
Max.	82	82	92	87
	Growing season precipitation, in.			
	5.8	11.8	11.4	9.7
	Applications, operations			
	2,4-D ester herbicide in June.	Glyphosate pre-planting; 75 lb/ac organic fertilizer (8-2-4 N-P-K) ^b in April.	Organically managed, no applications.	Maestro (1.5 pt/ac) and Harmony Extra (0.5 oz/ac) herbicides in May; urea fertilizer (80 lb/ac N) in May.
Seeding	Seeding rates were adjusted for seed weight and germination rate to achieve 23 live plants per square foot except in Whatcom (17 plants/sq ft). Seed was placed with a double disc drill set on 6 in. spacing.			

^aOnly 12 varieties were included in the 2014 Whatcom trial.

^bWilgro Proganic, Wilbur-Ellis Company, Yakima, WA.

Table A3. 2014 field notes

All locations	Gray speck (manganese deficiency) was observed, and a very minor infestation of powdery mildew towards the end of the season. Other than this, no disease was observed. Cereal leaf beetle affected plants at all locations.
Island	An application of 2,4-D ester to control weeds in the surrounding barley crop may have contributed to stunted flowering and uneven ripening of the crop since oats are sensitive to this herbicide.
Skagit	Abundant rains in spring and late summer contributed to very severe lodging pressure.
Thurston	High weed pressure contributed to lower yields.
Whatcom	No unusual observations. Only 12 varieties were included in this trial.

Table A4. 2014 field data

Variety	Days to heading/earliness ^a				Canopy height, in.				Lodging index, 0-100 ^b			
	Island	Skagit	Thurston	Whatcom	Island	Skagit	Thurston	Whatcom	Island	Skagit	Thurston	Whatcom
AC Lu	E	74	—	—	47.3	54.1	45.5	—	—	93	—	—
AC Morgan	M	79	—	M	51.3	55.4	43.0	51.8	—	58	—	7
Buckskin	E	67	—	E	39.0	46.7	35.3	39.2	—	87	—	39
Chaps	E	72	—	—	45.0	54.1	42.2	—	—	86	—	—
Esker	E	70	—	—	44.7	53.9	38.0	—	—	97	—	—
Excel	E	68	—	—	42.3	47.8	38.7	—	—	42	—	—
Furlong	E	78	—	M	48.7	57.7	39.7	47.2	—	89	—	20
HiFi	E	75	—	—	50.7	56.3	41.0	—	—	87	—	—
Horsepower	E	69	—	E	43.3	48.0	35.8	41.3	—	68	—	2
IL06-5465	E	65	—	E	39.3	46.9	36.8	37.8	—	13	—	1
Jay	E	69	—	—	40.3	43.8	35.8	—	—	19	—	—
Jim	E	70	—	—	46.3	53.9	41.5	—	—	100	—	—
Jordan	L	84	—	L	43.3	46.5	44.8	42.3	—	65	—	60
Kaufmann	E	78	—	—	49.7	61.7	47.5	—	—	98	—	—
Leggett	E	77	—	—	47.0	53.4	38.7	—	—	67	—	—
NZA293,111	M	82	—	—	47.7	53.0	43.5	—	—	54	—	—
Ogle	E	70	—	—	42.0	50.7	36.8	—	—	65	—	—
Pinnacle	E	79	—	—	49.7	61.4	44.5	—	—	87	—	—
Proleaf 234	M	79	—	M	47.0	54.1	40.7	45.5	—	33	—	0
Robust	E	74	—	—	40.0	49.5	40.3	—	—	20	—	—
Rockford	M	76	—	E	50.3	57.6	39.0	50.0	—	94	—	25
Rodeo	E	74	—	—	48.0	53.1	41.7	—	—	65	—	—
Ronald	M	80	—	—	43.0	51.8	41.8	—	—	60	—	—
Saber	E	73	—	—	45.7	52.6	38.0	—	—	46	—	—
Souris	E	76	—	E	42.3	52.9	39.8	46.2	—	80	—	28
Spurs	E	67	—	—	41.7	53.3	33.0	—	—	9	—	—
Summit	E	78	—	—	44.0	47.9	39.2	—	—	37	—	—
Tack	E	69	—	E	43.7	47.5	39.3	43.5	—	32	—	41
UC 125	E	77	—	E	32.7	44.5	38.0	35.3	—	8	—	5
Viking	L	83	—	L	43.7	52.5	40.3	44.2	—	39	—	0
Mean	—	74	—	—	44.7	52.1	40.0	43.7	—	60	—	19
SD	—	5	—	—	4.7	5.6	5.1	5.3	—	36	—	23

^aReported as days between planting and the date when 50% of panicles in the plot are emerged; where heading dates were not measured, earliness designations (E = early, M = mid, L = late) are reported based on visual assessment of relative earliness of flowering.

^bPercentage of plot lodged + (0.5 × % of plot leaning or brackled), where lodging is stem angle 45–90° and leaning is stem angle 0–45°, and brackled plants are those bent partway up the stem.

Table A5. 2014 yield and test weights

Variety	Yield, lb/ac ^a				Test weight, lb/bu ^a			
	Island	Skagit	Thurston	Whatcom	Island	Skagit	Thurston	Whatcom
AC Lu	5,142	8,052	4,254	—	44.9	42.3	38.0	—
AC Morgan	2,985	7,913	4,512	7,122	35.3	41.6	37.5	37.1
Buckskin	3,065	6,962	2,829	5,889	45.0	41.4	39.5	41.6
Chaps	3,872	6,800	3,979	—	38.4	39.4	37.4	—
Esker	4,070	7,489	2,915	—	41.0	39.9	38.1	—
Excel	2,824	7,101	3,234	—	38.8	40.9	37.4	—
Furlong	4,962	6,739	3,175	6,794	42.9	41.4	38.0	38.2
HiFi	4,134	6,092	2,451	—	41.0	42.9	38.5	—
Horsepower	5,332	7,298	3,291	6,914	44.2	42.6	38.2	41.6
IL06-5465	2,721	6,403	2,600	6,096	43.3	41.0	38.6	41.7
Jay	2,552	7,059	3,443	—	41.6	42.2	39.2	—
Jim	3,181	6,550	2,971	—	41.2	40.6	39.0	—
Jordan	3,628	6,853	3,411	6,848	36.1	36.6	33.9	30.9
Kaufmann	6,238	7,989	3,950	—	43.1	41.8	38.8	—
Leggett	4,284	6,529	3,470	—	41.9	42.6	37.2	—
NZA293,111	5,253	6,866	3,713	—	42.9	40.7	37.9	—
Ogle	2,624	7,180	3,394	—	38.6	39.3	34.4	—
Pinnacle	2,177	8,667	3,830	—	35.1	40.9	36.3	—
Proleaf 234	8,386	3,612	6,540	2,935	39.9	37.0	35.2	37.1
Robust	2,591	7,017	3,012	—	42.6	41.7	40.7	—
Rockford	2,937	6,297	3,511	6,527	39.0	43.5	39.4	42.7
Rodeo	4,308	6,745	3,934	—	39.1	40.5	37.3	—
Ronald	3,330	6,975	3,668	—	39.6	40.9	38.2	—
Saber	3,808	7,366	3,246	—	39.7	40.9	37.5	—
Souris	3,228	5,755	2,943	6,779	42.9	40.5	38.9	39.8
Spurs	2,961	6,388	2,438	—	44.3	42.3	41.5	—
Summit	2,799	8,381	4,150	—	38.1	41.0	38.7	—
Tack	4,368	5,975	4,124	6,601	44.7	43.2	40.7	44.0
UC 125	7,177	4,324	6,257	3,486	39.3	37.1	38.7	40.9
Viking	1,813	7,575	3,817	5,810	35.7	42.3	37.8	38.5
Mean	3,910	6,824	3,633	5,984	40.6	41.0	38.1	39.5
SD	1,637	1,253	1,247	1,480	3.1	1.9	2.1	3.7

^aStandardized to 14% grain moisture.

Table A6. 2014 seed size data

Variety	Thousand kernel weight, g				Thin kernels, % ^a			
	Island	Skagit	Thurston	Whatcom	Island	Skagit	Thurston	Whatcom
AC Lu	39.7	38.0	34.1	—	3	2	9	—
AC Morgan	28.6	37.4	34.1	29.9	6	1	4	9
Buckskin	35.7	29.6	29.8	29.8	3	5	19	12
Chaps	28.1	31.1	33.1	—	8	3	11	—
Esker	39.7	37.2	36.7	—	2	2	5	—
Excel	32.2	37.7	33.7	—	4	1	6	—
Furlong	48.9	47.1	41.1	38.7	1	1	3	3
HiFi	34.3	33.5	31.3	—	5	3	15	—
Horsepower	35.3	33.8	28.6	29.6	2	2	16	7
IL06-5465	35.5	32.8	32.0	32.9	2	3	12	3
Jay	33.3	31.6	30.4	—	3	3	14	—
Jim	33.3	32.2	32.5	—	5	3	10	—
Jordan	40.3	43.0	37.6	30.2	2	1	3	4
Kaufmann	44.6	45.1	44.3	—	1	1	2	—
Leggett	37.0	39.5	29.8	—	4	1	12	—
NZA293,111	39.9	38.8	38.1	—	4	1	4	—
Ogle	30.9	32.9	30.4	—	7	2	17	—
Pinnacle	29.3	37.1	33.1	—	7	1	6	—
Proleaf 234	37.3	33.4	28.5	33.0	1	7	13	3
Robust	31.7	34.8	33.1	—	4	2	8	—
Rockford	30.7	33.2	29.6	29.3	6	3	12	12
Rodeo	31.9	30.9	31.1	—	5	2	11	—
Ronald	34.5	33.4	29.9	—	4	3	13	—
Saber	31.1	31.6	30.7	—	6	3	15	—
Souris	32.9	31.7	31.7	25.3	4	5	8	22
Spurs	31.4	32.9	33.3	—	6	3	12	—
Summit	31.8	36.3	32.5	—	4	2	8	—
Tack	36.5	33.2	34.7	32.5	3	4	10	6
UC 125	39.8	36.1	32.8	37.7	3	4	6	2
Viking	28.0	33.0	31.4	26.5	5	1	5	10
Mean	34.8	35.3	33.0	31.3	4	3	10	8
SD	5.5	4.8	4.8	4.4	2	2	9	6

^aDefined as kernels passing through a slotted sieve with apertures measuring 5/64 × 3/4 in.

Table A7. 2015 weather and management data

	Location			
	Island	Skagit	Thurston	Whatcom ^a
	48.189N, -122.695W	48.440N, -122.388W	46.806N, -123.081W	48.861N, -122.303W
Planted	4/16/2015	4/7/2015	5/15/2015	4/29/2015
Harvested	8/5/2015	8/7/2015	9/10/2015	8/3/2015
	Air temp., °F			
Min.	37	35	39	35
Mean	55	59	60	60
Max.	87	87	94	92
	Growing season precipitation, in.			
	1.3	2.7	3.7	1.3
	Applications, operations			
	Organically managed, no applications or operations.	Glyphosate pre-planting; 72-11-24-15 N-P-K-S fertilizer at 75 lb N/ac in April; tine weeding in May; a Maestro (1.5 pt/ac) and Harmony Extra (0.5 oz/ac) in May.	Organically managed, no applications; tine weeding in June. ^a	Organically managed, no applications or operations.
Seeding	Seeding rates were adjusted for seed weight and germination rate to achieve 23 live plants per square foot. Seed was placed with a double disc drill set on 6 in. spacing.			

^aLely spring tine weeder, Lely Turf Products, Pella, IA.

Table A8. 2015 field notes

All locations	Very low rainfall resulted in water stress at all sites and contributed to lower yield and grain quality results in 2015 than 2014.
Island	BYD symptoms were observed in trial plots in May and could explain variable plant height affecting plots later in the season. Short plant height, poor seed fill, and low grain number were observed, suggesting water stress. Extensive damage was done to the trial by redwing blackbirds, contributing to lower yields.
Skagit	BYD symptoms were observed in trial plots. An infestation of cereal leaf beetle removed 40–90% of photosynthetic leaf area by early June. Aphid infestation also contributed to crop stress. Plants headed earlier and at a shorter height than normal.
Thurston	Plants formed relatively few fertile tillers, possibly owing to water stress. Weed pressure was high.
Whatcom	Weed pressure was low and soil conditions excellent. An unexplained field effect was observed to cause stunting, reduced stand density, and leaf rolling in two clearly defined patches of the trial; affected plots were excluded from data analysis.

Table A9. 2015 field data

Variety	Days to heading ^a				Canopy height, in.				Lodging index, 0-100 ^b			
	Island	Skagit	Thurston	Whatcom	Island	Skagit	Thurston	Whatcom	Island	Skagit	Thurston	Whatcom
AC Lu	68	69	—	53	46.3	35.7	27.7	44.3	1	2	40	1
AC Morgan	74	73	—	56	46.7	39.2	32.8	44.3	5	0	3	1
Buckskin	59	64	—	48	40.3	26.7	24.0	33.5	0	1	1	0
Chaps	63	66	—	50	42.0	33.0	29.0	40.3	3	0	3	0
Esker	65	67	—	51	46.2	35.0	29.7	40.3	0	0	6	0
Excel	61	63	—	48	42.7	35.3	28.0	37.5	0	1	2	0
Furlong	74	72	—	54	50.0	38.3	28.8	47.0	4	1	40	2
HiFi	69	72	—	53	49.3	33.7	28.3	44.0	3	3	27	0
Horsepower	62	64	—	50	42.3	28.7	25.0	38.0	1	0	3	0
IL06-5465	58	62	—	47	40.3	31.7	25.0	39.3	1	0	3	0
Jay	63	63	—	51	39.2	27.0	24.5	32.5	1	0	0	0
Jim	64	64	—	49	47.3	30.5	28.7	42.0	1	1	5	0
Jordan	74	74	—	56	47.0	36.5	33.0	45.0	16	0	6	4
Kaufmann	70	71	—	53	52.7	41.2	30.3	49.5	5	8	16	2
Leggett	71	70	—	54	46.7	31.5	27.8	42.0	3	1	4	0
NZA293,111	76	74	—	61	46.8	34.3	29.0	45.3	3	0	0	0
Ogle	64	65	—	51	44.5	32.0	25.7	40.5	0	0	2	0
Pinnacle	74	73	—	52	48.3	37.0	31.7	45.5	14	1	16	2
Proleaf 234	75	74	—	60	44.7	34.3	30.8	44.0	1	0	3	0
Robust	68	67	—	52	43.0	32.0	25.7	38.0	1	0	0	0
Rockford	69	69	—	53	46.7	37.3	31.3	48.0	2	0	25	0
Rodeo	68	68	—	54	44.8	34.8	30.5	40.3	1	0	10	0
Ronald	73	71	—	54	46.0	33.3	30.5	41.5	12	1	46	2
Saber	61	64	—	49	43.2	32.8	27.2	42.5	1	1	8	0
Souris	67	68	—	54	44.7	30.2	24.7	38.0	0	2	21	0
Spurs	62	65	—	50	41.3	30.5	26.0	37.0	0	0	0	0
Summit	69	68	—	53	47.3	32.7	30.8	42.0	3	1	38	1
Tack	61	64	—	50	42.8	27.3	30.3	40.0	0	0	0	0
UC 125	71	72	—	61	35.7	24.0	25.2	31.8	0	0	0	0
Viking	78	76	—	57	43.2	35.0	29.3	37.5	3	0	0	0
Mean	68	68	—	53	44.7	33.1	28.4	41.1	3	1	11	1
SD	6	4	—	4	3.9	4.5	3.1	4.5	5	2	15	1

^aReported as days between planting and the date when 50% of panicles in the plot are emerged.

^bPercentage of plot lodged + (0.5 × % of plot leaning or brackled), where lodging is stem angle 45–90° and leaning is stem angle 0–45°, and brackled plants are those bent partway up the stem.

Table A10. 2015 yield and test weights

Variety	Yield, lb/ac ^a				Test weight, lb/bu ^a			
	Island	Skagit	Thurston	Whatcom	Island	Skagit	Thurston	Whatcom
AC Lu	2,402	3,294	1,800	5,382	29.4	31.9	39.2	36.7
AC Morgan	1,715	4,471	2,697	5,542	27.2	32.7	38.1	36.1
Buckskin	1,736	2,525	1,949	3,693	31.4	36.7	39.6	38.4
Chaps	1,677	3,080	2,332	4,644	26.8	33.4	37.5	36.0
Esker	1,927	3,326	2,550	4,691	29.0	33.7	39.6	36.8
Excel	2,044	3,526	2,575	4,617	29.1	36.5	38.6	38.2
Furlong	1,320	3,786	1,717	4,488	27.1	33.9	38.6	36.3
HiFi	1,799	2,965	1,683	4,524	30.5	33.9	37.7	38.2
Horsepower	2,185	2,977	1,982	4,705	32.9	36.3	39.6	39.2
IL06-5465	1,229	3,039	2,291	4,151	28.0	36.8	39.5	39.3
Jay	1,607	2,882	1,930	4,557	29.2	36.5	40.0	39.9
Jim	1,527	3,624	2,141	5,014	29.0	35.3	38.4	38.6
Jordan	1,509	4,827	2,594	5,826	24.3	31.2	36.7	35.3
Kaufmann	1,492	4,771	1,695	5,593	28.1	35.3	38.6	38.5
Leggett	1,676	3,170	2,101	4,700	29.8	35.8	40.3	37.9
NZA293,111	1,577	3,763	1,602	4,686	27.2	33.9	36.4	36.9
Ogle	2,054	2,880	2,043	4,544	27.3	33.3	38.0	35.2
Pinnacle	1,263	4,029	2,212	5,774	27.1	34.4	40.2	37.9
Proleaf 234	2,440	3,523	2,374	5,451	26.0	31.9	38.3	34.4
Robust	2,234	3,849	2,404	4,493	27.2	35.7	39.7	40.0
Rockford	1,480	3,159	2,306	5,890	29.6	36.2	41.3	40.4
Rodeo	1,802	3,845	2,647	5,055	26.0	34.7	36.8	36.5
Ronald	1,318	3,026	1,627	5,418	28.8	36.1	40.7	39.1
Saber	2,269	3,674	2,570	5,124	28.2	36.0	39.8	37.8
Souris	1,425	2,819	1,935	4,248	30.4	35.4	39.8	37.3
Spurs	1,871	2,870	2,114	4,098	29.6	36.8	41.0	36.9
Summit	1,835	3,682	1,890	5,435	29.7	37.2	39.9	38.0
Tack	1,863	2,754	2,663	4,267	32.5	36.3	39.8	39.1
UC 125	2,336	3,055	1,836	3,563	30.7	34.6	39.3	35.6
Viking	1,782	3,546	2,162	3,979	27.8	33.0	36.8	37.9
Mean	1,780	3,425	2,147	4,791	28.7	34.8	39.0	37.6
SD	389	811	453	866	2.2	1.8	1.7	1.8

^aStandardized to 14% grain moisture.

Table A11. 2015 seed size data

Variety	Thousand kernel weight, g				Thin kernels, % ^a			
	Island	Skagit	Thurston	Whatcom	Island	Skagit	Thurston	Whatcom
AC Lu	29.3	36.3	36.3	37.3	13	9	4	6
AC Morgan	28.0	40.4	40.2	37.1	14	6	2	6
Buckskin	26.7	30.2	31.7	32.9	28	14	6	12
Chaps	25.2	31.4	32.3	31.0	25	10	4	9
Esker	31.4	35.7	39.5	38.4	14	6	1	5
Excel	30.5	36.7	37.5	37.5	11	4	2	3
Furlong	30.5	39.3	40.9	40.8	16	7	3	6
HiFi	27.3	31.4	31.5	34.4	26	19	10	9
Horsepower	28.6	32.0	32.5	31.5	14	11	4	7
IL06-5465	26.8	32.7	34.1	33.5	16	6	1	4
Jay	27.3	31.5	34.0	35.2	15	10	3	5
Jim	27.2	32.5	33.5	37.7	20	8	4	4
Jordan	33.3	41.5	45.3	41.5	17	4	3	3
Kaufmann	32.8	42.8	42.3	43.8	9	3	3	2
Leggett	27.0	33.2	35.7	33.7	20	14	5	10
NZA293,111	31.6	40.0	38.9	41.5	14	6	3	4
Ogle	27.3	32.0	34.1	30.5	26	9	3	13
Pinnacle	24.9	33.7	35.5	38.6	15	6	2	3
Proleaf 234	28.9	35.5	35.9	37.4	17	10	5	7
Robust	26.1	34.6	34.4	37.1	16	7	4	3
Rockford	26.1	31.6	32.0	36.2	24	11	6	2
Rodeo	26.2	31.1	31.4	31.7	21	10	6	8
Ronald	26.1	32.9	33.9	35.1	20	15	5	5
Saber	26.1	32.2	34.5	32.5	27	12	3	9
Souris	25.9	30.5	32.4	29.2	24	14	7	19
Spurs	28.3	33.1	35.7	32.9	22	10	4	18
Summit	27.3	35.2	37.3	35.1	14	7	3	5
Tack	28.8	32.6	35.9	35.8	18	10	3	9
UC 125	31.4	39.3	41.3	36.4	13	4	2	7
Viking	26.3	34.5	33.3	34.3	12	6	3	4
Mean	28.1	34.5	35.8	35.7	18	9	4	7
SD	2.5	4.0	3.6	4.2	6	5	2	6

^aDefined as kernels passing through a slotted sieve with apertures measuring 5/64 × 3/4 in.



Use pesticides with care. Apply them only to plants, animals, or sites as listed on the label. When mixing and applying pesticides, follow all label precautions to protect yourself and others around you. It is a violation of the law to disregard label directions. If pesticides are spilled on skin or clothing, remove clothing and wash skin thoroughly. Store pesticides in their original containers and keep them out of the reach of children, pets, and livestock.

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