Practical considerations for growing malting-quality barley in Ohio

Introduction

Winter malting barley is a new crop to Ohio. As of 2015, little data exists regarding cultural practices in Ohio that will result in the highest quality grain and maximum yield possible. A number of organizations associated with malting barley cultivation in their regions offer extremely useful information on the cultivation of barley for malting purposes. The reader is encouraged to seek out information from these sources, which include Malting Barley Requirements, the Idaho Spring Barley Production Guide, and the Barley Growth Guide; all of which are listed under "references and further reading."

Most of the malting barley grown in North America is spring barley that is grown in a corridor of northern U.S. states stretching from Minnesota to Washington and extending into Rocky Mountain States, and in the Western Prairies of Canadian Provinces Manitoba, Saskatchewan, and Alberta. In Europe and especially in the United Kingdom, there has long been the use of winter barley for malting purposes.

One aspect that makes Ohio and our neighboring Great Lakes, Midwestern, and Northeastern state regions attractive for winter malting barley cultivation is that soil moisture levels are usually non-limiting at seedling establishment in autumn and during grain-fill, and under non-limiting moisture conditions extremely high quality grain for malting purposes can be obtained.

In 2009 we initiated a winter malting barley breeding program. We began by testing different varieties obtained from outside sources for their suitability in Ohio. Some of the data from these trials is presented in the following. As winter-hardiness is the most critical parameter for successful barley cultivation in the Midwest (Poehlman, 1952), emphasis on winter-hardiness and developing winter-hardy barley varieties is a key breeding program goal.

When and how to plant (seeding date and rate)

It is recommended to plant winter barley after "Hessian Fly Safe Date." Typically this is about the third week in September, with an earlier date in Northern Ohio and a later date in Southern Ohio. Hessian Fly Safe Date coincides with reduced numbers of adult aphids, which transmit Barley Yellow Dwarf Virus to seedlings in autumn (Paul and Hammond, 2010). The virus persists through winter, and when plants begin vigorous growth in the spring, full-blown BYDV infection can occur reducing grain yield and grain quality significantly.

Seeding rate is 80-100 lbs. per acre, drilled to a depth of 1" at a row spacing of 7.5". In our experimental plots we seed at 100 lbs. per acre (80 g per 5' × 15 ' plot). Depending on the year, yields of the best lines in experimental plots in Wooster (Wayne County) range 75–100 bushels per acre. Slightly lower yields were obtained from OARDC sites in Custar (Wood County), Fremont (Sandusky County), and Piketon (Pike County). In Hartford (Licking County) Ohio Foundation Seeds, Inc. seeded 'Maja' at 80 lbs. per acre, producing 85 bushels per acre 2013–2014. These yields have been obtained from barley sown as late as mid-October.

Future studies may guide optimizing seeding rates for each variety to obtain the highest quality grain and the highest yield attainable. For example planting 'Maja' at a higher density (110–120 lbs. per acre) may reduce tillering such that only the main tiller produces a head, and these heads will yield very plump grain, which is precisely what maltsters and brewers desire.

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Nutrition and fertilization
Preliminary knowledge of the soil nutrient status should guide nutrient applications. Ideally plants should be under nitrogen non-limiting conditions early in development and finish in a mildly nitrogen deficient state.

At the OARDC in Wooster, we follow the Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat, and Alfalfa described in Extension Bulletin E-2567 (http://ohioline.osu.edu/e2567/).

Soil is limed using recommended application rates to bring the soil pH up to 6.8 when the lime test index (LTI) falls below 68.

At OARDC Wooster 25 lbs. per acre actual nitrogen is added to the soil as a pre-plant fertilizer. Phosphorus and Potassium levels in the pre-plant fertilizer are adjusted to insure minimum levels are present for maximum yield potential. Phosphorous is important early for tiller development. At spring green-up, an additional 90 lbs. actual nitrogen per acre is applied. This has resulted in 80-90 bushels yield per acre, and protein levels of 10-12% for malting varieties, which is ideal.

Excess nitrogen can lead to lodging. Lodging is when the stem is displaced from the upright position; i.e., the plant falls over before harvest. Lodging can lead to significant yield losses.

Excess nitrogen can also lead to high grain protein levels, which causes problems in the brewhouse, particularly haze formation in the final product. Differences between varieties exist, and breeders work to develop lodging-resistant, low protein varieties, but extremes in environmental conditions can overwhelm the genetic capabilities possessed by the best varieties.

Grain quality and the possibility of lodging will also vary by site. Lodging is highly variable because it is usually caused by weather-related factors. On nitrogen-limiting soils the chance of lodging may be reduced by split applications of nitrogen in the spring. Staging the nitrogen applications such that the first application is early in the spring will encourage tiller development, while a second application later in the spring will encourage canopy expansion. The idea is to maximize both the numbers of heads and the numbers of kernels per head. However, split application also adds an extra step, and if applied too late in the season, will cause nitrogen to be mobilized into the grain, reducing grain quality.

Weed Control
Choice of herbicide should be dictated by the weed for which control is sought. Check with a local extension agent or farm advisor. Herbicides must be registered for use on barley. It is important to use an herbicide at no more than the recommended rate because barley is not resistant to these herbicides, it only tolerates the herbicide at some level.

At the OARDC site in Wooster we use the herbicide Harmony Extra SG50 (0.9 oz. per acre) in spring for the post-emergence control of broadleaf weeds in our winter barley variety trials. At the OARDC site in Custar (Northwest) the herbicide Stinger has been used for broadleaf weed control. At the OARDC site in Freemont (North Central) no herbicides are used so as to avoid carry over onto the vegetable crops grown at this site.

For the control of warm season grassy weeds in spring barley we have used Axial XL (16.4 oz. per acre) + MCPA amine (8 oz. per acre) with mixed results and are hesitant to recommend this herbicide until further tests are carried out under Ohio conditions. Axial XL is also not currently registered for use in Ohio.

Guides that are available for herbicide control of weeds in barley may be obtained from Penn State University (http://extension.psu.edu/agronomy-guide/pm/tables/table-2-5-5), North Carolina State University (http://www.smallgrains.ncsu.edu/_Pubs/Xtrn/AgChemHerbicides.pdf), and North Dakota State University https://www.ag.ndsu.edu/weeds/weed-control-guides/nd-weed-control-guide-1/wcg-files/3.1-Wheat.pdf).

Diseases

The main disease problem is head blight, also known as scab (Osborne and Stein, 2007). The causal agent, *Fusarium graminearum*, is a fungus producing a multitude of toxins that have various levels of toxicity to human and animal digestive systems. Toxins can survive malting and kilning and can cause gushing in bottled beer when opened. One of the toxins is deoxynivalenol (DON) and it is used as an indicator of fungal contamination levels of grain. Threshold levels of 1 ppm DON in barley seed will result in the rejection of barley for malt purposes.

Fusarium is not a new problem for small grains but its incidence has been tremendously exasperated by increased cultivation of corn and the management practices of no-till and low-till, because the fungus overwinters on corn residue. If temperature, humidity, and rainfall the following spring and early summer are optimal for fungal growth, then there can be a tremendous increase in production of fungal spore inoculum. When high fungal spore counts coincide with the opening of wheat and barley flowers (anthesis), the fungus infects and colonizes the tissues around the developing seed, reducing grain quality and grain yield. Severe infections will ruin the grain.

It is recommended that barley follow soybean in the rotation, not corn. If barley follows corn, all corn residue from the previous season's crop should be completely tilled under in fields planted to barley, as well as adjacent fields (Lipps, 1996).

Predictability models for the likelihood of a Fusarium threat have been developed for wheat that are based on weather patterns and offer guidance as to whether fungicide sprays are warranted. Models were developed in part by Dr. Pierce Paul in the Plant Pathology Department at OSU in conjunction with other researchers at Kansas State University, North and South Dakota State Universities, Penn State University, and Purdue University. These predictability models have produced "The Fusarium Head Blight (FHB) Scab Alert," a real-time alert system in which alerts are delivered to subscribers via cell phone text messages or email warning them when conditions in their region are favorable for scab (FHB) development. This tool can be accessed via the World Wide Web at: http://www.wheatscab.psu.edu/riskTool.html. Even when the best on-farm management is practiced do not become complacent because in a worst case-scenario fungal spores can become airborne and travel hundreds of miles.

The fungicides Prosaro (Bayer Crop Sci) and Carumba (BASF) are currently the most effective chemical control measures (Paul, 2011). Application should be made at the beginning of flowering (Paul, 2011). Applications made when the plants are fully headed out (Feekes 10.5) will not be as effective as application at earlier flowering (Paul, 2011). The better the sprayer coverage of the plant, the more effective the control. Prosaro and Carumba are systemic, which means they are taken up by the plant. Prosaro, applied in conjunction with the surfactant "Induce" (0.125% vol/vol), has been shown to be rainfast under field conditions if applied one hour prior to rainfall (Andersen et al., 2014). The half-life in the plant appears to be 6-9 days, which means control should continue after application (Andersen et al., 2014).

Other diseases that have been observed over multiple seasons include scald and net blotch, caused by fungi *Rhynchosporium secalis* and *Pyrenophora teres*, respectively. Both diseases can be controlled with Prosaro and Carumba. Note that only one application of Prosaro and Carumba is permissible per season when used at their recommended rates. But, it is permissible to use each in separate applications because Prosaro and Carumba are of different chemical makeup. Nonetheless these are expensive fungicides.

The North Dakota Barley Council publishes an excellent guide for visual identification of barley diseases and offers means to control these diseases (Neate and McMullen, 2005).

Insects

Cereal leaf beetle (*Oulema melanopus*) seems to recur each year late in the life cycle of the barley plant after grain-fill is completed, making control not cost-effective. Were beetle larva to attack plants and destroy the flag leaf prior to grain-fill, then control measures are probably cost-effective because the flag leaf serves as the primary food source to the developing grain (Hammond et al., 2014).

Harvest and storage

Barley is harvested between late June and early July – about two weeks before wheat. Barley can be harvested with the same combine head used for soybean and wheat. The same combine used for corn may be used for barley but corn uses a different combine head, so a combine head for barley will be required.

It is important to realize that the quality of the grain is of utmost importance to meet malting standards – damaged grain or grain that has poor germinability is not suitable for malting because malting *is* the germination process. Kernels should not be broken or damaged and the husk should remain tightly-adhered to the grain.

Weather-related factors will usually dictate when the actual harvest can take place. Mature grain that remains on the plant or in the field for an extended period of time is prone to shattering and pre-harvest sprouting. Shattering is the separation of the grain from the rachis (the stem of the seed head) prior to harvest. If it occurs, significant yield loss will occur. Pre-harvest sprouting is just that – the grain germinates on the plant. Sprouted grain is unsuitable for malting. Varieties differ in their predisposition to these characters but at present we have no data on varietal differences here in Ohio.

Barley is physiologically mature at ~35% moisture. However harvesting at moisture levels of 20% or greater makes the kernel highly prone to damage during combining, which can make it unusable for malting. For our experimental harvesters the barley must be less than 17% moisture, otherwise the harvester clogs.

Seed produced for planting needs to be free of awns. Seed produced for malting may retain a portion of the awn if the choice is between awns and damaged kernels. The Idaho Spring Barley Production Guide and Harvesting, Drying, and Storing Malting Barley To Get Market Premiums detail how the combine should be adjusted to obtain the highest quality grain possible (American Malting Barley Association Inc. et al., and Various authors, 2003).

Following harvest the grain should be dried to its "equilibrium moisture content," which is about 12% at 70°F and 60% relative humidity. Using natural air or low temperature drying gives the highest quality grain. If heat is used it should be less than 110°F. An excellent discussion on drying barley for the highest quality grain is put out by the American Malting Barley Association, Inc., Institute for Barley and Malt Sciences, & North Dakota State University (American Malting Barley Association Inc. et al.). Desiccants should never be used for drying malting barley. Barley dried with the use of desiccants will be rejected by the malting and brewing industry.

Double cropping

Long-term studies indicate that including winter wheat in the crop rotation cycle with corn and soybeans increases corn yields the years corn is grown (Nafziger, 2007). Winter barley presents an opportunity to double crop, particularly in the more southern regions of the state.

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Varieties (cultivars) to grow

We have been testing winter malting barleys for their cultivation suitability in Ohio since the 2008–2009 season. All lines have been put into yield comparison trials with other Ohio and local varieties and selections, including Ohio No. 1 (1940 release), Mercer (collected pre 1940), Dayton (1955 release), Ray (1988 release), and 'Thoroughbred' (2003 release and a Virginia Tech six-row feed barley that is at present the only Certified Seed barley cultivar available in Ohio). Hundreds of malting barley varieties have been tested. The list includes modern elite lines and traditional heirloom lines. The six-row variety 'Maja' was one of the first tested. The two-row variety 'Puffin' was first tested 2011–2012. The following year 'Puffin' revealed itself as a high malting quality candidate suitable for large scale cultivation in Ohio. 'Maja' and 'Puffin' have subsequently gone into production scale seed increases.

Figure 1 shows yield data from variety trials carried out at four Ohio locations 2014–2015 and Figure 2 shows the yield trends of several key varieties over the three previous seasons.

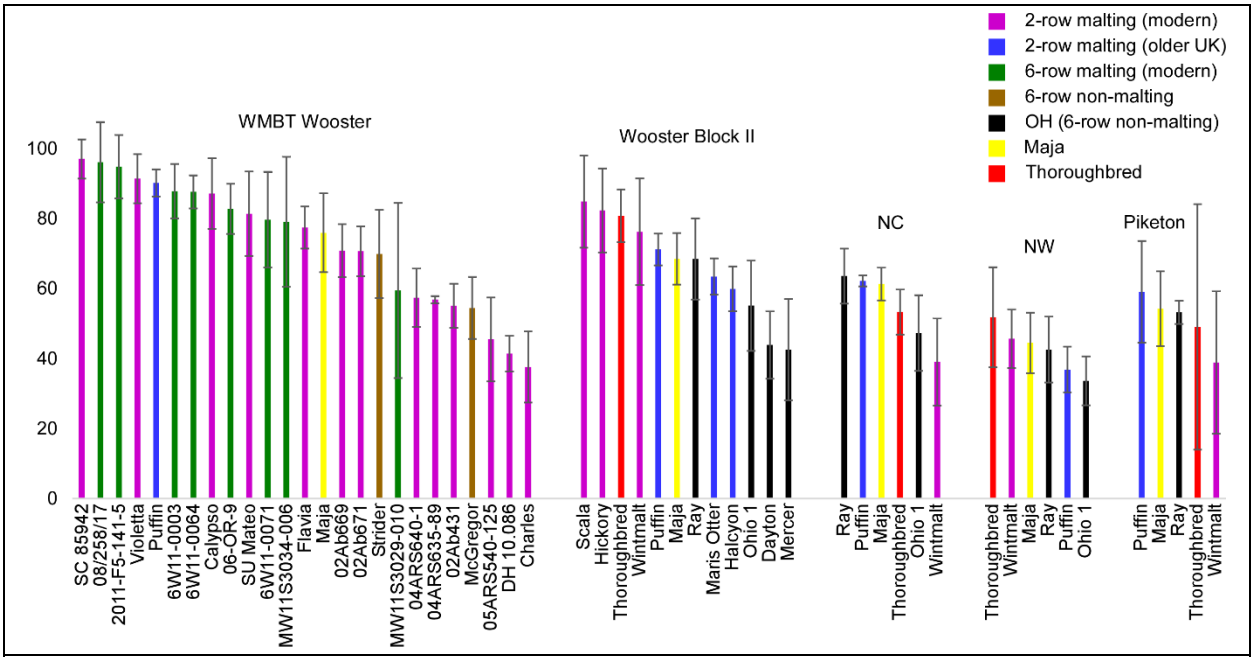

Figure 1. Estimated bushels per acre 2014–2015. Data are separated by the five experimental field sections and sites grown. From left to right: Winter Malting Barley Trial at Schaffter Farm (WMBT Wooster, plus 'Puffin'), additional cultivars Schaffter Farm (Wooster Block II), OARDC North Central at Fremont Sandusky County (NC), OARDC Northwest at Custar Wood County (NW), and OARDC South Centers Piketon in Pike County (Piketon). Data are based on sowing 100 lbs. per acre (0.12 lb. seed per 5' × 10' yield test plot Wooster, Fremont, and Custar; or 0.042 lb. seed per 2' ×10' plot Piketon). Colored bars distinguish different types of cultivars or individual cultivars.

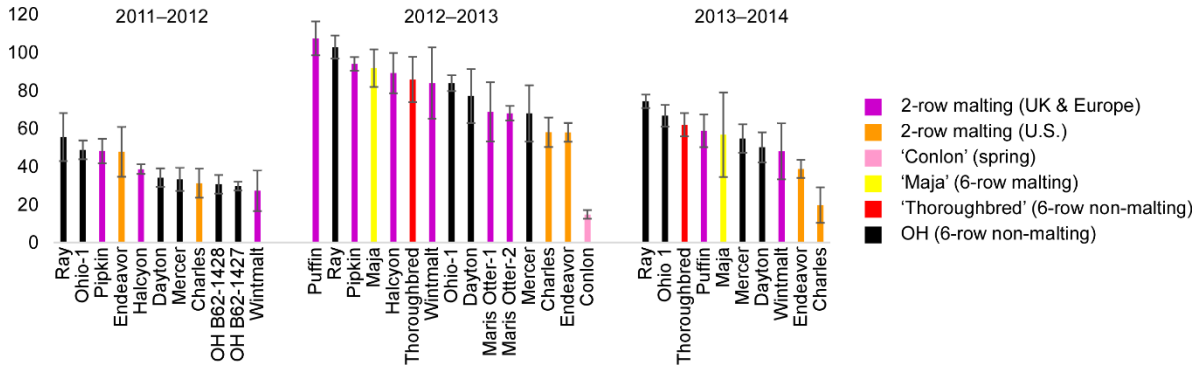

Figure 2. Yield trends at Schaffter Farm Wooster OH. The 2012–2013 and 2013–2014 data are based on sowing 100 lbs. per acre (0.12 lb. seed per 5' × 10' yield test plot). The 2011–2012 data are based on sowing 50 lbs. per acre (0.06 lb. seed per 5' × 10' yield test plot).

The data from these multiyear yield trials support the conclusion that the top yielding six-row line is the feed barley 'Ray' and the top yielding two-row line is the malting barley 'Puffin', and that 'Maja' is competitive with 'Thoroughbred'.

Since 'Maja' and 'Puffin' went into production, additional lines have been identified that may surpass 'Maja' and 'Puffin'. These include WMBT lines tested 2014–2015, Wooster Block II, and lines from the Stockinger breeding program. For 2015–2016 the top-ranked two-row and six-row lines from the Wooster trials have been put into yield trials at OARDC sites around the state.

Malting quality

Table 1 provides malting quality data for 'Maja', 'Puffin', and 'Wintmalt' grown at three locations across Ohio 2014–2015. Table 1 also provides malting quality for seven additional cultivars grown at the Wooster site. The additional cultivars include the six-rows 'Ray' and 'Thoroughbred', and the two-rows 'Halcyon', 'Hickory', 'Maris Otter', 'Pipkin', and 'Scala'. 'Halcyon', 'Pipkin', and 'Maris Otter' are older classic UK two-row cultivars; 'Hickory' and 'Scala' are modern two-row cultivars.

'Maja', 'Scala', and 'Wintmalt' are the highest scoring cultivars as a consequence of approaching ideal levels of individual traits more closely than the other cultivars. Similarly, the overall quality score of 'Maja' (59) is far greater than that of either of the two six-rows 'Ray' (39) and 'Thoroughbred' (41). Another key point from this data is that location has a major effect on malting quality. Malting quality of 'Maja', 'Puffin 'and 'Wintmalt' was in general much higher from the Custar and Wooster sites than from the Fremont site (Table 1). This information indirectly indicates proper management and cultural practices will be critical for production of the highest quality barley for malting purposes.

In collaboration with Andrea and Christian Stanley of Valley Malt (http://valleymalt.com/) and Andy Tveekrem of Nano Brew Cleveland (http://nanobrewcleveland.com/), 10 gallons of a Scotch-style ale were produced from 'Puffin' and presented at the Master Brewers Association of the Americas Midwest Chapter Spring meeting 2015. The ale was favorably received by meeting attendees. Mashing and sparging proceeded well even though β-glucan levels in the finished malt are above ideal AMBA targets.

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Table 1. Malting quality of winter barley lines grown 2014–2015 at OARDC sites in Wood County (Custar), Sandusky County (Fremont) and Wayne County (Wooster).

Cultivar	Rowed	Site*	Kernel weight (mg)	On 6/64" (%)	Barley color (Agtron)	Malt extract (%)	Wort color	Wort clarity	Barley protein	Wort protein	S/T (%)	DP (°ASBC)	Alpha-amylase (20°DU)	Beta-glucan (ppm)	FAN (ppm)	Quality score
Maja	6	NW	28.8	92.5	26	80.5	**7.6**	2	11.8	**6.16**	**53.3**	**103**	69.0	43	340	47
Puffin	2	NW	39.4	97.6	25	81.0	**3.1**	1	13.3	**6.12**	**47.2**	**100**	60.2	**369**	232	36
Wintmalt	2	NW	41.2	98.6	28	81.6	**5.3**	1	12.5	5.98	**50.7**	114	69.1	60	269	57
Maja	6	NC	**26.7**†	87.9	22	78.3	**10.1**	2	11.6	**3.85**	**30.4**	**96**	70.5	24	435	42
Puffin	2	NC	**37.2**	95.9	27	79.4	**3.2**	1	12.7	**3.97**	**33.0**	**84**	59.3	**293**	229	36
Wintmalt	2	NC	**32.5**	88.0	30	**77.8**	**6.8**	2	**14.4**	4.46	**27.6**	152	75.3	132	382	33
Maja	6	W	28.6	81.9	28	80.6	**3.1**	1	11.7	4.84	43.4	148	66.7	153	227	59
Ray	6	W	29.6	**57.1**	26	78.0	**3.5**	2	**11.4**	4.82	43.8	141	68.6	**281**	201	39
Thoroughbred	6	W	31.3	88.7	36	79.6	2.3	2	11.7	**4.48**	**40.7**	135	61.3	**297**	**178**	41
Halcyon	2	W	**34.3**	**83.4**	33	80.3	2.3	1	12.2	4.40	**38.3**	129	51.1	**299**	**159**	40
Maris Otter	2	W	**33.1**	86.6	22	80.5	2.7	1	12.0	4.62	40.5	144	51.4	**202**	256	53
Pipkin	2	W	**32.2**	**84.7**	18	79.5	n.d.	3	11.4	4.60	41.8	113	68.5	**233**	206	45
Puffin	2	W	**37.2**	96.4	23	80.4	2.4	1	12.2	4.74	41.5	110	52.0	**317**	259	52
Hickory	2	W	40.4	97.0	32	81.6	n.d.	3	**10.6**	5.13	**49.0**	**91**	54.1	124	236	46
Scala	2	W	41.8	97.1	26	83.1	**3.1**	1	11.9	5.13	46.4	150	60.4	**222**	242	62
Wintmalt	2	W	39.3	97.0	31	80.7	**4.1**	2	11.2	4.85	44.9	125	52.9	107	233	59

*NW = Northwest; i.e., Custar, NC = North Central; i.e., Fremont, W = Wooster.
†**Blue bold**, <AMBA target minimum; **green bold**, >AMBA target maximum

Seed sources
Each year the Ohio Seed Improvement Association (http://ohseed1.org/) publishes a directory listing Ohio seed dealers that supply Certified Seed. The Craft Malting Guild (http://www.craftmalting.com/) also provides a seed source listing. In 2015–2016 there are 400 acres of 'Maja' under cultivation to provide Certified Seed to farmer-growers autumn 2016. One year behind 'Maja' is 'Puffin'.

Crop Insurance
Federal Crop Insurance programs exist as part of the Small Grains Crop Provisions for malting barley grown under a contractual basis. It is unclear how this program operates in Ohio counties because malting barley is a new crop: http://www.rma.usda.gov/policies/2016/16-0091b.pdf. We are also not qualified to offer advice.

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Spring barley

We have far less experience with spring barley cultivation, and thus have very little data.

It is recommended to plant spring barley as early as possible to obtain the maximum yield possible. Later plantings result in lower yields. The challenge however, is that once the soil has thawed it is usually too wet to bring heavy equipment into the field without facing compaction problems. Warm-season grassy weeds can also present a greater competition problem in spring-planted barley – especially with later sowings. Fusarium head blight is also likely to be a greater problem as ideal temperature and humidity conditions and inoculum levels for infection are usually much greater when spring barley is heading out.

Below is yield data from the Eastern Spring Barley Nursery (ESBN) grown at Wooster in 2015.

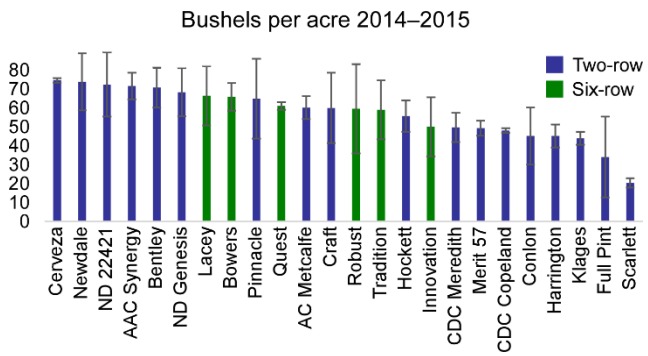

Figure 3. 2015 Eastern Spring Barley Nursery (ESBN) yield data in estimated bushels per acre at the Campus Lot A site, Wooster OH. Data are based on sowing 100 lbs. per acre. 'Craft', 'Hocket', 'Merit 57', and 'Bowers' were not part of the official ESBN but were included as additional lines that merited testing. 'Bowers' is the only spring line available as Certified Seed in Ohio.

As a result of heavy rainfalls in Ohio late May thorough June 2015 lodging was evident in many lines. The two-row lines 'ND Genesis', ND 22421, and 'Pinnacle'; and the six-row line 'Lacey' exhibited no lodging whereas some degree of lodging was detected in all other lines.

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