NORTHWEST CROPS & SOILS PROGRAM

2020 Winter Barley Variety Trial

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With the development of a robust localvore movement and the revival of the small grains industry in the Northeast, craft breweries and distilleries have expressed an interest in sourcing local barley for malting. Malting barley must meet specific quality characteristics, such as moderate protein content and high germination rate. Winter barley has not been traditionally grown in the Northeast due to severe winterkill. However, newly developed varieties and a changing climate have encouraged our team to investigate this crop for the area. In 2019-2020, UVM Extension's Northwest Crops and Soils Program conducted a winter barley trial to evaluate the yield, quality and agronomic characteristics of malting barley varieties.

MATERIALS AND METHODS

A winter barley variety trial was initiated at Borderview Research Farm in Alburgh, VT. Winter barley was planted on 20-Sep 2019. 29 winter varieties (Table 1) were planted in a randomized complete block design with three replicates. The seedbed was prepared by conventional tillage methods. Plots were 5' x 20' and were seeded into a Benson rocky silt loam at 125 lbs ac^{-1} with a Great Plains cone seeder. Rows were spaced at 6". All plots were managed with practices similar to those used by producers in the surrounding areas (Table 2).

Table 1. Winter malting barley varieties and seed sources.

Variety	Row Type	Seed Source
Charles	2	Univ of Idaho Foundation Seed
Thoroughbred	6	VA Tech
Endeavor	2	Univ of Idaho Foundation Seed
Wintmalt	2	Tri State Seeds
DH130910	2	Oregon State University
DH140088	2	Oregon State University
DH140963	2	Oregon State University
DH141132	2	Oregon State University
Flavia	2	Ackermann Saatzucht
Lyberac	2	Ackermann Saatzucht
Rossignola	6	Ackermann Saatzucht
AC13/028/53 (Marouetta)	6	Ackermann Saatzucht
Hirondella	6	Ackermann Saatzucht
Pixel	6	SECOBRA RECHERCHES
Visuel	6	SECOBRA RECHERCHES
Delicatesse	2	SECOBRA RECHERCHES
KWS Orbit	6	Albert Lea Seed
KWS Flemming	6	Albert Lea Seed
KWS Scala	2	KWS Cereals
KWS Somerset	2	KWS Cereals
KWS Donau	2	KWS Cereals

KWS Faro	6	KWS Cereals
MW12_4007-001	6	Univ of MN
08ARS509-1	2	USDA-ARS
08ARS632-5	2	USDA-ARS
13ARS537-13	2	USDA-ARS
13ARS537-19	2	USDA-ARS
VA16M-81	2	VA Tech
VA16M-84	2	VA Tech

Table 2. Winter barley agronomic practices and trial information.

Trial information	Alburgh, VT Borderview Research Farm
Soil type	Benson rocky silt loam
Previous crop	Spring grains
Seeding Rate (lbs ac^{-1})	125
Row spacing (in)	6
Replicates	3
Planting date	20-Sep 2019
Harvest date	7-Jul 2020
Harvest area (ft)	5 x 20
Tillage operations	Fall plow, spring disk & spike tooth harrow

Fall emergence was measured on 29-Oct 2019 by comparing the populations of plants that had sprouted to the seeding rate. Winter survival was measured on 15-Apr 2020 by counting live plants per plot and comparing to fall emergence figures. Heading date was recorded through the spring as the date when at least 50% of the plot had headed. The trial was scouted for arthropod pests and plant diseases on 15-Jun 2020. Five plants from each plot were examined. The top two leaves were examined and evaluated for the presence of disease and insect damage. The Clive James, 'An Illustrated Series of Assessment Keys for Plant Diseases, Their Preparation and Usage' was used to identify and determine the severity of plant disease infection. Damage recorded as a percent of the leaf surface that was affected by each pest and disease. Heights and lodging were recorded on 7-Jul 2020 prior to harvest. Heights were measured, excluding awns, in centimeters for three plants in each plot, and lodging was assessed by visual estimate of the percentage of the plot was completely lodged and could not be harvested. Winter barley was harvested with an Almaco SPC50 small plot combine on 7-Jul 2020.

Following harvest, seed was cleaned with a small Clipper cleaner (A.T. Ferrell, Bluffton, IN). Quality measurements included standard testing parameters used by commercial malt houses. Plot yields were recorded. Harvest moisture was determined for each plot using a DICKEY-john Mini GAC moisture and test weight meter. Generally the heavier the barley is per bushel, the higher malting quality. A one-pound subsample was collected to determine quality. The samples were then ground into flour using the Perten LM3100 Laboratory Mill, and were evaluated for crude protein content using the Perten Inframatic 8600 Flour Analyzer. Falling number for all barley varieties were determined using the AACC Method 56-81B, AACC Intl., 2000 on a Perten FN 1500 Falling Number Machine. The falling number is related to the level of sprout damage that has occurred in the grain. It is measured by the time it takes, in seconds, for a stirrer to fall through a slurry of flour and water to the bottom of the tube. Falling numbers greater than 350 indicate low enzymatic activity and sound quality barley. A falling number lower than 200 indicates high enzymatic activity and poor quality. Deoxynivalenol (DON) analysis was analyzed using Veratox DON 2/3 Quantitative test from the NEOGEN Corp. This test has a detection range of 0.5 to 5 ppm. DON values greater than 1 ppm are considered unsuitable for human consumption. Percent germination (germination energy) was determined by incubating 100 seeds in 4.0 ml of water for 72 hours and counting the number of seeds that did not germinate. Each sample was run in duplicate. Grain assortment or plumpness was determined with the Pfeuffer Soritmat using 100g of clean seed, and was determined by the combining the amount of seed remaining on the 2.78mm and 2.38mm sieves.

Data was analyzed using mixed model analysis procedure of SAS (SAS Institute, 1999). Replications were treated as random effects, and treatments were treated as fixed. Mean comparisons were made using the Least Significant Difference (LSD) procedure when the F-test was considered significant ($p<0.10$).

Variations in yield and quality can occur because of variations in genetics, soil, weather, and other growing conditions. Statistical analysis makes it possible to determine whether a difference among varieties is real or whether it might have occurred due to other variations in the field. At the bottom of each table a LSD value is presented for each variable (e.g. yield). Least Significant Differences at the 10% level of probability are shown. Where the difference between two varieties within a column is equal to or greater than the LSD value at the bottom of the column, you can be sure in 9 out of 10 chances that there is a real difference between the two varieties. In this example, variety A is significantly different from variety C, but not from variety B. The difference between A and B is equal to 725, which is less than the LSD value of 889. This means that these varieties did not differ in yield. The difference between A and C is equal to 1454, which is greater than the LSD value of 889. This means that the yields of these varieties were significantly different from one another. The letters 'a' and 'b' indicate which varieties are statistically similar to each other in terms of yield; variety B is similar to both varieties A and C, but variety A and C are not statistically similar to each other.

Variety	Yield
A	3161[b]
B	3886[ab]
C	**4615[a]**
LSD	**889**

RESULTS AND DISCUSSION

Seasonal precipitation and temperature recorded at a weather station in Alburgh, VT are shown in Table 3. Historical averages are for 30 years of data (1981-2010). The fall weather was overall warm and moist, leading to good establishment and winter survival. The spring overall was cooler and drier than normal, with the early summer months of June and early July much warmer and drier than normal. There were 5165 growing degree days between fall of 2019 and spring of 2020, three more growing degree days than the 30 year average.

Table 3. Weather data for winter barley variety trial in Alburgh, VT.

Alburgh, VT	Sep-19	Oct-19	Nov-19	Mar-20	Apr-20	May-20	Jun-20	Jul-20
Average temperature (°F)	68.3	60.0	50.4	35.0	41.6	56.1	66.9	74.8
Departure from normal	-0.51	-0.51	2.32	3.94	-3.19	-0.44	1.08	4.17

Precipitation (inches)	3.87	6.32	2.38	2.79	2.09	2.35	1.86	3.94
Departure from normal	0.21	2.76	-0.74	0.57	-0.72	-1.04	-1.77	-0.28
Growing Degree Days (base 32°F)	840	571	128	193	315	746	1046	1326
Departure from normal	-15	58	-122	27	-99	-13	35	132

*Based on weather data from a Davis Instruments Vantage Pro2 with WeatherLink data logger. Historical averages are for 30 years of NOAA data (1981-2010) from Burlington, VT.

The variety with the highest fall emergence was Endeavor, with 93.3% of planted seed emerging. This was statistically the same as all but three other varieties: 08ARS632-5, MW12_4007-001, and Flavia, which all had fall emergence below 85%. The variety with the best winter survival was Orbit; 100% of the plants of this variety survived the winter without any winterkill. This was statistically similar to 13 other varieties with 95% or greater survival (Table 4). Heading dates for all varieties fell within a six day period between May 26 to June 1. The weather at heading date is often related to fusarium infection and presence of deoxynivalenol toxin, with colder, wetter weather associated with higher infection rates and higher toxin concentrations. The late May weather in 2020 was warm and dry and was not conducive to fungus growth. One rep of each variety tested for DON (data not shown). All samples tested below detectable limit for the DON vomitoxin test (<0.5 ppm).

Disease and pest scouting occurred on 15-Jun 2020. Scouters examined the top two leaves from five plants per plot and recorded the percentage of the foliar surface that was damaged by several different pests and foliar diseases. Foliar diseases reduce photosynthetic leaf area, use nutrients, and increase respiration and transpiration within colonized host tissues. Diseased plants may exhibit reduced vigor, growth, and seed fill. Earlier occurrence, greater degree of host susceptibility, and longer duration of conditions favorable for disease development can increase the yield loss. When scouted on 20-Jun, each plot was assessed for several distinct diseases. These individual disease ratings were combined into a single foliar disease rating for statistical analysis.

64% of plants examined had some degree of leaf spotting caused by foliar diseases. The average infected plant had 3.9% of the foliar surface affected by leaf spots. Powdery mildew was the most prevalent foliar disease in the winter barley trial. 44% of plants examined had powdery mildew, with an average of 7.5% of the foliar surface affected in infected plants. 30% of plants were infected with leaf rust although the infected plants averaged only 1.8% of the foliar surface affected. The variety with the lowest disease burden was KWS Orbit, with 1.6% of the foliar surface affected in the average plant of this variety. Most other varieties were statistically similar with less than 7% of foliar surface affected by disease. The varieties DH140088, MW12_4007-001, KWS Donau, Lyberac, and 13ARS537-13 had more than 7% of their foliar surface affected by pathogens.

Damage was noted from several arthropod pests including thrips, mites, aphids, slugs, and cereal leaf beetle. Leaf damage from all pests was combined into a single arthropod pest damage category for statistical analysis. The most common arthropod pests noted were mites. 78% of plants scouted showed mite damage. Thrips affected only 15% of plants scouted. 7% of plants showed damage from cereal leaf beetle. 2% of plants showed damage from European corn borer. Aphids and slug affected less than 1% of plants scouted. No individual pest damaged more than 4% of foliar surface on average. MW12_4007-001 had the least pest damage, with less than 1% of foliar surface affected on average. The variety exhibiting most pest damage was Somerset, with 6.92% of foliar surface damaged by pests.

Table 4. Agronomic characteristics for winter barley variety trial in Alburgh, VT.

Variety	Spring Emergence	Winter survival	Heading date	Disease	Arthropod Damage	Height	Lodging
	%	%		% foliar surface affected	% foliar surface affected	cm	%
08ARS509-1	88.3^{ab}	88.3^{ef}	26-May	2.32^{ef}	2.54^{b-e}	62.1^{e-g}	**0.0**^{d}
08ARS632-5	83.3^{bc}	90.0^{d-f}	30-May	2.65^{ef}	3.97^{b-d}	63.3^{d-f}	**0.0**^{d}
13ARS537-13	91.7^{a}	86.7^{f}	26-May	7.17^{a-e}	1.58^{de}	48.8^{p}	**0.0**^{d}
13ARS537-19	86.7^{a-c}	91.7^{c-f}	26-May	5.93^{c-f}	2.64^{b-e}	51.2^{m-p}	1.7^{cd}
AC13/028/53 (Marouetta)	88.3^{ab}	96.7^{a-c}	26-May	2.94^{ef}	3.04^{b-e}	70.3^{bc}	9.3^{bc}
Charles	88.3^{ab}	96.7^{a-c}	26-May	3.69^{d-f}	2.82^{b-e}	49.6^{op}	1.7^{cd}
Delicatesse	90.0^{ab}	93.3^{b-e}	27-May	1.67^{ef}	4.42^{a-c}	54.8^{i-p}	1.7^{cd}
DH130910	91.0^{a}	96.7^{a-c}	27-May	1.70^{ef}	4.38^{a-c}	60.0^{f-j}	**0.0**^{d}
DH140088	88.3^{ab}	90.0^{d-f}	26-May	12.41^{a}	4.78^{a-c}	57.1^{g-m}	**0.0**^{d}
DH140963	90.0^{ab}	95.0^{a-d}	29-May	1.88^{ef}	3.22^{b-d}	58.3^{f-k}	**0.0**^{d}
DH141132	91.7^{a}	93.3^{b-e}	28-May	2.59^{ef}	4.06^{b-d}	59.6^{f-k}	**0.0**^{d}
Endeavor	**93.3**^{a}	95.0^{a-d}	29-May	5.14^{c-f}	2.64^{b-e}	67.1^{c-e}	**0.0**^{d}
Flavia	80.0^{c}	88.3^{ef}	26-May	5.31^{c-f}	4.36^{bc}	54.4^{j-p}	**0.0**^{d}
Hirondella	90.0^{ab}	96.7^{a-c}	27-May	2.49^{ef}	3.56^{b-d}	60.7^{f-i}	**0.0**^{d}
KWS Donau	90.0^{ab}	93.3^{b-e}	29-May	10.14^{a-c}	3.30^{b-d}	58.4^{f-l}	0.7^{d}
KWS Faro	90.0^{ab}	95.0^{a-d}	26-May	1.70^{ef}	3.17^{b-e}	56.0^{j-n}	**0.0**^{d}
KWS Flemming	86.7^{a-c}	91.7^{c-f}	27-May	4.62^{c-f}	2.82^{b-e}	68.2^{b-d}	**0.0**^{d}
KWS Orbit	91.7^{a}	**100.0**^{a}	27-May	**1.59**^{f}	2.37^{c-e}	72.0^{a-c}	**0.0**^{d}
KWS Scala	90.0^{ab}	93.3^{b-e}	30-May	3.98^{d-f}	4.40^{a-c}	55.7^{i-n}	**0.0**^{d}
KWS Somerset	90.0^{ab}	91.7^{c-f}	29-May	2.26^{ef}	6.92^{a}	62.6^{d-g}	**0.0**^{d}
Lyberac	91.7^{a}	95.0^{a-d}	27-May	8.95^{a-d}	5.00^{ab}	53.6^{k-p}	5.0^{cd}
MW12_4007-001	83.3^{bc}	96.7^{a-c}	26-May	12.29^{ab}	**0.67**^{e}	66.8^{c-e}	71.7^{a}
Pixel	90.0^{ab}	96.7^{a-c}	26-May	2.29^{ef}	3.38^{b-d}	51.0^{n-p}	**0.0**^{d}
Rossignola	88.3^{ab}	91.7^{c-f}	26-May	1.68^{ef}	3.53^{b-d}	55.1^{i-n}	**0.0**^{d}
Thoroughbred	91.7^{a}	98.3^{ab}	26-May	6.79^{b-f}	2.60^{b-e}	57.3^{f-l}	13.3^{b}
VA16M-81	91.7^{a}	95.0^{a-d}	26-May	5.24^{c-f}	3.08^{b-e}	**77.9**^{a}	**0.0**^{d}
VA16M-84	91.7^{a}	96.7^{a-c}	26-May	4.47^{d-f}	2.92^{b-e}	74.0^{ab}	**0.0**^{d}
Visuel	86.7^{a-c}	88.3^{ef}	27-May	1.84^{ef}	2.78^{b-e}	52.8^{l-p}	2.7^{cd}
Wintmalt	91.7^{a}	98.3^{ab}	1-Jun	1.97^{ef}	3.49^{b-d}	62.0^{e-h}	**0.0**^{d}
Trial Mean	89.2	93.8	27-May	4.40	3.39	60.0	3.7
LSD (0.10)	6.72	6.02	NS	5.56	2.54	6.02	7.97

Varieties that share a letter are statistically similar for that parameter. The top performer is indicated in **bold.** NS indicates that no significant difference was detected.

Heights and lodging were measured prior to harvest. Taller plants can be desirable for better competition against weeds; however very tall plants can be prone to lodging. The tallest variety was VA16M-81 at 77.9 cm tall. This was statistically similar to VA16M-84 and KWS Orbit, both more than 70 cm tall. Although not in the statistically tallest group, MW12_4007-001 had the highest degree of lodging. 71.7% of this variety was too lodged to be harvested. Thoroughbred and AC13/028/53 were statistically similar and experienced 13.3% and 9.3% lodging respectively.

Table 5. Yield and quality data for winter barley variety trial in Alburgh, VT.

Variety	Yield @13.5% moisture content	Moisture	Test Weight	Crude Protein @ 12% moisture content	Falling Number	Germination	Plumpness
	lbs ac^{-1}	%	lbs bu^{-1}	%	seconds	%	%
08ARS509-1	4303^{a-d}	13.9^{b-g}	44.0^{c-g}	10.8^{c-h}	402^{a-d}	**100.0**^{a}	91.9^{ef}
08ARS632-5	3556^{cd}	15.6^{a}	42.5^{f-h}	10.2^{e-k}	411^{a}	98.7^{a}	98.1^{ab}
13ARS537-13	3177^{d}	14.7^{a-c}	43.4^{e-g}	10.0^{g-m}	362^{d-i}	99.0 ^{a}	94.2^{c-e}
13ARS537-19	3887^{a-d}	13.4^{c-j}	46.7^{a-d}	11.1^{a-d}	380^{a-h}	98.3 ^{a}	97.9^{ab}
AC13/028/53 (Marouetta)	5310^{a-c}	12.2^{i-n}	45.7^{a-f}	9.9^{h-m}	358^{e-i}	96.7 ^{ab}	98.6^{ab}
Charles	4210^{a-d}	12.6^{h-n}	41.6^{gh}	10.1^{f-l}	408^{ab}	99.3 ^{a}	98.0^{ab}
Delicatesse	4806^{a-d}	13.6^{c-j}	43.5^{d-h}	10.5^{d-k}	355^{e-i}	86.0 ^{bc}	98.9^{ab}
DH130910	4546^{a-d}	13.2^{d-k}	47.0^{a-c}	10.9^{a-f}	369^{b-h}	80.3 ^{c}	98.8^{ab}
DH140088	3654^{cd}	12.1^{j-n}	43.4^{e-h}	11.6^{a}	404^{a-c}	**100.0** ^{a}	99.1^{a}
DH140963	4668^{a-d}	14.3^{a-d}	44.9^{b-f}	10.9^{a-e}	360^{e-i}	86.0 ^{bc}	99.0^{a}
DH141132	4685^{a-d}	14.0^{b-f}	44.1^{c-g}	10.5^{c-i}	359^{e-i}	94.0 ^{ab}	98.5^{ab}
Endeavor	4541^{a-d}	15.1^{ab}	47.1^{a-c}	10.5^{c-i}	380^{a-h}	99.0 ^{a}	97.4^{ab}
Flavia	4603^{a-d}	12.3^{h-n}	46.1^{a-e}	9.7^{j-m}	329^{ij}	93.3 ^{ab}	99.1^{ab}
Hirondella	4975^{a-c}	11.9^{k-n}	44.0^{d-g}	10.9^{a-e}	**350**$^{f-i}$	**100.0** ^{a}	97.5^{ab}
KWS Donau	4451^{a-d}	13.7^{c-g}	45.7^{a-f}	10.8^{b-g}	329^{ij}	94.7 ^{ab}	**99.6**^{a}
KWS Faro	**5631**^{a}	11.4^{mn}	44.4^{c-g}	9.7^{k-m}	306^{j}	97.0 ^{ab}	95.9^{b-d}
KWS Flemming	5606^{ab}	12.1^{j-n}	38.1^{i}	11.2^{a-d}	412^{a}	91.0 $^{a-c}$	93.6^{de}
KWS Orbit	5560^{ab}	12.7^{f-m}	38.4^{i}	10.5^{d-i}	366^{c-i}	58.3 ^{d}	98.1^{ab}
KWS Scala	3986^{a-d}	14.3^{a-e}	45.0^{b-f}	11.1^{a-d}	379^{a-h}	92.0 ^{ab}	98.9^{ab}
KWS Somerset	3905^{a-d}	15.2^{ab}	40.5^{hi}	11.0^{a-e}	352^{e-i}	96.7 ^{a}	99.6^{a}
Lyberac	4624^{a-d}	13.4^{c-j}	**48.3**^{a}	9.3^{lm}	384^{a-f}	98.7 ^{a}	99.1^{ab}
MW12_4007-001	4563^{a-d}	11.5^{l-n}	40.6^{hi}	10.9^{a-e}	391^{a-e}	99.7 ^{a}	85.2^{g}
Pixel	5502^{ab}	11.6^{l-n}	43.1^{e-h}	10.8^{a-g}	371^{b-h}	97.3 ^{ab}	97.0^{a-c}
Rossignola	4540^{a-d}	**11.3**^{n}	45.7^{a-e}	9.2^{m}	341^{h-j}	99.3 ^{a}	98.9^{ab}
Thoroughbred	4498^{a-d}	**11.3**^{n}	45.8^{a-e}	9.8^{i-m}	362^{d-i}	98.7 ^{a}	90.2^{f}
VA16M-81	3821^{b-d}	12.9^{e-l}	47.9^{ab}	11.6^{ab}	383^{a-g}	98.0 ^{a}	99.4^{a}
VA16M-84	3979^{a-d}	13.2^{d-k}	48.0^{ab}	11.3^{a-c}	360^{e-i}	89.7 $^{a-c}$	99.4^{a}
Visuel	3635^{cd}	14.1^{b-f}	43.6^{d-h}	10.5^{d-k}	341^{h-j}	94.7 ^{ab}	99.1^{a}
Wintmalt	4754^{a-d}	14.8^{a-c}	43.6^{d-h}	10.7^{c-h}	343^{g-j}	99.0 ^{a}	98.6^{ab}
Trial Mean	4482	13.2	44.2	10.5	367	94.3	97.2
LSD (0.10)	1785	1.43	3.24	0.83	39.8	11.6	3.03

Varieties that share a letter are statistically similar for that parameter. The top performer is indicated in **bold.** NS indicates that no significant difference was detected.

Winter barley yields were good, averaging over two tons per acre (Table 5). The highest yielding variety was KWS Faro, with a yield of 5631 lbs ac^{-1}. Warm, dry weather near harvest allowed for harvesting at nearly ideal timing for peak grain condition. Harvest moisture overall was low and few plots required drying down for storage. Falling number was also very good, with all varieties testing between 306 and 412 seconds, indicating sound grain quality. Protein for all varieties was between 9.2% and 11.6%, within the ideal range for protein for malting barley. Test weights were low overall, with no varieties meeting the industry standard of 50 lbs bu^{-1}. Germination was variable, with several varieties exhibiting 100% germination (08ARS509-1, DH140088, and Hirondella). Fifteen other varieties were at or above the 95% germination rate desired for malting. Germination and other quality tests were performed within six weeks of harvest, so it is possible that many of the varieties that had lower germination rates will perform better after the dormant period, the length of which can be highly variety specific. Plumpness, a proxy for starch content and overall malting quality, was very good in this year's winter barley. All varieties were above the 80% industry minimum, with 24 of the varieties having plumpness over 95%.

Nineteen varieties had yields above two tons ac^{-1} and plumpness over 90%, indicating both high yield and high quality for these varieties (Figure 1).

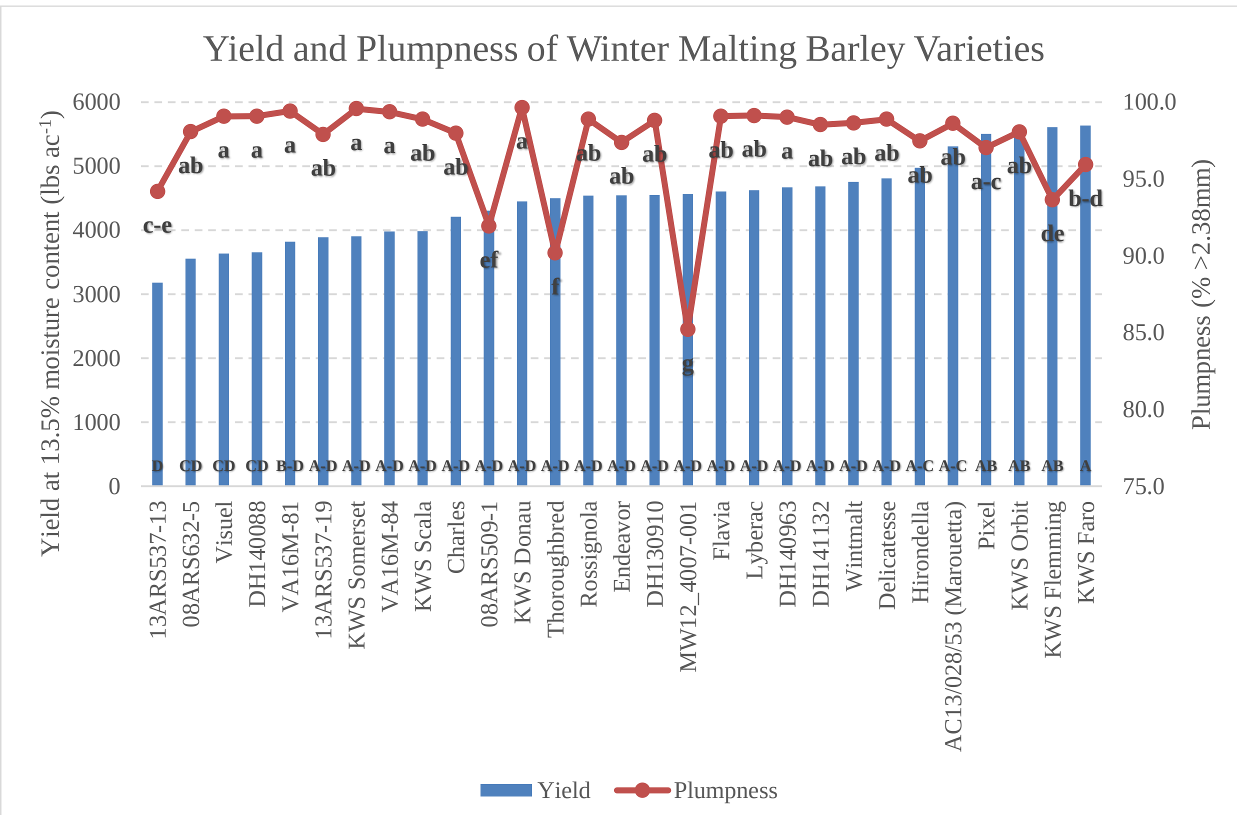

Figure 1. *Varieties with the same capital letter did not differ significantly by yield. Varieties with the same lower case letter did not differ significanlty by plumpness.*

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