2019 Vermont Flint and Dent Corn Performance Trial

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In the northeast there is a strong demand from consumers to have access to a wide range of locally produced food products. This demand creates opportunities for specialty value-added markets and crops to emerge. One market that has been gaining popularity and expanding recently in the northeast is the specialty corn market. Flint corn has very hard starch and can be ground and used in tortillas, tamales, corn meal, grits, and other products. Flint has a high proportion of hard starch in the kernel that produces a coarse meal. This is different than a soft-starch flour corn that, when ground, results in a fine flour. Dent corn is similar as it has a lower proportion of hard starch than flint corn, and thus forms a small dent on top of each kernel when mature (Figure 1). Flint and flour corn types, although recorded as being grown by Native Americans, have largely not been produced on a commercial scale in this region. However, new food entrepreneurs are looking to source local grain corn, producing potential value-added markets for local farmers. Therefore, it is important to evaluate both commercially available and locally saved flint, flour, and dent corn varieties to determine varieties that are well suited to our northern climate and produce economically viable yields and meet the quality expectations of this new market. The University of Vermont Extension Northwest Crops and Soils Program conducted a flint and dent corn variety trial in 2019 to evaluate commercially available and locally saved corn varieties for yield, quality, and suitability to our northern climate. It is important to remember that the data presented are from a replicated research trial from only one location in Vermont and represent only one season. Crop performance data from additional tests in different locations and over several years should be compared before making varietal selections.

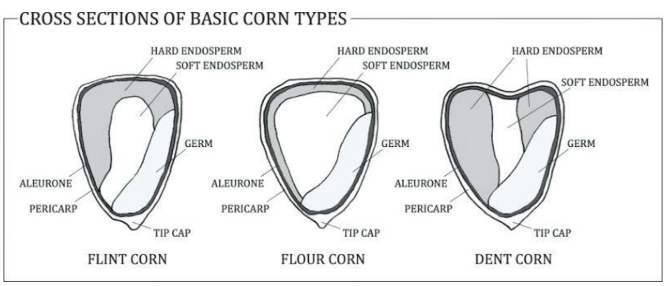

Figure 1. Difference in starch composition of grain corn types (Burton & Fincher, 2014).

MATERIALS AND METHODS

In 2019, flint and dent grain corn varieties were evaluated at Borderview Research Farm in Alburgh, Vermont. The plot design was a randomized complete block with four replications. Treatments were 14 corn varieties from five companies (Table 1). Several varieties were also sourced from local seed savers (Table 2). Varieties were evaluated for grain yield and quality. Relative maturity (RM) and varietal characteristics are provided in Table 2.

Table 1. Participating companies and contact information.

Adaptive Seeds	Albert Lea Seedhouse	Baker Creek Heirloom Seed Co.	Johnny's Selected Seeds	Victory Seed Company
25079 Bush Creek Rd. Sweet Home, OR 97386 (541) 367-1105	1414 West Main St, PO Box 127 Albert Lea, MN 56007 (800) 352-5247	2278 Baker Creek Road Mansfield, MO 65704 (417) 924-8917	13 Upper Main Street Fairfield, ME 04091 1-877-564-6697	PO Box 192 Molalla, OR 97038 (503) 829-3126

Table 2. Grain corn varieties evaluated in Alburgh, VT, 2019.

Variety	Type	RM	Source
Abenaki	Flint	85	Adaptive Seeds
Bronze Orange	Flint	77	Victory Seeds
Canadian White	Flint	Unknown	Ruth Fleishman, Île Bizard, Quebec
Cascade Ruby-Gold	Flint	85	Adaptive Seeds
Dakota White	Flint	85	Sylvia Davatz, Hartland, VT
Early Riser	Dent	Unknown	Butterworks Farm, Westfield, VT
Elliot's White	Dent	85	Albert Lea Seeds
Flint's Flint Corn	Flint	Unknown	UVM Extension, Alburgh, VT
Gaspe	Flint	70	Ruth Fleishman, Canadian Maritimes
Minnesota 13	Dent	95	Albert Lea Seeds
Oaxacan Green	Dent	95	Johnny's Selected Seeds
Osage Brown	Flour	90	Baker Creek Heirloom Seed
Roter Tessinmais	Flint	Unknown	Sylvia Davatz, Hartland, VT
Wapsie Valley	Flint	85	Aurora Farms, Charlotte, VT

The soil type at the Alburgh location is a Benson rocky silt loam (Table 3). The seedbed was prepared with spring disking followed by a spike tooth harrow. The previous crop was spring wheat. Prior to planting, plots were fertilized with 19-19-19 at a rate 300 lbs ac^{-1} on 25-Apr. Plots were planted on 21-May with a 4-row cone planter with John Deere row units fitted with Almaco seed distribution units (Nevada, IA) at a rate of 40,000 seeds ac^{-1}. Some varieties with limited seed availability were seeded at a reduced rate. These included Roter Tessinmais (36,590 seeds ac^{-1}), Dakota White (37,000 seeds ac^{-1}), and Bronze Orange (36,590 seeds ac^{-1}). Liquid starter fertilizer (9-18-9) was applied at planting at a rate of 5 gal ac^{-1}. Plots were 20' long and consisted of four rows of corn 30" apart. Populations were counted in each plot and thinned if needed to approximately 28,000 plants ac^{-1} on 19-Jun. An application of Steadfast was made on 24-Jun at a rate of 0.75 qt ac^{-1} to control quackgrass. On 29-Jun plots were top-dressed with 513 lbs ac^{-1} 28-0-0.

On 11-Oct and 6-Nov short and long maturity corn varieties were harvested respectively. Corn populations and the number of ears in each plot were counted. Corn was picked by hand, husked, and weighed for each plot. The corn from each plot was bagged and hung to dry in a grain bin. The varieties Gaspe and Canadian White were not harvestable and therefore do not have measures reported. On 5-Dec, the corn from each plot was shelled and analyzed for moisture content and test weight using a Dickey John Mini-GAC Plus moisture and test weight meter. Kernel yield from each plot was also measured at this time. A subsample from each plot was taken and combined to create a composite sample for each variety. The composite samples were ground using a cyclone mill (UDY Corporation) to obtain a 1mm particle size. The samples were then analyzed for crude protein, fat, fiber, and starch content using NIR (near infrared spectroscopy) methods at the UVM Cereal Grain Testing Laboratory (Burlington, VT) on a FOSS DS2500 Forage and Feed Analyzer. Samples were also analyzed for dexoynivalenol (DON) content using Veratox DON 2/3 Quantitative test from the NEOGEN Corp. This test has a detection range of 0.5 to 5 ppm. DON is a vomitoxin associated with infection by the *Fusarium* fungus. The fungus can overwinter in soils, and spores can be transported by air currents and infect corn plants. Consuming DON at over 1 ppm poses a health risk to both humans and livestock, and products with DON values greater than 1 ppm are considered unsuitable for human consumption by the FDA. Falling numbers (AACC Method 56-81B, AACC Intl., 2000) were also measured on a Perten FN 1500 Falling Number Machine. 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. In wheat, falling numbers greater than 350 indicate low enzymatic activity and a sound quality wheat while a falling number lower than 200 indicates high enzymatic activity and poor quality wheat. Since the major grain constituent in corn is starch, high enzyme activity could indicate starch degradation which could influence dough and end product texture and strength. Therefore, falling number may be a useful measure to distinguish corn flour quality, however, specific falling number guidelines have not been determined as they have for wheat.

Mixtures of true proteins, composed of amino acids, and non-protein nitrogen make up the crude protein (CP) content of forages. The CP content is determined by measuring the amount of nitrogen and multiplying by 6.25. Starch is the carbohydrate storage molecule for plants. In corn, this starch may be either soft or hard. Flint corns form almost entirely hard starch, dent corns form hard starch on the sides of the kernels but soft starch in the middle and top of the kernel, and flour corns form almost entirely soft starch. These types of starch and the overall quantity of starch in the kernel can impact their use in making food products such as tortillas or chips.

Table 3. Flint corn variety trial information, Alburgh, VT, 2019.

Location	**Borderview Research Farm Alburgh, VT**
Soil type	Benson rocky silt loam
Previous crop	Spring wheat
Row width (in)	30
Plot size (ft)	10 x 20
Seeding rate (seeds ac^{-1})	40,000
Planting date	21-May
Tillage operations	Spring disk, spike tooth harrow
Harvest dates	11-Oct (short RMs) 6-Nov (long RMs)

Yield data and stand characteristics were analyzed using mixed model analysis using the mixed procedure of SAS (SAS Institute, 1999). Replications within trials were treated as random effects, and hybrids were treated as fixed. Hybrid 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 due to variations in genetics, soil, weather, and other growing conditions. Statistical analysis makes it possible to determine whether a difference among hybrids 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 (i.e. yield). Least Significant Differences (LSDs) at the 0.10 level of significance are shown. Where the difference between two hybrids within a column is equal to or greater than the LSD value at the bottom of the column, you can be sure that for 9 out of 10 times, there is a real difference between the two hybrids. Hybrids that were not significantly lower in performance than the highest hybrid in a particular column are indicated with an asterisk. In this example, hybrid C is significantly different from hybrid A but not from hybrid B. The difference between C and B is equal to 1.5, which is less than the LSD value of 2.0. This means that these hybrids did not differ in yield. The difference between C and A is equal to 3.0, which is greater than the LSD value of 2.0. This means that the yield of these hybrids were significantly

Hybrid	**Yield**
A	6.0
B	7.5*
C	**9.0***
LSD	2.0

different from one another. The asterisk indicates that hybrid B was not significantly lower than the top yielding hybrid C, indicated in bold.

RESULTS

Weather data was recorded with a Davis Instrument Vantage Pro2 weather station, equipped with a WeatherLink data logger at Borderview Research Farm in Alburgh, VT (Table 4). Overall, the season began cooler and wetter than normal but became hot and dry in the middle of the summer. July brought above normal temperatures and little rainfall. The longest period without rainfall in July lasted 12 days. This dry period, which occurred around the time corn plants were developing tassels and silks for pollination, may have negatively impacted corn plant growth and productivity. This was evident in smaller than normal ears and poor tip fill experienced in corn fields around the region. However, these warm conditions did provide optimal Growing Degree Days (GDDs) through the season with a total of 2400 GDDs accumulated May-Oct, 188 above normal.

Table 4. Weather data for Alburgh, VT, 2019.

Alburgh, VT	May	June	July	August	September	October
Average temperature (°F)	53.3	64.3	73.5	68.3	60.0	50.4
Departure from normal	-3.11	-1.46	2.87	-0.51	-0.62	2.22
Precipitation (inches)	4.90	3.06	2.34	3.50	3.87	6.32
Departure from normal	1.45	-0.63	-1.81	-0.41	0.23	2.72
Growing Degree Days (50-86°F)	189	446	716	568	335	146
Departure from normal	-9	-29	76	-13	17	146

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.

Varieties varied statistically in harvest characteristics (Table 5). Although all plots were planted above optimal seeding rates and thinned to the target population of 28,000 plants ac^{-1} for grain corn, none of the varieties maintained this population through the season. The variety Osage Brown produced the highest plant population of 23,414 plants ac^{-1} and was statistically similar to three other varieties. The variety Flint's Flint Corn produced the lowest population at 10,890 plants ac^{-1}. Lodging and other quality issues related to plant lodging can be a significant challenge for grain corn production. To capture plant standability differences, we noted lodging presence and severity at harvest. To standardize these observations, a 1 was assigned to a plot in which severe lodging was noted and a .5 (1/2) was assigned to a plot in which lodging at a lower severity was noted. These measures were then summed across variety replicates and are expressed as a percentage of plots that were lodged. The highest incidence and severity of lodging was observed in varieties Dakota White, Oaxacan Green, and Cascade Ruby Gold. These varieties had lodging present in over 50% of the plots in the trial. The varieties that exhibited the best standability were Wapsie Valley, Osage Brown, Flint's Flint, and Roter Tessinmais as these exhibited less than 15% lodging. Variable populations led to ear yields between 6643 ears ac^{-1} and 23,740 ears ac^{-1}. Ear yields for lbs ac^{-1} ranged from 1491 to 10,075 lbs ac^{-1} with the variety Minnesota 13 producing the highest yield for lbs ac^{-1}. If we consider the number of plants these ears were produced on, we see that ear yields per plant ranged from 0.459 to 1.11 ears per plant. Values greater than 1.00 indicate varieties that produced 2 harvestable ears on some plants while values less than 1.00 indicate varieties that had some stalks with no harvestable ears formed.

However, with variations in ear size and moisture, we must compare these varieties at a standard moisture content and on a kernel basis. Corn grain yields ranged from 970 to 6681 lbs ac^{-1} or 17.3 to 119 bu ac^{-1}. These yields, although lower than expected in the Midwest, are in line with VT yields as the highest reported VT yield in 2019 was 140 bu ac^{-1}. The highest yielding variety was Minnesota 13, which was not statistically similar to any other variety. The next highest yielding variety was Wapsie Valley which produced 79.3 bu ac^{-1}. The lowest yielding variety was Bronze Orange which only produced 17.3 bu ac^{-1}. Test weights ranged from 56.7 to 62.7 lbs bu^{-1} indicating that all varieties were at or above the industry standard 56 lbs bu^{-1} (Table 6).

Table 5. Harvest characteristics of 12† flint/dent corn varieties, 2019.

Variety	Population	Lodging	Ear yield		Grain yield @ 15.5% moisture	
	plants ac^{-1}	% of plots	ears ac^{-1}	lbs ac^{-1}	lbs ac^{-1}	bu ac^{-1}
Abenaki	15355	50	9692	2301	1583	28.3
Bronze Orange	15682	25	8385	1815	970	17.3
Cascade Ruby-Gold	16444	50	13504	3129	1854	33.1
Dakota White	12741	75	8385	1491	1166	20.8
Early Riser	21018*	25	16008	5919	4225	75.4
Elliot's White	14484	37.5	6643	3991	2187	39.0
Flint's Flint Corn	10890	12.5	11217	4284	2775	49.5
Minnesota 13	20364*	25	20364*	**10075**	**6681**	**119**
Oaxacan Green	14157	62.5	9801	3800	2527	45.1
Osage Brown	**23414**	0	17533	3357	1759	31.4
Roter Tessinmais	21453*	12.5	**23740**	6964	4283	76.5
Wapsie Valley	13177	**0**	11652	6979	4439	79.3
LSD (p = 0.10)	4052	N/A	4107	1276	908	16.2
Trial Mean	16598	31.25	13077	4509	2871	51.3

†The varieties Canadian White and Gaspe were not included in analyses as they were not harvestable.
Varieties with an asterisk performed statistically similarly to the top performer in **bold.**
N/A – statistical analysis was not performed for this parameter.

Corn quality characteristics measured on the composite variety samples are also summarized in Table 6. Crude protein levels ranged from 9.7 to 13.1%. Grain corn in the US typically averages around 9% protein, so many of these flint or less common dent corn varieties had much higher protein levels. Fat levels ranged from 3.26 to 6.23%. The average fat for grain corn is typically around 4% indicating that a few of these varieties, including Bronze Orange, Dakota White, and Flint's Flint, had higher fat content. Fiber content ranged from 2.51 to 3.62. Starch content ranged from 61.6 to 67.7% and averaged 64.8%. This is lower than the average for grain corn which is typically around 70% starch. Differences in starch content between varieties may be an important factor in variety selection depending on the intended end use of the corn. When making food products exclusively with corn (i.e. tortillas, chips, tamales, etc.) the texture and behavior of the dough will be heavily influenced by the starch. Another important aspect of corn grain quality is mycotoxin analysis. Corn is susceptible to infection by a number of fungal pathogens that can produce compounds (mycotoxins) that are toxic to humans and animals at certain concentrations. One of these fungal pathogens is *Fusarium* which can produce a mycotoxin called Deoxynivalenol or DON. The FDA recommends that human food products contain no more than 1 ppm DON. The majority of the varieties tested contained very low levels of DON between 0 and 0.4 ppm. However, the varieties Bronze Orange and Cascade Ruby-Gold had levels of 0.6 and 1.0 ppm.

Table 6. Quality characteristics of 12 flint/dent corn varieties, 2019.

Variety	Test Weight	Crude protein	Fat	Fiber	Starch	Falling number	DON
	lbs bu^{-1}	% of DM				seconds	ppm
Abenaki	61.4	13.0	4.23	2.75	65.1	82	0.300
Bronze Orange	57.4	**13.1**	**6.23**	3.22	61.6	284	1.00
Cascade Ruby-Gold	60.0	11.8	4.59	3.02	65.6	62	0.600
Dakota White	61.1	12.8	5.75	3.03	63.0	65	0.200
Early Riser	60.9	10.9	4.21	2.77	64.4	323	0.200
Elliot's White	57.5	10.2	3.26	2.94	**67.7**	290	0.200
Flint's Flint Corn	61.3	12.4	5.34	2.55	64.5	67	0.400
Minnesota 13	59.0	9.7	4.22	2.87	65.1	332	0.200
Oaxacan Green	57.8	11.3	4.17	2.51	65.3	334	0.100
Osage Brown	56.7	10.4	3.98	2.99	64.5	175	**0.000**
Roter Tessinmais	**62.7**	11.8	3.54	**3.62**	64.4	**359**	0.200
Wapsie Valley	61.6*	11.3	4.13	2.79	64.7	327	0.200
LSD (p = 0.10)	1.27	N/A					
Trial Mean	59.8	11.5	4.43	2.93	64.8	233	0.623

*Varieties with an asterisk are not significantly different than the top performer in **bold**.
N/A – only bulked grain was analyzed for quality and statistical analysis was not performed.

Although these levels would still be considered safe for human consumption, these differences could indicate differences in susceptibility to *Fusarium* infection which, in years with wetter conditions in the late summer and fall, could pose concern with DON formation in these varieties. Susceptibility could be related to physical characteristics of the ears including husk cover and orientation (upward or downward facing). These characteristics were not formally recorded in this trial but will be considered in future trials. Finally, we also analyzed the composite samples for falling number. Although this measure is more commonly used with wheat and other small grains, we are interested in understanding if falling number could be a useful indicator of corn quality for certain end uses. The falling numbers ranged from 62 to 359 seconds and averaged 233 seconds across all varieties. In general, the flint varieties tended to have lower falling numbers than the dent varieties. This may suggest that these varieties experienced more starch degradation, however, it may also simply be a reflection of the differences in soft and hard starch proportions influencing the amount of time and heat required to gelatinize the starch which would in turn influence the viscosity and therefore the falling number. Connecting these laboratory quality measures with product testing will provide a better understanding of the interpretability of this measure and its application in corn flour analysis.

DISCUSSION

Grain corn varieties differed dramatically in both yield and quality performance in 2019 (Figure 2). Of the 12 varieties ultimately harvested from the initial 14 varieties, there were six varieties that seem more promising in terms of establishment, productivity, and quality. These varieties include Minnesota 13, Early Riser, Wapsie Valley, Roter Tessinmais, Oacaxan Green, and Flint’s Flint. All of these varieties produced over 40 bu ac^{-1} with Minnesota 13 producing 119 bu ac^{-1}. Although we had trouble establishing decent populations of some of these varieties, the fact that they still yielded over 40 bu ac^{-1} indicates good ear development on the existing plants. If populations can be improved, these varieties would have a much higher yield potential. In terms of quality, these varieties produced test weights above the average 56 lbs bu^{-1}, had DON concentrations below the 1 ppm FDA guideline for human consumption, and produced a nutritional profile similar to or better than average grain corn currently produced in the US (protein, starch, fat). We do not yet fully understand which of these parameters will prove most important in the end uses local processors are interested in and will continue to work with both growers, processors, and end users to develop this understanding and ultimately recommendations for specialty corn production in Vermont and the northeast.

REFERENCES

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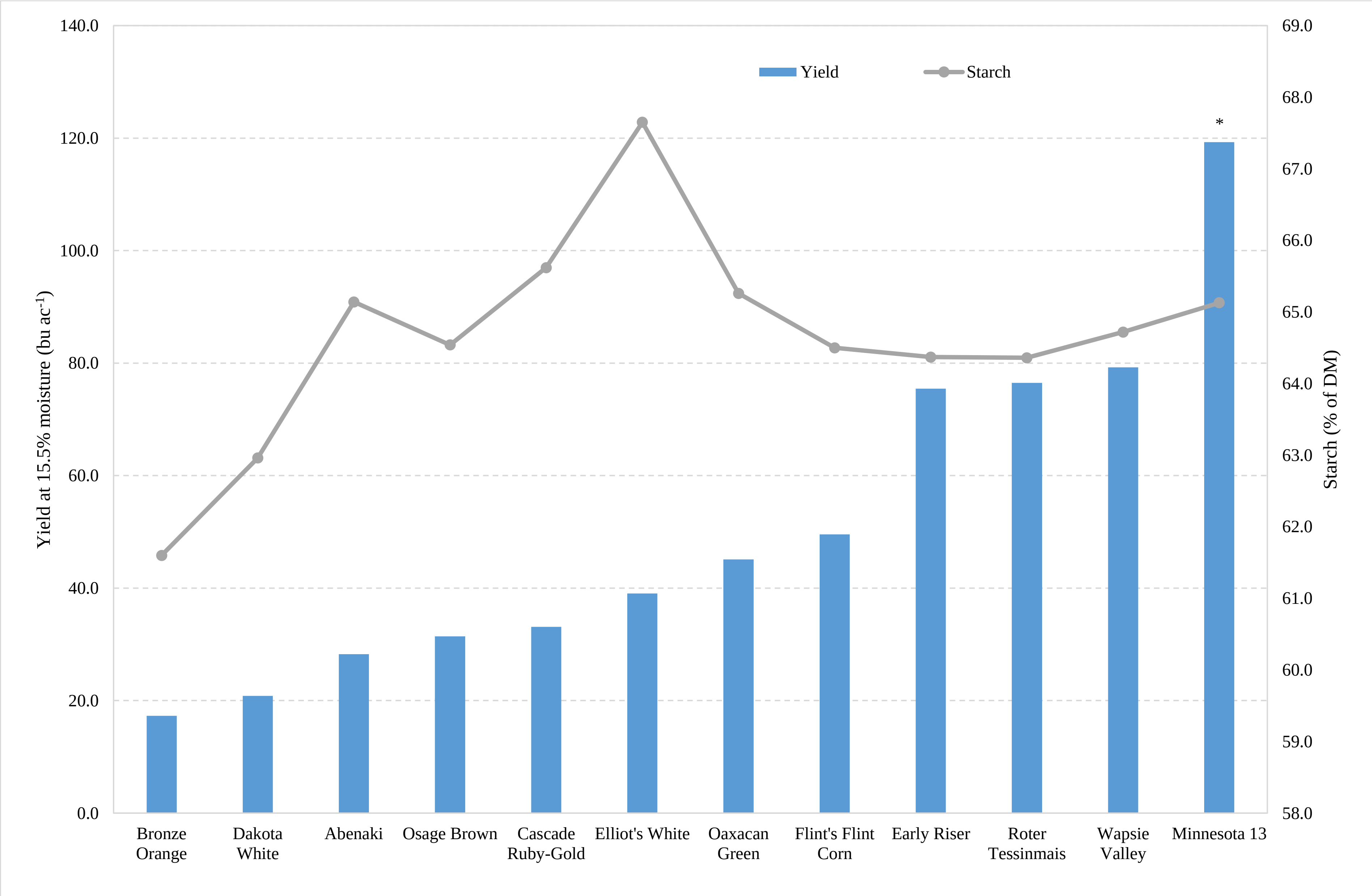

Figure 2. Yield and starch content of 12 grain corn varieties, 2019.
Varieties with an asterisk* performed statistically similarly to the top performer.
Statistical analyses were not performed for starch content.