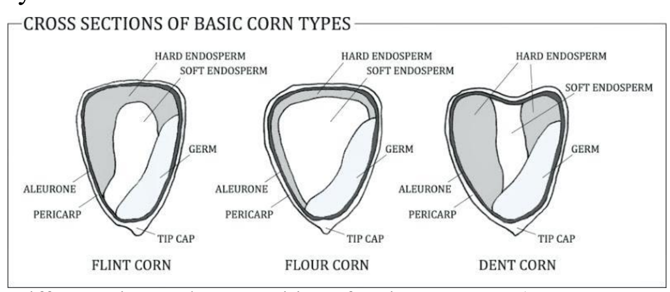
Revitalizing Northern Flint Corn in the Northeast:

Evaluating Northern Flint Corn Germplasm from Agronomic and Nutritional Perspectives

Introduction

For centuries corn has been an integral agricultural and culturally significant food crop across North and South America and the regions' Indigenous communities. In New York and Vermont, tribes belonging to the Haudenosaunee and Wabanaki Confederacies have inhabited the St. Lawrence, Mohawk, and Champlain Valleys for centuries. Each of these confederacies are alliances of multiple nations each having several tribes distributed across various parts of the states. While their individual histories and specific cultural practices and traditions may differ from one another, these communities all depended on corn for both cultural and subsistence reasons: corn is one of the crops in the traditional companion planting termed the Three Sisters in which corn is interplanted with beans and squash in a mound of soil; in Haudenosaunee cultures, one of the 13 annual celebrations is dedicated to corn; and traditional culinary dishes and crafts using many forms of corn are integral parts of everyday life.

Since corn was domesticated from its ancestor plant Teosinte in southern Mexico approximately 9,000 years ago, Indigenous communities have carefully selected populations to be locally adapted to the climate and suit their various cultural and culinary needs. This led to the diversity of corn landraces found across the Americas that laid the foundation for the eventual development of our modern-day corn varieties. These races included flour corns with soft starch endosperms, flint corns with hard starch endosperms, dent corns with a combination of hard and soft starch endosperm, sweet corn with high sugar content, and popcorns with small flinty kernels. Each type also included a diversity of ear and kernel sizes, shapes, and colors. The most common type utilized by Indigenous communities in the northeastern U.S. was flint corn. This corn typically produces very long, slender ears with eight to ten rows of broad, shallow kernels that appear translucent due to their hard starch containing endosperm. The plants are often short in stature with relatively thin weak stalks and can produce many tillers. These characteristics differ dramatically from the modern-day dent corns that now dominate our landscape.



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

Flint corn plant and ear phenotype (left) vs modern dent corn (right).

While these historical genetics are rarely expressed in today's conventional marketplace, they are critical to many Indigenous cultures and could prove an invaluable genetic resource for local breeding efforts. The temperate climate of the northeast in combination with its relatively short growing season, provides unique challenges for grain corn production and is rarely, if ever, included in modern corn breeding programs. As local communities adapt to climate change, more localized breeding efforts incorporating historical genetics are needed in order to develop crop varieties that remain well-suited and productive in our new climate. While some Indigenous communities have been able to maintain their cultural history and practices, many find it increasingly challenging as they face an aging demographic, diminishing populations and interest from the younger generation, and resource constraints. In addition to preserving existing knowledge and practices, these communities must also continue to engage in efforts to adapt to changing pressures such as climate change. The constant selection of northern flint corns by Indigenous communities is what allowed them to feed their people and partake in culturally significant activities for centuries. As the Indigenous knowledge of cultivation, cultural and culinary uses of corn fade and new pressures of climate change emerge, the need for local agricultural knowledge preservation and crop breeding efforts only grow more necessary. Without intensive and intentional selection under these new selective pressures, the traditional varieties and landraces that were handed down through generations may be rendered unviable in the future.

This factsheet summarizes the results of agronomic and nutritional evaluations of historic, culturally important, and modern flint corn germplasm. This project was made possible with funding support through the University of Vermont Food Systems Research Center and could not have been completed without the partnership of the local Abenaki community.

Methods

Twenty-six samples were obtained from the USDA Germplasm Resources Information Network's National Plant Germplasm System Genebank. Some of these lines had previously been evaluated for one growing season at Borderview Research Farm (Alburgh, VT) and displayed promising characteristics for performance in our climate. Additionally, five samples were obtained from local Abenaki community members and other seed savers that represented locally relevant and culturally important varieties. Finally, eight samples were purchased from commercial seed companies. Two represented modern flint corn varieties, two modern dent corn varieties, and the other four were flint corns that were commercially available in larger quantities. A total of thirty-nine lines were included in agronomic, nutritional, and fatty acid profile evaluations (Table 1).

For the agronomic performance evaluation, samples were grown at Borderview Research Farm (Alburgh, VT) on 30-inch rows at approximately 26,000 seeds ac^{-1}. The plots were evaluated for silk and tassel dates, stand populations, barren plants, kernel yield, kernel test weight, plant height, height to lowest ear attachment, plant lodging, and ear disease prevalence. Lodging was assessed visually on a 0-5 scale where 0 = none and 5 = completely lodged. Ear disease was also assessed visually while harvesting on a 0-3 scale where 0 = no diseased ears and 3 = more diseased ears than non-diseased ears. The nutritional value evaluation consisted of carbohydrate, protein, ash, fat, starch, calories, fiber, total carotenoids and a carotenoid profile (Eurofins). The fatty acid content and profile was analyzed by direct transesterification using 2% H2SO4/methanol and a combination of acetone and toluene (2 hours at 70°C). Samples were subsequently purified using a mixture of charcoal and silica gel. The fatty acid profiles (as fatty acid methyl esters, FAME) were analyzed by gas chromatography (GC) with flame ionization detection (FID; Shimadzu, Kyoto, Japan) using a highly polar 100 m fused-silica capillary column (Varian, Palo Alto, CA). FAME were identified by comparison of retention times with known FAME standards (Nu-Check Prep 463 and 674; NuCheck Prep, Inc., Elysian, MN). Total fatty acid content was determined using C13:0 as an internal standard and the fatty acid profile covers approximately 70 fatty acids in the range of C10:0 to C26:0.

Table 1. Flint corn germplasm/varieties included in different evaluations.

Name	Source	Agronomic performance	Nutritional value	Fatty acid profile
Abenaki Rose	Community		x	x
Amber flint	USDA	x	x	x
Assiniboine	USDA	x	x	x
Bronze Beauty	USDA	x		
Byron	Commercial markets	x		
Carpenter's Rhode Island Flint	USDA	x		
Cascade ruby-gold	Commercial markets	x	x	x
Comstock Family Flint	USDA	x	x	x
Dark Yellow King Philip	USDA	x	x	x
Flint's Flint	Community	x	x	x
Floriani red	Commercial markets	x	x	x
Gaspe	Community		x	x
Gigi Hall	USDA	x	x	x
Golden flint	USDA	x	x	x
Hubbard flint	USDA	x	x	x
Johnny Cake corn	USDA	x	x	x
King Philip	USDA	x		
Koasek	Community		x	x
Longfellow	USDA	x		
Longfellow flint	USDA	x	x	x
Magic Manna	Commercial markets	x		
Minnesota 13	Commercial markets		x	x
Parker's flint	USDA	x	x	x
Rhee flint	USDA	x	x	x
Rhode Island Double White Cap Flint	USDA	x		
Rhode Island White Cap Flint	USDA	x	x	x
Roter Tessinermais	Community	x	x	x
Roy's Calais Flint	Commercial markets	x		
Saltzer’s White Flint	USDA	x	x	x
Saskatoon White	USDA	x		
Smut Nose	USDA	x		
SW3834	Commercial markets		x	x
Tama Flint	USDA	x	x	x
Twitchell’s pride	USDA	x	x	x
Wampum flint	USDA	x	x	x
Wapsie Valley	Commercial markets		x	x
Washonge	USDA	x	x	x
Yellow Flint	USDA	x		
6-Nations	USDA	x		
		33	27	27

Results- Agronomic performance

Agronomic performance varied widely across the germplasm trialed (Table 2). Yields ranged from 119 to 5124 lbs ac^{-1} which translated to approximately 2 to 82 bu ac^{-1}. The highest yield is approximately 50% of the average dent corn yield for New York in the last 10 years (USDA NASS). Of the 33 varieties, 13 yielded over 50 bu ac^{-1} and only 7 yielded over 60 bu ac^{-1} (Figure 1).

Table 2. Agronomic performance of 33 flint corn varieties/lines.

Variety	Kernel yield 15.5% moisture		Test weight	Tassel	Harvest	Harvest Population	Barren plants	Plant height	Ear height	Ear height % plant height	Lodging	Ear disease
	lbs ac^{-1}	bu ac^{-1}	lbs bu^{-1}	Days after planting		plants ac^{-1}		cm			0-5	0-3
Amber Flint	1577	26.1	60.3	59	126	19457	0	194	56.3	29.0	1.00	1.00
Assiniboine	2034	36.8	55.1	51	119	20038	1162	133	36.2	28.1	2.50	2.00
Bronze Beauty	3505	57.3	61.2	61	157	18223	327	193	66.5	34.2	0.50	2.00
Byron	502	8.3	60.4	51	118	18295	871	184	73.7	40.0	1.00	3.00
Carpenter's Rhode Island Flint	3003	47.5	63.4	61	149	27152	1416	251	83.7	33.6	1.50	1.50
Cascade ruby-gold	415	6.6	62.7	51	112	27225	1960	175	53.0	30.3	1.00	3.00
Comstock Family Flint	2612	42.7	62.2	53	115	20437	762	210	67.5	32.0	2.00	2.00
Dark Yellow King Philip	3465	56.4	61.6	60	142	18150	1742	227	96.8	42.6	1.50	0.50
Flint's Flint	3753	59.9	62.7	55	146	24394	871	258	102	39.6	1.00	1.00
Floriani Red	3513	57.1	61.6	58	157	16988	545	245	99.7	40.5	1.00	1.00
Gigi Hall	1997	33.6	59.5	59	126	16553	0	181	43.0	23.7	1.00	0.00
Golden Flint	1891	31.2	60.6	55	126	15682	0	188	60.7	32.2	1.00	0.00
Hubbard Flint	1014	17.0	59.7	59								
Johhny Cake Corn	4285	68.8	62.3	62	138	14520	0	238	101	42.4	1.00	0.00
King Philip	3206	52.5	61.1	61	156	17860	581	188	92.0	49.1	1.50	2.00
Longfellow	3398	54.7	62.2	57	134	29076	3376	245	91.3	37.4	1.50	1.00
Longfellow Flint	1450	23.6	61.7	59	125	19021	1307	212	82.5	39.5	1.50	2.00
Magic Manna	171	6.2	55.4	50	112	17424	1742	152	20.3	13.3	2.00	2.00
Parker's Flint	1717	27.5	63.0	60	119	22942	726	181	49.7	27.5	1.00	1.50
Rhee Flint	1817	29.6	61.4	55	118	15682	0	166	45.7	27.6	3.00	2.00
Rhode Island Double White Cap Flint	4014	63.7	63.2	57	157	19602	581	229	95.0	41.8	2.50	1.50
Rhode Island White Cap Flint	4045	65.0	62.3	60	146	24684	290	250	86.0	34.4	2.00	2.00
Roter Tessinermais	2822	45.0	62.7	54	146	23522	218	227	94.7	41.8	1.00	1.00
Roy's Calais Flint	1417	22.2	63.8	52	118	22651	436	215	86.0	40.0	1.00	2.00
Salzer’s White Flint	5124	82.4	62.0	60	148	21308	1307	223	80.2	36.6	0.50	1.00
Saskatoon White	119			47	112	18949	1089	112	19.0	17.0	2.00	3.00
Smut Nose	2836	47.1	60.3	57	157	19602	980	226	84.0	37.0	2.50	2.00
Tama Flint	2179	37.1	58.8	62	168	14230	0	252	101	40.1	0.00	2.00
Twitchells Pride	1367	22.3	61.4	53	118	16553	0	198	64.7	32.6	2.00	2.00
Wampum Flint	3513	60.3	58.4	55	140	22361	581	190	58.8	31.2	1.50	1.50
Washonge Corn	4019	64.9	61.7	61	134	24031	1198	225	85.2	37.9	1.50	0.50
Yellow Flint	2707	44.8	61.6	58	149	21780	1960	233	65.7	28.4	1.00	2.50
6-Nations	3176	60.4	52.8	55	128	30928	3775	209	60.2	28.8	2.00	2.00

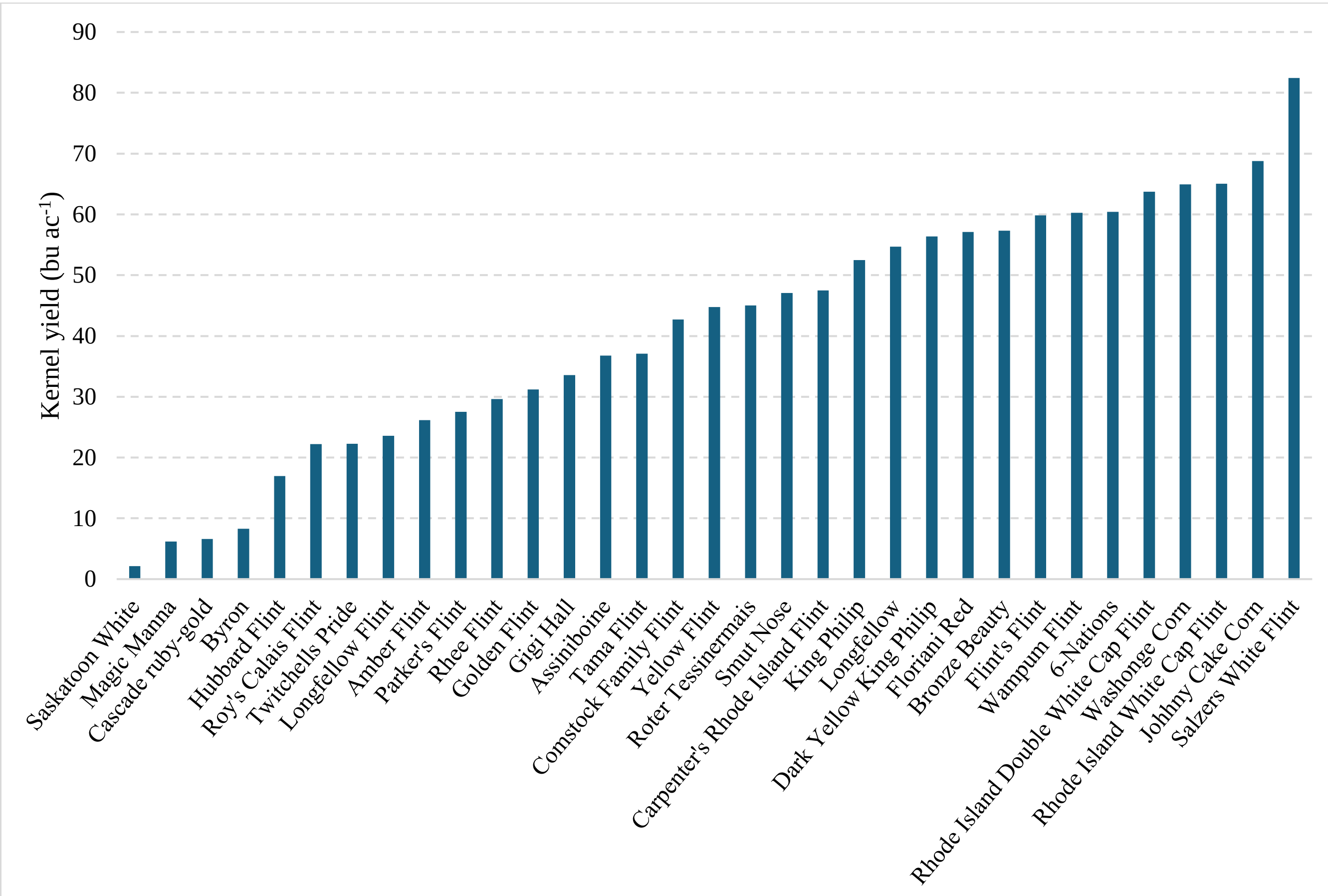


Figure 1. Kernel yield at 13% moisture of 33 flint corn germplasm.

Test weight can provide insight into kernel quality and if the plant experienced challenges during kernel formation and fill. The standard test weight for dent corn in the U.S. is 56 lbs bu^{-1}. Only 3 varieties did not reach this standard and one variety had too small of a yield to measure the test weight accurately. The germplasm included here were harvestable between 112 and 168 days after planting, which was between mid-Sep to early-Nov. As day length shortens and temperatures drop, varieties that require too long of a season to reach physiological maturity may not reach maturity before the onset of freezing conditions. In addition, delays in harvest, especially in inclement weather, risk further yield or quality losses. Conversely, varieties that have very short maturation timings often sacrifice yield as they are not able to take advantage of the full season. Instead of just looking at yield per acre, we can consider the yield per acre that was achieved relative to the length of season required to reach physiological maturity (Figure 2). As we'd expect, yield tends to increase as days to maturity increase, but only to a point before they begin to decrease. This suggests that varieties that require more than 145 days to reach maturity after planting may be riskier in northern areas in the region as weather conditions later in the season can pose challenges for maturation and harvest.

In addition to kernel yield and quality, plant standability and growth characteristics are important considerations for varietal suitability and success, especially in the northeast where a wide range of climatic conditions can be experienced. There was a wide range of plant heights, ear heights, and tillering across these lines. Plants ranged from 112 to 258 cm in total height with the lowest ears set at as low as 13.3% of the plant height or as high as 49.1% of the total height. Higher ears can be beneficial for avoiding pest and disease pressure and can better allow for mechanical harvest. Taller plants also may be susceptible to lodging if exposed to high wind conditions. Figure 3 shows plant height vs lodging severity.

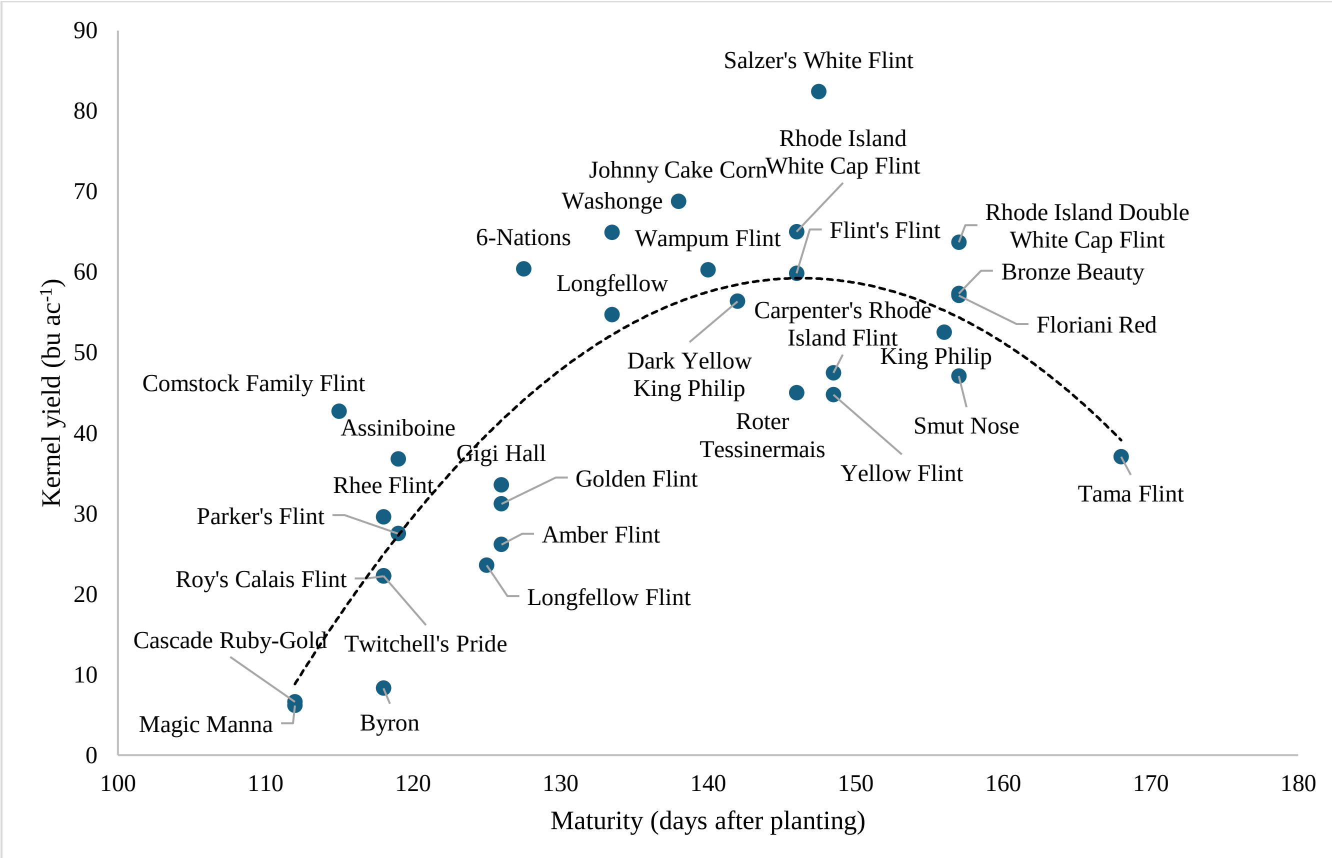


Figure 2. Kernel yield at 13% moisture vs number of days after planting to reach maturity.

Germplasm that appear in the bottom right quadrant represent plants that, despite being above average height, had below average lodging. These generally would be considered to have good standability. Conversely, plants in the top right quadrant are plants that were above average in both height and lodging and generally would be considered to have poor standability. The three points in the top left quadrant are interesting as these represent germplasm that were below average height but above average lodging. These also had poor standability despite their shorter stature. Lodging in annual crops can also be associated with nitrogen status. Overfertilization with nitrogen can cause rapid growth without formation of structural components necessary to support that additional growth. It is possible that these germplasm have different responses to nitrogen in terms of growth and lodging compared to our modern dent varieties and thus may require different management. These aspects of crop production have yet to be explored with these lines but would be an important addition to successful breeding and varietal development.

Image 1. Flint corn kernels.

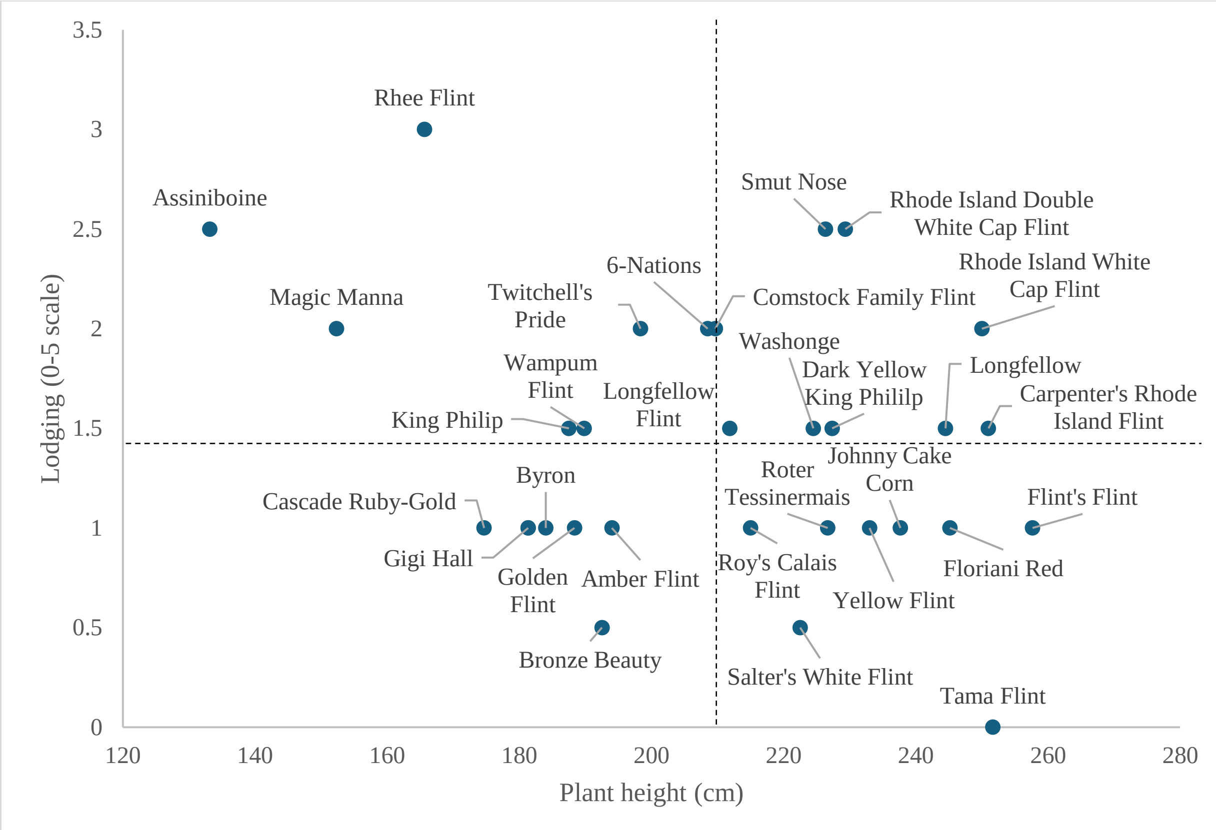


Figure 3. Plant height vs lodging severity.

Table 3 shows the nutritional value of 17 germplasm, 5 community-derived, 3 flint checks, 2 commercial dent checks, and a reference from FoodData Central.

Table 3. Nutritional value of 17 germplasm, 5 community-derived, 3 flint checks, 2 commercial dent checks, and a reference from FoodData Central.

Variety	Carbohydrates	Fat	Protein	Starch	Fiber	Ash	Calories	Lutein	Zeaxanthin	Beta carotene	Total carotenoids
			%				kcal/100g			µg/g	
Abenaki Rose	72.7	5.74	8.06	58.5	1.90	1.68	375	0.200	0.090	0.000	0.280
Amber flint	69.4	6.99	12.06	55.1	1.50	1.54	389	1.49	0.650	0.190	2.73
Assiniboine	68.7	5.83	12.50	53.1	1.90	1.48	377	1.35	0.350	0.190	2.09
Cascade ruby-gold	72.9	4.89	11.00	59.8	1.40	1.31	380	8.84	2.16	0.530	12.3
Comstock Family Flint	73.5	5.18	12.44	56.8	1.50	1.40	387	6.25	1.94	0.650	9.56
Dark Yellow King Philip	70.2	4.18	12.00	57.7	1.50	1.21	366	8.55	2.59	0.930	13.2
Flint's Flint	73.7	5.82	11.19	60.1	1.70	1.59	392	7.35	5.18	0.950	14.5
Floriani red	75.0	5.19	12.50	61.5	1.80	1.50	391	1.65	9.08	1.40	15.0
Gaspe	70.2	6.47	11.06	52.3	1.70	1.63	383	4.78	0.860	0.680	6.45
Gigi Hall	71.9	5.52	11.44	59.2	1.20	1.35	383	0.260	0.180	0.050	0.550
Golden flint	69.9	4.98	11.63	53.1	1.40	1.34	371	6.36	2.10	0.940	10.3
Hubbard flint	71.8	5.60	11.56	58.7	1.50	1.38	384	5.45	2.33	0.400	8.90
Johnny Cake corn	-	5.03	12.25	-	-	-	-	0.710	0.250	0.070	1.14
Koasek	69.9	7.20	11.00	49.4	2.00	1.87	389	2.43	0.640	0.000	3.26
Longfellow flint	69.9	4.67	12.44	55.3	1.70	1.36	372	8.06	3.71	1.41	14.6
Minnesota 13	73.7	4.81	9.63	59.2	1.90	1.42	377	11.80	5.57	0.610	20.5
Parker's flint	70.1	4.57	11.94	56.1	1.70	1.17	369	5.36	3.49	1.36	11.7
Rhee flint	69.7	5.25	11.80	55.0	1.40	1.31	373	2.61	0.630	0.000	3.23
Rhode Island White Cap Flint	75.3	5.42	11.50	65.0	1.50	1.43	393	0.950	0.470	0.100	1.66
Roter Tessinermais	72.9	4.12	10.06	57.3	1.30	1.15	369	4.54	8.40	0.980	15.8
Saltzers White Flint	73.7	5.61	10.88	62.0	1.40	1.35	389	0.830	0.470	0.170	1.61
SW3834	74.3	4.49	10.30	59.3	1.70	0.00	379	11.90	0.380	0.190	13.2
Tama Flint	69.4	5.71	11.38	55.6	1.30	1.28	375	0.120	0.070	0.000	0.210
Twitchell's pride	68.9	4.53	13.06	55.4	1.30	1.38	369	6.41	1.96	1.00	10.2
Wampum flint	70.6	5.16	11.81	56.9	1.90	1.34	376	0.460	0.180	0.000	0.720
Wapsie Valley	74.6	4.41	8.69	60.1	1.80	1.40	373	9.58	4.91	0.520	16.40
Washonge	74.2	5.95	10.94	61.7	1.60	1.40	394	0.350	0.210	0.000	0.630
Yellow grain corn[1]	74.3	4.74	9.42	-	-	1.20	365	1.36		-	-

[1]Grain corn, yellow. FoodData Central database.