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2017 Cabbage Variety Trial: Evaluation of Green Varieties for Long Term Storage and Processing Qualities

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Executive Summary

Growers in the Fraser Valley need more options for long-term storage cabbage varieties. Thrips susceptibility, along with other agronomic traits, is particularly important in determining if a new variety is suitable for this area, as they are difficult to manage and their damage can go undetected in storage. In this study, nine varieties were assessed for thrips and disease susceptibility, yield, density, colour and shape by performing field and storage assessments. Amtrak had a significantly higher mean yield per head than Bloktor, Hazleton, Loughton, Paradox and Ultra Vantage but did not differ statistically from Expect, Lennox and Storage #4. By the final assessment conducted after five months in storage, Ultra Vantage was statistically the least dense variety, while Expect was statistically denser than Amtrak, Lennox and Ultra Vantage, but equivalent to all other varieties. Overall differences in shape and colour were very subtle between all varieties when compared to Loughton. Storage #4 had significantly higher thrips damage at harvest compared to other varieties. There were no detectable differences between varieties in terms of disease incidence in both storage assessments and disease severity did not significantly differ between varieties.

Introduction

Cabbage is an important vegetable crop in the Fraser Valley and new long-term storage varieties are needed to provide growers with choices for locally appropriate options. Recently developed varieties may have improved characteristics which can assist growers with pest management and storability. Important considerations for a local cabbage variety trial are uniformity, yield, processing quality, storability and pest resistance. Concerning storability, firmness, colour and freedom of pests are important grower considerations (Kevin Husband, Emma Lea Farms, personal communication). Thrips (*Thrips tabaci*, *Frankliniella schultzel*, and other species) are a concern for cabbage production, as they are difficult to manage once they enter the inside layers of a cabbage head because most insecticides require contact (Shelton *et al.*, 2008). Damage caused by thrips can affect many layers under the surface, making it difficult to notice and remove prior to sale. This not only reduces marketability of cabbage but can also create trust issues with purchasers. Certain varieties have noted resistance to thrips and locally some varieties have been found to have fewer thrips and damage than others (Shelton *et al*., 2008, E.S. Cropconsult Ltd. unpublished data). While effective insecticides are one tool for thrips control, varietal tolerance or resistance can play a very important role.

The objective of this study was to evaluate cabbage varieties based on storability, processing quality, yield and pest resistance.

Methods

Site

The trial was conducted in a commercial cabbage field in Delta, BC. Cultivation, fungicide applications, and crop maintenance were done by the grower. The trial was hand weeded on September 26, 2017. After harvest, cabbages were placed in mesh onion sacks and stored inside plastic tote boxes in a commercial refrigerated cabbage storage facility in Delta, BC.

Trial design and varieties

The trial consisted of nine green cabbage varieties: Hazelton, Storage #4, and Ultra Vantage from Osborne Seed Company LLC; Amtrak, Expect, Lennox, and Paradox from Noresco; Bloktor and Loughton from Stokes Seeds. A minimum of 100 seeds per variety were hand seeded in conventional 8 by 15 plug trays (120 plants/tray) on May 6, 2017. The plants were transplanted into the field by hand on June 12, 2017. Each variety was replicated six times, except Hazelton, which was replicated four times due to seed sourcing challenges (total of 52 plots). Varieties were randomly assigned to plots. Each plot consisted of 22 plants planted consecutively within two rows (11 plants per row), spaced 11 inches apart, with a buffer of 33 inches between plots and a buffer of nine feet on either end of the trial.

Assessments

Field assessments

A plant recovery count was completed by counting the number of surviving plants per plot on June 29, 2017. On July 10, 2017 and August 31, 2017, pest assessments were completed by assessing three plants per plot for pests. Presence of thrips, caterpillars, caterpillar damage, downy mildew, and any other pests or damage were recorded. As very few insects were present on July 10, 2017, just three replicates per variety were evaluated. For the assessment on August 31, all replicates per variety were evaluated.

Harvest and storage assessments

All heads per plot were hand harvested and yield (lbs) was assessed per head on October 2, 2017. A pre-storage assessment was done in the field the day after harvest on October 3, 2017, and two storage assessments were performed on January 11 and March 1, 2018 using the same protocol. Subsamples of three cabbages per replicate were evaluated for the following: colour (relative to the Loughton variety, our “standard” for this trial), thrips numbers, thrips damage, disease incidence and severity, and any other pests or damage present. These assessments were done by cutting each cabbage in half on its polar axis and peeling back three layers of the head for examination. Colour was rated zero if it was lighter than Loughton, one if it was the same, and two if it was darker. Colour was not assessed at the final assessment due to most cabbages having some levels of discoloration due to disease/breakdown on the outside layer. Thrips damage was rated by counting 3 cm^2 patches up to a maximum of 10, creating a scale of 0-10. Disease severity was measured by counting the number of layers (up to three) affected by disease. Heavily diseased cabbage heads were counted and removed to avoid losing a replicate due to disease spread, as per grower practice. Photos of any disease symptoms were taken, and samples (from the second assessment only) were submitted to the BCAGRI plant health lab in Abbotsford, BC for identification.

Assessments of density were also done during the pre-storage and the two storage assessments. These assessments were conducted on the same heads to observe any changes in density over time. To do this, five cabbages per replicate were randomly selected during the first assessment and placed into individual labelled mesh bags (inside the larger mesh bags that all cabbage heads were stored in), to be easily recovered from the bins during each assessment.

Polar diameter (PD) and equatorial diameter (ED) were measured using a caliper and, along with the weight of each cabbage head, these values were used to calculate density, where density = weight/volume. The ratio between polar and equatorial diameters were calculated to give a measure of the shape of the cabbage: PD/ED=1 is a spherical cabbage, anything above is an oblong or taller cabbage, while anything below one is a disk-shaped or flatter cabbage. Volume was calculated based on the formula of a spherical ellipse adapted to measure cabbages, specifically:
$V = \frac{4}{3}\pi\left(\frac{PD}{2}\right)\left(\frac{ED}{2}\right)^2$ (Kleinhenz and Radovich, 2004).

Statistical analysis

For disease, incidence was found by calculating the proportion per plot of cabbages with any disease. For disease severity, a severity score for each replicate was calculated by summing the severity score of the three cabbages assessed (maximum possible score of nine per replicate).

One-way ANOVA was used to test for differences between varieties in the following characteristics: yield, density, thrips damage, disease incidence, disease severity and number of discards due to disease. If the ANOVA produced significant differences between varieties, a Tukey's pairwise comparison was conducted to investigate which varieties were different from each other. A generalized linear model using a quasi-poisson distribution (for zero-inflated data) was used to test for a correlation between thrips number and thrips damage. Disease incidence data were arc-sine transformed prior to analysis. All data were analysed using R (R Foundation for Statistical Computing, 2017).

Results

Yield and Marketability Traits

In terms of yield, there were significant differences between varieties (Fig. 1; $F_{8, 43}$ =10.46, p<.001). Amtrak had a significantly higher mean yield per head than Bloktor, Hazleton, Loughton, Paradox and Ultra Vantage but did not differ statistically from Expect, Lennox and Storage #4.

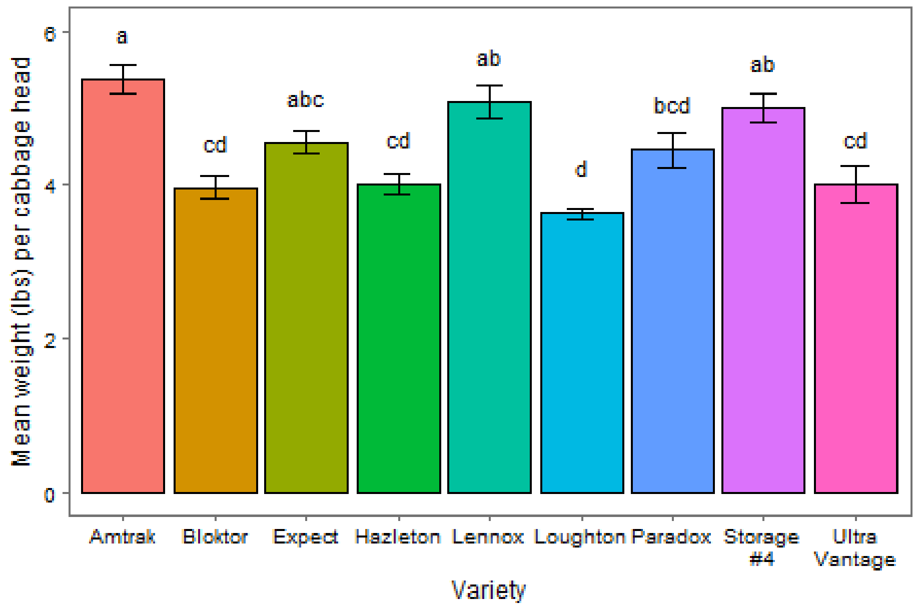

Figure 1: The mean weight (± s.e.m.) per cabbage head in pounds of cabbages at harvest across nine varieties. Letters above bars denote statistical significance, where bars sharing the same letter are not statistically different from each other.

Density values were higher for all varieties during the first pre-storage assessment than in subsequent assessments ($F_{2, 144}$ =374.09, p<.001), and there were significant differences in density between varieties at all assessments (Figs. 2a-c; October 3, 2017: $F_{8, 43}$ =5.06, p<.001; January 11, 2018: $F_{8, 43}$ =7.08, p<.001; March 1, 2018: $F_{8, 42}$ =14.18, p<.001). In the pre-storage assessment, Expect and Storage #4 were denser than Amtrak and Ultra Vantage but could not be statistically distinguished from all other varieties (Fig. 2a). All varieties became less dense in the second assessment, with Ultra Vantage ranking significantly lower than all other varieties except Amtrak (Fig. 2b). By the final assessment, at the end of the storage period, Expect was statistically denser than Amtrak, Lennox and Ultra Vantage, but equivalent to all other varieties (Fig. 2c).

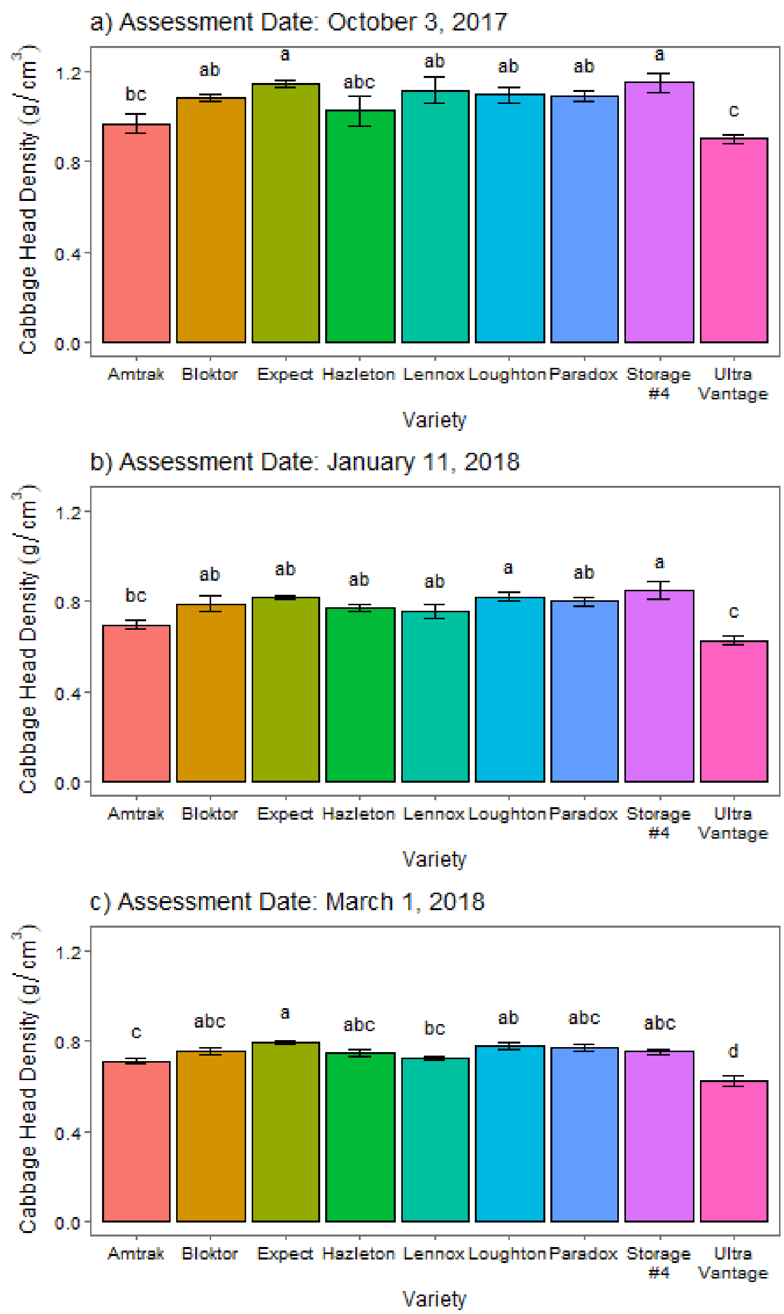

Figure 2a-c: Cabbage density (±s.e.m.) values across nine varieties for each of the three assessment dates: pre-storage assessment on October 3, 2017 (a), and two storage assessments on January 11, 2018 (b), and March 1, 2018 (c). Letters above bars denote statistical significance, where bars sharing the same letter are not statistically different from each other.

Colour variations between variety were subtle (Table 1). In general, Ultra Vantage was consistently lighter, and Paradox was consistently darker when compared to Loughton. During the second assessment, Bloktor was also perceived to be darker in colour than Loughton. All other varieties appeared the same, or a very similar, shade to Loughton (Table 1). Differences in shape were similarly minimal between varieties. Overall, Expect was slightly flat, Paradox was round, and all other varieties were slightly tall. Amtrak and Ultra Vantage were most consistently among the tallest cabbages (Table 1, Appendix I).

Pest and disease tolerance

Field assessments during the season showed very low levels of pest and disease pressure (data not shown). By August 31, across the entire trial, there were 20 plants with aphids, 10 with caterpillars, and one with thrips. No downy mildew or other diseases were detected. Plant recovery was very high after transplantation, where only one Amtrak, and one Loughton had died by June 29.

In the pre-storage assessment and first storage assessment, thrips damage differed significantly between Storage #4 and all other varieties, with Storage #4 having significantly higher levels of damage (Figs. 3a-b; $F_{8, 43} = 6.68$, $p<.001$; $F_{8, 43} = 6.68$, $p<.001$). The other varieties were not significantly different from each other during these assessments. Results from the final assessment on March 1, 2018, showed that there were no significant differences in thrips damage across all varieties (Fig. 3c; $F_{8, 43} = 2.05$, $p = 0.062$). A positive correlation between thrips damage and thrips numbers was found ($F_{1, 154} = 100.7$, $p<.001$), despite very low numbers of thrips being seen throughout the study.

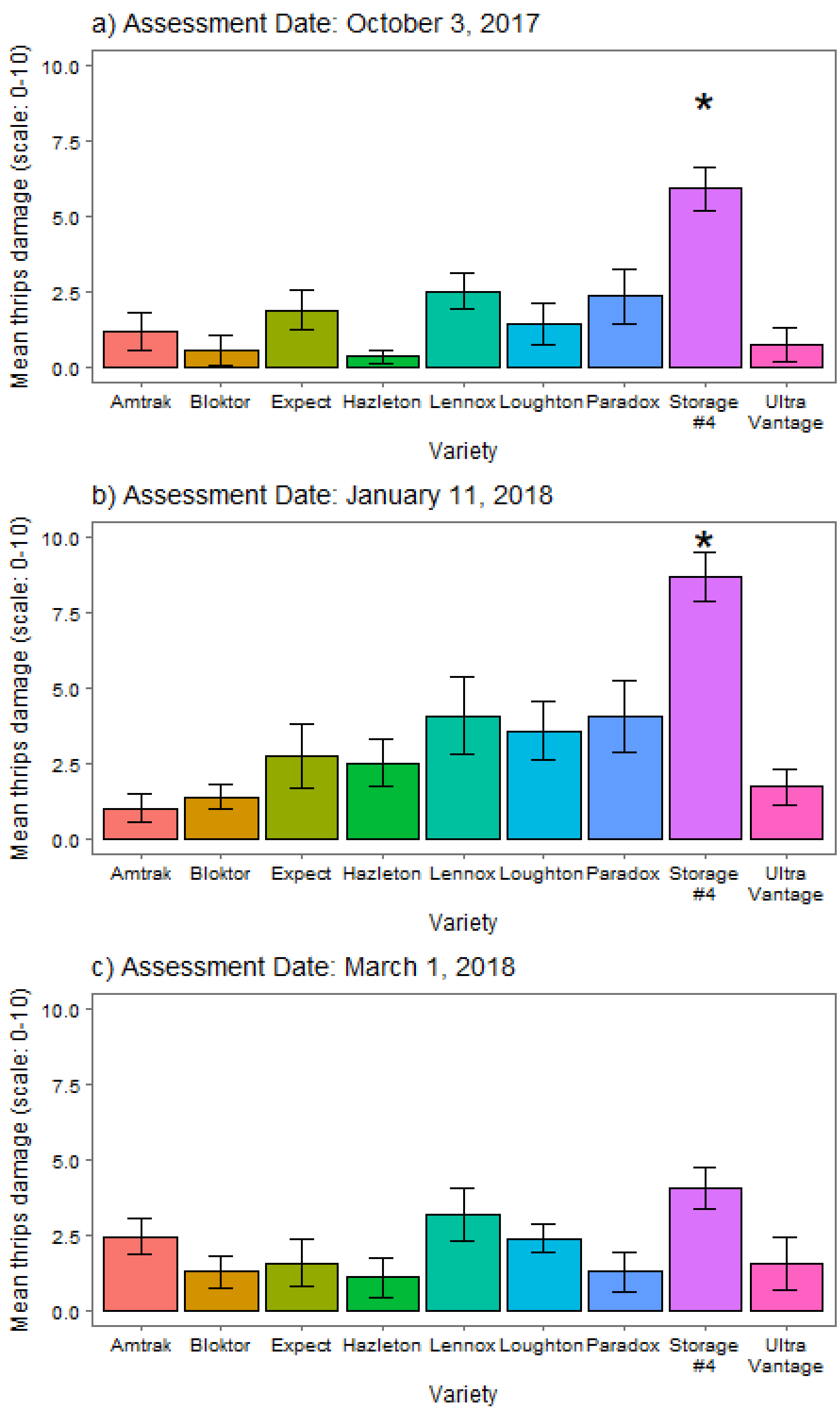

Figure 3a-c. Mean thrips damage (±s.e.m.) across nine varieties during a pre-storage assessment on October 3, 2017 (a), and storage assessments on January 11, 2018 (b) and March 1, 2018 (c). Bars with an asterix (*) denotes statistical significance from other bars.

Across all varieties, disease symptoms were not seen prior to, or at the time of harvest (pre-storage assessment). The first storage assessment indicated no significant differences in disease incidence between varieties (Fig. 4a; $F_{8, 43} = 1.98$, p=0.072). During the final storage assessment, disease incidence appeared to vary significantly between varieties (Fig. 4b; $F_{8, 43} = 2.21$, p=0.046) but pair-wise comparisons did not highlight any significant differences between specific varieties.

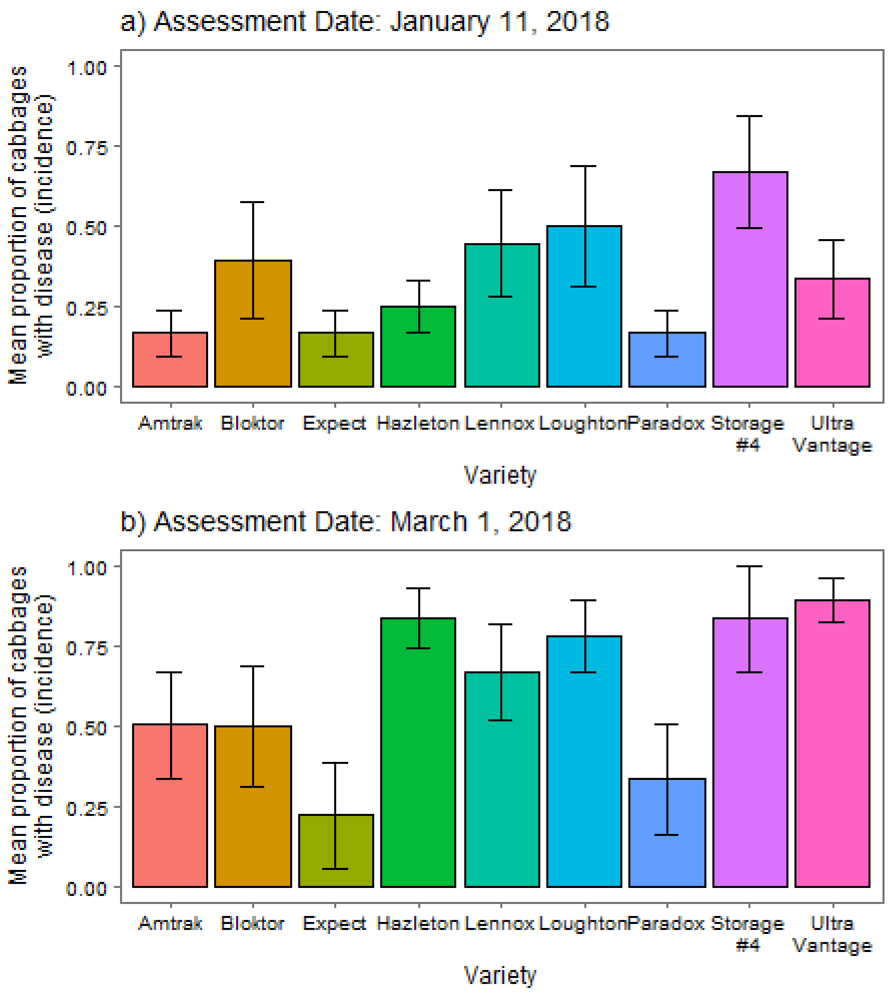

Figure 4a and b. Disease incidence (±s.e.m.) across nine varieties during the two storage assessments on January 11, 2018 (a) and March 1, 2018 (b). Incidence is shown as the proportion of cabbages with disease.

Disease severity was not significantly different across varieties during either of the two storage assessments (Figs. 5a-b; $F_{8, 43} =1.35$, p= 0.244; $F_{8, 43} = 1.92$, p= 0.0817). While the incidence was overall moderate to high, the severity was overall low (Figs. 4 and 5). Additionally, there were no significant differences in the total number of cabbages per variety that were discarded due to disease in storage (Table 1; $F_{8, 43} =1.54$, p= 0.172). Out of the 132 cabbages per variety that went into storage (88 for Hazleton), most varieties lost between 12 and 18 heads in total due to excessive disease symptoms.

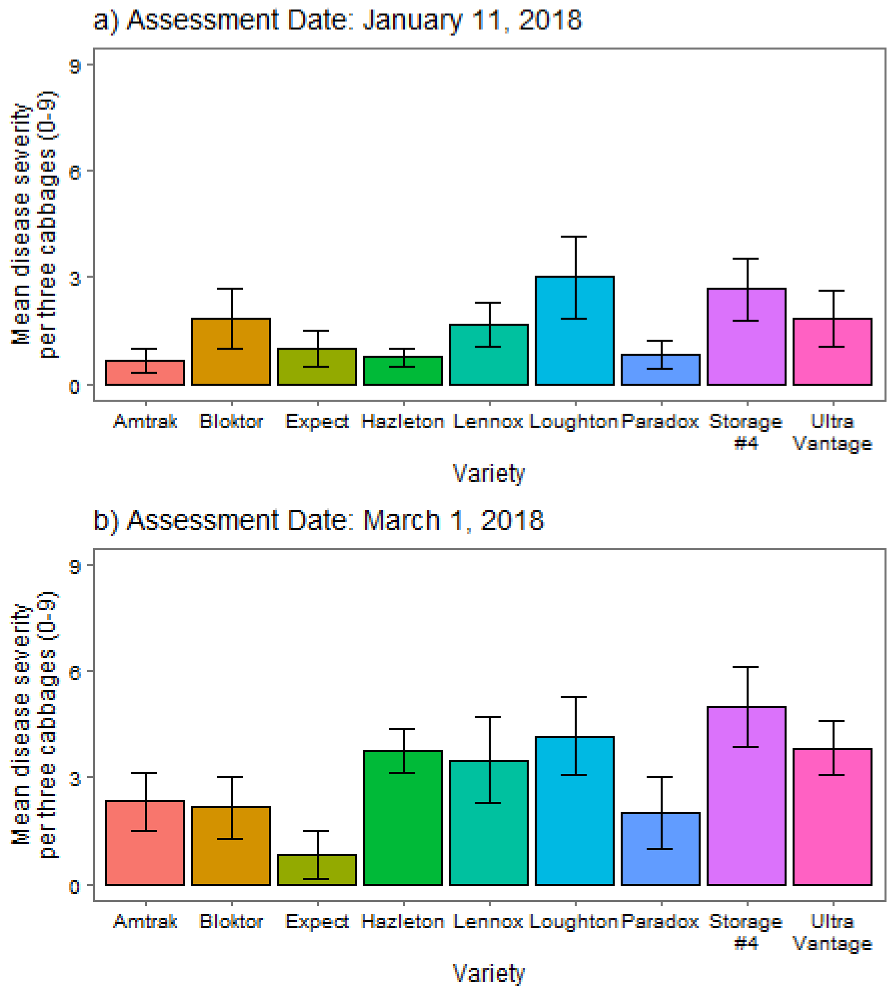

Figure 5a and b. Mean disease severity (±s.e.m.) of nine cabbage varieties during two storage assessments on January 11, 2018 (a) and March 1, 2018 (b). Disease severity is calculated as the sum of severity scores in three cabbage heads per replicate.

Disease causing organisms confirmed by incubation and microscopic examination at the BCAGRI lab included: *Botrytis cinerea*, *Cladosporium* sp., *Stemphylium* sp., *Rhizopus* sp., *Alternaria* sp., and *Epicoccum* sp. Most samples had multiple diseases present and therefore data on prevalence of different organisms is unavailable from this study.

Table 1: Colour, shape, and discards due to disease across nine cabbage varieties and at three assessments; during a pre-storage assessment on October 3, 2017, and two storage assessments on January 11, 2018 and March 1, 2018, showed per variety (6 reps, 132 cabbages per variety, except for Hazelton which had 4 reps for a total of 88 cabbages)

Variety	Assessment date	Mean colour rating (±SEM)	Colour (compared with Loughton)	Mean shape value (±SEM)	Shape	Total number of disease discards
Amtrak	October 3, 2017	1.06 (±0.13)	No different	1.10 (±0.02)	Taller	0
Bloktor	October 3, 2017	1.06 (±0.06)	No different	1.11 (±0.01)	Taller	0
Expect	October 3, 2017	1 (±0.26)	No different	0.95 (±0.02)	Wider	0
Hazleton	October 3, 2017	0.92 (±0.28)	No different	1.06 (±0.02)	Taller	0
Lennox	October 3, 2017	1 (±0.23)	No different	1.01 (±0.02)	Taller	0
Loughton	October 3, 2017	1 (+-0)	Standard	1.06 (±0.01)	Taller	0
Paradox	October 3, 2017	1.17 (±0.11)	Darker	1.01 (±0)	Round	0
Storage #4	October 3, 2017	1.39 (±0.16)	Darker	1.12 (±0.03)	Taller	0
Ultra Vantage	October 3, 2017	0.78 (±0.2)	Lighter	1.13 (±0.02)	Taller	0
Amtrak	January 11, 2018	1.17 (±0.27)	No different	1.08 (±0.01)	Taller	4
Bloktor	January 11, 2018	1.28 (±0.2)	Darker	1.05 (±0.03)	Taller	5
Expect	January 11, 2018	1.06 (±0.2)	No different	0.97 (±0.01)	Wider	1
Hazleton	January 11, 2018	1.17 (±0.29)	No different	1.08 (±0.01)	Taller	0
Lennox	January 11, 2018	0.94 (±0.23)	No different	1.07 (±0.02)	Taller	1
Loughton	January 11, 2018	1 (+-0)	Standard	1.05 (±0.01)	Taller	2
Paradox	January 11, 2018	1.5 (±0.25)	Darker	1.00 (±0.01)	Round	2
Storage #4	January 11, 2018	1.06 (±0.23)	No different	1.13 (±0.03)	Taller	3
Ultra Vantage	January 11, 2018	0.28 (±0.1)	Lighter	1.10 (±0.02)	Taller	1
Amtrak	March 3, 2018	*Not assessed*		1.11 (±0.01)	Taller	12
Bloktor	March 3, 2018			1.09 (±0.01)	Taller	9
Expect	March 3, 2018			0.97 (±0.01)	Wider	2
Hazleton	March 3, 2018			1.11 (±0.02)	Taller	13
Lennox	March 3, 2018			1.07 (±0.02)	Taller	18
Loughton	March 3, 2018			1.06 (±0.01)	Taller	17
Paradox	March 3, 2018			0.99 (±0.01)	Round	12
Storage #4	March 3, 2018			1.1 (± 0.01)	Taller	16
Ultra Vantage	March 3, 2018			1.11 (±0.02)	Taller	16

Discussion and Conclusion

Overall, most varieties performed comparably well under the conditions of the trial and would make adequate alternatives for Loughton if they have other desired qualities for a grower. Pest levels during the growing season were low across all varieties. The highest yield per head was seen in Amtrak, Lennox, Storage #4, and Expect, but these can also be differentiated by other properties. Amtrak, for example, produced heavy heads, but they were less densely packed than some other varieties (Fig. 2a-c, Appendix I), and were also among the tallest cabbages with long cores (Table 1). Expect was densely packed and firm but had a slightly flat shape. Both of these varieties have a similar colouration to Loughton and may therefore be desirable if a grower is looking to specifically improve yield or head weight. Storage #4 had very good yield and was somewhat darker in colour than Loughton but was also the only variety to suffer heavily from thrips damage in the field, which increased during storage. This difference in thrips damage was not observed in the final assessment, but Storage #4 also had one of the highest number of heads discarded due to disease, although the difference was not significant (Table 1). It is possible that heads damaged by thrips are more likely to be diseased and then removed, which would explain why thrips damage levels in Storage #4 were not as high in the final assessment compared with other varieties as in earlier assessments. Storage #4 may not be a good choice in a field with a history of thrips issues because, while this data doesn't necessarily demonstrate resistance or susceptibility, it does indicate a possible preference for this variety by thrips. Despite having a smaller head weight, Paradox had a round shape, was darker in colour than Loughton, and had a density value that fell within the highest rated group throughout all assessments, so it may have a place in some markets.

In terms of storability, all varieties still had high numbers of potentially marketable cabbages left in storage after the final assessment on March 1, meaning all are decent candidates for long-term storage. There were no detectable differences between varieties in terms of disease incidence in both storage assessments. Furthermore, disease severity did not vary significantly across varieties in either storage assessment. Across all varieties, the number of heads discarded due to disease was relatively low; Expect only had two discarded heads, which may indicate lower susceptibility to disease in storage, although this was not statistically significant in this trial.

Continued investigation of some of these traits (thrips and disease susceptibility) for varieties including Expect, Storage #4, and Hazleton would be beneficial. In addition, it should be noted that a single growing season is not adequate to note how varieties may perform across different weather conditions, and simply repeating this work would be a valuable next step to see if trends hold.

All varieties in this trial may have something to offer depending on the target market of an individual grower, and some may perform better in different years or fields. It is important for growers to identify traits that are important to them to inform their decision to grow any of these varieties in their operation.

Acknowledgements

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Appendix I: Variety Photos