Variety Trials

Cabbage Hybrid Trials in North Dakota

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SUMMARY. In an effort to promote commercial vegetable production in North Dakota and to determine the cabbage (*Brassica oleracea* L. Capitata Group) hybrids best adapted to this area, we conducted cabbage variety trials from 1993 to 1997 at the Oakes Irrigation Research Site in North Dakota. We evaluated cabbage yield and quality characteristics, and also demonstrated cabbage production to farmers in this area. Cabbage grows

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very well in North Dakota. Highest yields were in 1996 when temperatures in May were coolest. Lowest yields were in 1994 when May temperatures were the hottest. Hybrids with the highest yields and best appearance included 'Gideon', 'Bronco', and 'Royal Vantage' for the fresh market, and 'Fresco', 'Cheers', 'Bravo', and 'Bronco' for the processing market. Despite differences in weather over the 5 years of the study, cabbage hybrids were fairly consistent as to yield and quality characteristics. Suitability of cabbage hybrids for coleslaw and shredded cabbage was tested through sensory evaluations in 1993. 'SCB8101', 'Stonehead', 'Hinova', 'Green Boy', and 'Charmant' scored highest on these sensory evaluations in this single-year test.

Variety trials in most areas support established production of the crop being tested. Funding comes from growers, seed companies, or others who expect to receive a timely benefit from the variety trials. Cabbage production in North Dakota is very small. The Garrison Diversion Conservancy District (a state agency responsible for water development in North Dakota), in cooperation with North Dakota State University and the North Dakota Agricultural Products Utilization Commission, decided to fund vegetable research (including variety performance trials) to help promote irrigated vegetable production in North Dakota. The cabbage variety performance trials serve the dual role of determining which cabbage hybrids are best adapted to North Dakota, while demonstrating to producers the high yields and quality possible.

Although cool temperatures in North Dakota hinder the production of some vegetables, cabbage thrives in this climate. Boswell and Jones (1941) stated that cabbage grows best at mean monthly temperatures of 60 to 70 °F (16 to 21 °C). Maynard and Hochmuth (1997) gave 60 to 65 °F (16 to 18 °C) as the optimum temperature range for cabbage growth. Growth is slow and abnormal, and the quality is usually poor, when the mean monthly temperatures exceed 70 °F (21 °C) (Boswell and Jones, 1941). Average temperatures for May, June, July and August at Oakes, N.D., are 55.6 (13.1), 65.3 (18.5), 71.5 (21.9), and 69.5 °F (20.8 °C), respectively. Daily high temperatures during the summer seldom surpass 95

°F (35 °C). The average frost free season is 140 d.

The objectives of this study were to identify cabbage hybrids best adapted to North Dakota conditions and evaluate those hybrids for quality and yield.

Materials and methods

We conducted cabbage hybrid performance trials from 1993 to 1997. The trials varied in size from 11 hybrids in 1997 to 32 hybrids in 1993. Each year, seed suppliers were invited to enter their hybrids in the trials. Some hybrids were only entered once during the 5-year period. Many were entered 2 to 4 years. Three hybrids, 'Royal Vantage', 'Gourmet', and 'Blue Pak', were entered each of the 5 years. Except for sensory evaluations, only those hybrids evaluated for at least 3 of the 5 years or 2 of the last 3 years are included in this report.

FIELD EXPERIMENT. Soils at the Oakes Irrigation Research Site are sandy loam to loam, with a pH of 6.9 to 7.6, and about 2% organic matter. All trials were either overhead sprinkler irrigated (1993, 1994, 1995, and 1997) or surface drip irrigated (1996). Hybrids were direct seeded on 27 April 1993, 19 April 1994, 28 April 1995, 23 April 1996, and 13 May 1997 with a precision belt planter (Stanhay S870; Stanhay Webb, Ltd., Newmarket, Suffolk, England). The late planting in 1997 was caused by heavy snows that did not melt until much later than normal. Seeds were spaced 7 inches (18 cm) apart in rows 16 or 17 inches (41 or 43 cm) apart. We later thinned plants to one every 15 inches (38 cm) (about 26,000 plants/acre or 64,000 plants/ha).

Soil tests were done each year and cabbage received N, P, K and S according to crop growth recommendations from the University of Minnesota. We controlled weeds with trifluralin (1995–97), DCPA (all years), napropamide (1996), sethoxydim (1994, 1995, and 1997), pyridate (1996–97), and hand weeding (all years). We controlled flea beetle [*Phyllotreta cruciferae* (Hubner)] with carbaryl sprayed 2 to 4 d after cabbage emergence, except in 1997 when no flea beetles attacked the cabbage. Cabbage looper [*Trichoplusia ni* (Hubner)] and imported cabbageworm [*Pieris rapae* (L.)] were controlled with *Bacillus thuringiensis* and esfenvalerate.

Main plots were cabbage hybrids. Subplots were time of harvest. Each main plot was 40 ft (12.2 m) long by one row wide. Main plots were split into

two, 20 ft (6.1 m) long subplots—one subplot for an early harvest (for fresh market) and the other subplot for a late harvest (for processing). Subplots were trimmed to 17 ft (5.2 m) long early in the season. Harvest data were taken from the entire 17 ft of the subplot. We harvested twice per week, beginning when the earliest hybrids began to mature. For the early harvest, cabbage heads were harvested when they were firm and of marketable size [usually 2 to 4 lb (1 to 2 kg)]. We evaluated each head separately, so there were one to five harvests in each early-harvest subplot, depending on uniformity of maturity of the hybrid. We harvested the late-harvest subplot 2 weeks after half the cabbage heads were removed from the corresponding early-harvest subplot. All the cabbage heads in the late-harvest subplot were harvested on the same day.

At each harvest, we counted and weighed the cabbage heads from each subplot. We then selected one to three heads from each subplot (depending on the number of heads harvested) which we considered to be representative heads for that subplot for that harvest date. These heads were sliced in half longitudinally and cabbage head characteristics of height, width, core length, core width, and a visual estimate of head density were recorded. For the early-harvest subplots, the final value for the head characteristics of the cabbage from each subplot was the weighted mean of the measurements of each harvest. This was necessary because variable numbers of heads were harvested from each subplot on each early harvest. Each mean was weighted by multiplying the subplot yield of each harvest by the value measured. For example, the final head density (Hd_f) value for the cabbage from a given subplot is given by the formula: $Hd_f = (Hd_1 \cdot Y_1 + Hd_2 \cdot Y_2 + \dots + Hd_n \cdot Y_n) / (Y_1 + Y_2 + \dots + Y_n)$, where Hd_x equals the head density value and Y_x equals the yield for the x^{th} harvest.

Because a different set of hybrids were received for evaluation each year, we analyzed each year separately. The early harvest data were analyzed separately from the late harvest data, because some hybrids matured and were harvested for the early harvest, but the season ended before it was time to harvest the corresponding late harvest plots. The early and late harvest were each analyzed as a randomized, complete block design with four replications. The means were separated either

Table 1. Early harvest (fresh market) yield, head weight, and overall cabbage quality.

Hybrid	Days to harvest	Yield (tons/acre) ^z	Head wt (lb/head) ^y	Overall quality (1 to 10)
1993				
Charmant	98 a ^x	32.4 bc	2.5 c	4.8 bc
Green Cup	105 b	31.8 bc	3.1 b	5.3 bc
Gourmet	110 c	25.7 cd	2.8 bc	4.5 bc
Bravo	110 c	41.5 a	3.8 a	5.5 abc
Fresco	110 c	38.1 ab	3.7 a	4.0 c
Blue Pak	110 c	22.3 d	2.7 bc	5.8 ab
Royal Vantage	113 cd	30.9 c	3.0 bc	7.0 a
Cheers	116 d	44.2 a	3.7 a	5.6 abc
Probability	***	***	***	***
1994				
Charmant	97 a	24.7 bcd	2.1 d	6.9 ab
Blue Vantage	110 b	17.5 d	2.8 b	6.0 bc
Green Cup	111 b	29.1 bc	2.7 bc	6.0 bc
Gourmet	111 b	22.6 cd	2.5 bcd	5.2 c
Blue Pak	113 bc	16.4 d	2.3 cd	6.7 ab
Royal Vantage	115 bc	30.3 bc	2.4 bcd	7.4 a
Bravo	116 bc	32.5 b	2.6 bc	6.7 ab
Cheers	118 c	41.9 a	3.6 a	6.9 ab
Probability	***	***	***	***
1995				
Charmant	94 a	27.1 cd	3.0 c–g	6.0 cde
Gourmet	101 b	34.7 a–d	3.2 a–d	4.2 f
Fresco	102 b	37.7 abc	3.3 abc	5.8 cde
Green Cup	107 bc	40.3 ab	2.5 g	5.1 ef
Blue Pak	109 cd	32.1 bcd	3.3 abc	7.0 ab
Blue Vantage	110 cd	35.4 a–d	3.5 a	5.5 de
Bronco	113 cde	39.7 ab	3.0 b–f	7.0 ab
Cheers	114 de	39.0 abc	2.7 d–g	6.2 bcd
Gideon	115 de	42.5 ab	3.5 ab	7.0 ab
Bravo	115 de	46.5 a	2.6 efg	6.4 abc
Royal Vantage	117 e	33.6 bcd	3.1 a–e	7.2 a
Fortress	117 e	24.2 d	2.5 fg	6.5 abc
Probability	***	***	***	***
1996				
Blue Pak	112.4 a	41.4 bc	3.9 a	6.2 ab
Fortress	118.0 bc	35.8 c	3.1 b	4.3 c
Fresco	113.6 ab	50.3 ab	4.2 a	6.3 ab
Gideon	123.7 d	52.8 a	4.4 a	7.1 a
Gourmet	110.9 a	48.9 ab	4.4 a	3.5 c
Royal Vantage	120.6 cd	44.7 abc	3.2 b	6.0 b
Probability	***	***	***	***
1997				
Blue Pak	103 c	29.4 a	3.3	5.7 b
Blue Vantage	100 bc	33.1 a	3.8	4.8 b
Bronco	100 bc	22.9 b	3.6	6.9 a
Cheers	99 ab	37.8 a	4.3	5.1 b
Gourmet	95 a	21.9 b	4.3	5.1 b
Royal Vantage	100 bc	31.4 ab	3.7	5.8 b
Probability	***	***	NS	***

^z1.0 ton/acre = 2.24 Mg·ha⁻¹.

^y1.0 lb = 0.45 kg.

^xValues in the same column and year followed by the same letter are not significantly different at the 0.05 level. Mean separation by protected LSD (0.05) or by the GLM-PDIFF procedure of SAS.

NS, **, *, *** Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Table 2. Early harvest (fresh market) head characteristics of cabbage.

Hybrid	Head ht (inch) ^z	Head width (inch)	Head density (1 to 3) ^y	Core length (inch)	Core width ^x (inch)
1993					
Charmant	5.7 ab ^w	6.0 bcd	2.1 abc	3.2 ab	1.3 ab
Green Cup	5.2 b	5.8 cd	2.3 ab	3.1 ab	1.1 a
Gourmet	5.4 b	5.6 de	1.1 d	4.5 c	1.2 ab
Bravo	6.1 a	6.7 a	1.5 cd	3.3 ab	1.5 b
Fresco	6.2 a	6.3 abc	1.6 bcd	3.8 bc	1.3 ab
Blue Pak	5.7 ab	5.1 e	2.3 ab	3.1 ab	1.3 ab
Royal Vantage	6.2 a	5.5 de	2.6 a	3.0 a	1.0 a
Cheers	6.2 a	6.5 ab	1.6 cd	3.8 bc	1.2 a
Probability	***	***	***	***	**
1994					
Charmant	4.9 b	5.3 de	2.1 cd	2.6 bc	1.2 d
Blue Vantage	5.5 a	6.3 a	2.0 d	3.0 cd	1.1 cd
Green Cup	5.4 ab	6.2 ab	2.0 d	2.4 b	1.0 abc
Gourmet	5.5 a	5.9 abc	1.2 e	3.3 d	1.1 cd
Blue Pak	5.0 b	4.8 e	2.5 ab	2.7 bc	1.0 abc
Royal Vantage	5.3 ab	5.4 cd	2.7 a	1.8 a	0.9 a
Bravo	4.9 b	5.7 bcd	2.2 bcd	2.7 bc	1.0 ab
Cheers	5.3 ab	6.3 a	2.4 a-d	2.8 bc	1.1 bcd
Probability	***	***	***	***	***
1995					
Charmant	5.1 c	5.4 fg	2.7 a-d	2.4 ab	1.0 d-g
Gourmet	6.1 a	6.1 a-d	1.5 f	2.9 bc	1.0 fg
Fresco	5.5 abc	5.4 g	2.5 bcd	2.6 abc	0.9 a-d
Green Cup	5.3 bc	5.8 a-g	2.0 e	2.7 abc	0.9 a-f
Blue Pak	5.6 abc	5.5 d-g	2.9 ab	2.8 abc	1.0 c-g
Blue Vantage	5.8 ab	5.4 efg	2.3 de	2.4 a	0.9 a-d
Bronco	5.9 ab	5.8 a-g	3.0 a	2.6 abc	1.1 g
Cheers	5.8 ab	6.4 a	2.5 bcd	3.1 c	1.0 fg
Gideon	5.9 ab	5.6 c-g	3.0 a	2.7 abc	1.0 efg
Bravo	5.7 ab	6.3 ab	2.5 bcd	3.0 c	0.9 b-g
Royal Vantage	5.7 ab	5.7 b-g	3.0 a	2.4 a	0.8 ab
Fortress	5.3 bc	5.9 a-g	2.4 cde	3.0 c	0.8 a
Probability	**	***	***	***	***
1996					
Blue Pak	6.5 a	6.1 bc	2.7 ab	2.9 a	1.0 ab
Fortress	6.0 b	6.0 bc	1.8 c	3.6 bc	1.0 ab
Fresco	6.4 a	6.4 b	2.5 b	3.2 ab	1.0 b
Gideon	6.5 a	5.9 c	3.0 a	3.2 ab	1.2 c
Gourmet	6.5 a	7.0 a	1.6 c	4.2 c	1.0 ab
Royal Vantage	6.3 ab	6.0 bc	2.3 b	2.8 a	0.9 a
Probability	***	***	***	***	***
1997					
Blue Pak	6.0 b	6.2	2.3 b	3.3 bc	1.0 ab
Blue Vantage	6.0 b	6.9	1.5 cd	2.8 a	0.9 a
Bronco	6.4 ab	6.4	2.8 a	3.1 ab	1.2 b
Cheers	6.3 ab	7.2	1.8 bc	3.2 abc	1.1 ab
Gourmet	6.8 a	7.2	1.3 d	3.6 c	1.0 ab
Royal Vantage	6.1 b	6.3	2.2 b	3.0 ab	0.9 a
Probability	**	NS	***	**	***

^z1.0 inch = 2.54 cm.^yVisual estimate of head density. The higher the number the more dense the head.^xWidth was measured at the base of the core (the widest point).^wValues in the same column and year followed by the same letter are not significantly different at the 0.05 level. Mean separation by protected LSD (0.05) or by the GLM-PDIFF procedure of SAS.NS, *, **, ***Nonsignificant or significant at $P \leq 0.01$ or 0.001, respectively.

with the ANOVA-protected LSD or the GLM-PDIFF procedures of SAS (SAS Institute Inc., 1989).

SENSORY EVALUATIONS. Cabbage hybrids grown in 1993 were used for sensory evaluation. Because of differences in maturity of the cabbage hybrids, these evaluations extended over a 4-week period. Heads were taken from the late-harvest subplots. After harvest from the field experiment, heads were stored in a refrigerator at 39 °F (4 °C) for less than 1 week. A representative section from two heads of each hybrid was shredded to obtain a 200-g (7-oz) sample that was placed in a plastic bag. About 24 h before testing, 77.1 g (2.7 oz) of a coleslaw dressing, obtained from a local food franchise that features coleslaw, was mixed with the shredded cabbage. The coleslaw was then refrigerated until tested. Samples prepared in this manner were labeled the 24-h coleslaw samples.

The next day, additional portions from each head were combined and shredded. Two 200-g samples were placed in separate plastic bags and refrigerated until 1 h before testing, at which time 77.1 g of coleslaw dressing was added to one bag and mixed. This was the 0-h coleslaw sample. The remaining bag of shredded cabbage (the shredded cabbage sample) was tested without any added ingredients.

Panelists for the sensory evaluation included faculty, staff, and students from the Departments of Horticulture and of Food and Nutrition at North Dakota State University and two homemakers. Following a brief training and explanation session on the first day, 10 panelists evaluated from 2 to 10 hybrids of cabbage each day. Panelists first evaluated the shredded cabbage samples in individual booths with water available for palate cleansing as needed. Each sample was placed in a 2-oz (60-mL) plastic souffle cup labeled with a three-digit random number. Samples were evaluated for the attributes of appearance and color, texture, and flavor using a nine-point hedonic rating scale (1 to 4 = poor, not acceptable; 5 to 6 = fair but acceptable; 7 to 9 = good). When a panelist had finished with the shredded cabbage samples, a tray of 0-h coleslaw samples, coded with different three-digit random numbers, was presented for evaluation using the same hedonic system. After a short break, panelists evaluated the 24-h coleslaw samples on the same hedonic scale used for the shredded cabbage and 0-h coleslaw samples.

Table 3. Late harvest (processing market) yield, head weight, and overall cabbage quality.

Hybrid	Days to harvest	Yield (tons/acre) ^z	Head wt (lb/head) ^y	Overall quality (1 to 10)
1993				
Charmant	114 a ^x	41.0 cde	3.9 cd	6.0 bc
Green Cup	120 bc	53.0 abc	5.2 abc	6.0 bc
Blue Pak	124 cd	39.4 de	4.6 bcd	6.6 bc
Bravo	124 cd	53.4 ab	4.8 abc	7.1 abc
Gourmet	124 cd	36.5 e	3.9 d	5.8 c
Fresco	126 de	62.5 a	5.7 a	7.3 ab
Royal Vantage	130 ef	49.7 bcd	4.3 cd	8.8 a
Cheers	134 f	59.9 ab	5.6 ab	8.0 ab
Probability	***	***	***	***
1994				
Charmant	110 a	23.6 cd	2.4 c	7.5
Gourmet	125 b	20.2 d	3.2 abc	6.4
Green Cup	126 b	32.5 bc	3.1 abc	7.3
Blue Vantage	127 b	28.4 b	3.3 ab	6.8
Royal Vantage	130 bc	35.9 ab	3.3 abc	7.8
Bravo	131 bc	38.2 ab	2.6 bc	6.8
Blue Pak	134 c	20.6 d	2.7 bc	7.5
Cheers	137 c	43.3 a	3.8 a	6.8
Probability	***	***	***	NS
1995				
Charmant	110 a	42.3 a	3.7 bc	7.3 ab
Fresco	115 ab	57.6 a	4.7 ab	7.4 ab
Gourmet	115 ab	52.1 a	4.6 ab	6.0 b
Green Cup	120 bc	39.3 ab	3.6 bc	7.0 ab
Blue Pak	125 cd	42.1 a	4.2 abc	8.0 a
Blue Vantage	126 cd	53.3 a	4.2 abc	6.8 ab
Cheers	127 cd	45.6 a	5.4 a	6.9 ab
Gideon	127 cd	50.5 a	4.1 abc	7.5 ab
Bravo	129 cd	49.6 a	4.2 abc	7.0 ab
Royal Vantage	130 d	46.4 a	3.9 abc	7.3 ab
Bronco	131 d	49.6 a	3.7 bc	7.3 ab
Fortress	135 d	22.4 b	2.8 c	7.0 ab
Probability	***	***	*	*
1996				
Gourmet	124 a	68.1 ab	6.3 a	4.4 c
Blue Pak	125 a	53.2 bc	4.6 c	6.3 b
Fresco	127 ab	78.1 a	6.0 ab	7.4 ab
Royal Vantage	128 ab	65.1 b	5.0 bc	7.3 ab
Fortress	135 b	51.2 c	5.3 abc	6.0 b
Gideon	147 c	59.0 bc	6.2 a	7.9 a
Probability	***	***	***	***
1997				
Royal Vantage	116 b	48.9 ab	7.4 a	7.8 a
Cheers	114 ab	58.2 a	6.9 ab	6.8 ab
Gourmet	110 a	31.8 c	6.0 bc	6.0 b
Blue Vantage	115 ab	51.4 ab	5.7 bc	6.9 ab
Bronco	116 b	49.3 ab	5.5 cd	7.1 ab
Blue Pak	118 b	39.2 bc	4.2 d	7.0 ab
Probability	***	*	***	***

^z1.0 ton/acre = 2.24 Mg·ha⁻¹.

^y1.0 lb = 0.45 kg.

^xValues in the same column and year followed by the same letter are not significantly different at the 0.05 level. Mean separation by protected LSD (0.05) or by the GLM-PDIFF procedure of SAS.

NS, *, **, ***Nonsignificant or significant at $P \leq 0.05$, 0.01, or 0.001, respectively.

Data for all samples evaluated using the hedonic scale were analyzed by determining the mean and standard error of the mean.

Results and discussion

In 1993, April and early May temperatures were above average, followed by a cool, wet season. In 1994, a warm May was followed by slightly below average temperatures and low rainfall the rest of the season. The 1995 season started out about average then turned warm and dry for June through August. The coolest early May was in 1996. This was followed by average temperatures and average precipitation throughout the rest of the growing season. The 1997 season was similar to 1996 except that heavy snows did not melt rapidly and delayed planting.

EARLY HARVEST (FRESH MARKET). Results of the early harvest study are given in Tables 1 and 2. Cabbage for the fresh market needs to have high head density, small to medium-sized heads, and good appearance. 'Bravo', 'Cheers', 'Fresco', and 'Gideon' had the highest yields. Heads of some hybrids grew too big before they were ready to harvest and were unmarketable. Cabbage hybrids that had good yields and medium-sized heads included 'Bravo', 'Green Cup', and 'Royal Vantage'.

Although head density varied from year to year, the relationship between different hybrids was fairly consistent. 'Bronco', 'Gideon', and 'Royal Vantage' had the highest head density, while 'Gourmet' had the lowest head density.

Cabbage head sizes (height and width) were similar in 1993 and 1995, smaller in 1994, and larger in 1996 and 1997. Small heads in 1994 could have been due to high temperatures early followed by a cool summer. The larger head size in 1996 and 1997 was probably due to excellent growing conditions during those 2 years. Hybrids with large heads included 'Cheers', 'Fresco', and 'Gourmet'. 'Blue Pak' and 'Charmant' had small heads.

Individual head weight comparisons between hybrids were fairly consistent across years except for 1995, the hottest year. In 1995, many hybrids that usually had high head weights, had lower head weights, and some that usually had low head weights had high head weights. Averaged over years, 'Cheers' and 'Gideon' had heavy heads. 'Charmant' and 'Fortress' had light weight heads. 'Royal Vantage', 'Green Cup',

'Blue Vantage', and 'Fresco' had small cores. 'Gourmet' had large cores. The core size comparisons between cabbage hybrids were consistent across years.

Overall quality scores given to the cabbage equated to how good the cabbage looked. Despite weather differences between years, some hybrids always scored high and other hybrids always scored low. 'Royal Vantage', 'Gideon', 'Blue Pak', and 'Bronco' received high scores, while 'Gourmet' received low scores.

LATE HARVEST (PROCESSING MARKET). Results of the late-harvest study are given in Tables 3 and 4. Cabbage hybrids classified as processing types that have too long a maturity do not do well in North Dakota. However, many cabbage hybrids classified as fresh market types develop large, solid heads and can be used for processing. Most cabbage can be used for either fresh market or processing depending on how long it is allowed to grow. In this study we harvested the cabbage for a processing market about 2 weeks after it reached the stage to be harvested for the fresh market. Some cabbage did not hold well during the 2-week wait and did not make good processing cabbage. Other hybrids were better for processing than for fresh market.

Most of the hybrids tested produced good yields. Average cabbage yields were 40.0, 29.1, 40.3, 62.0, and 42.2 tons/acre (89.6, 65.2, 90.3, 138.9, and 94.5 Mg·ha⁻¹) in 1993, 1994, 1995, 1996, and 1997, respectively. The average yields of the top 25% of cabbage hybrids were 53.8, 39.1, 58.2, 73.4, and 53.0 tons/acre (120.5, 87.6, 130.4, 164.4, and 118.7 Mg·ha⁻¹) for those same years. In 1996, the year the cabbage yields were highest, we had the coolest early-May temperatures. In 1994, when cabbage yields were lowest, we had the warmest May temperatures, followed by a cool summer. Although the yields were highest the year we used drip irrigation, we only used drip irrigation 1 year, so no scientifically valid comparisons can be made in these trials between the effects of sprinkler vs. drip irrigation on cabbage yield. Cabbage hybrids with consistently very high yields included 'Fresco', 'Cheers', and 'Bravo'. 'Royal Vantage', 'Blue Vantage' and 'Bronco' had high yields.

Hybrids were fairly consistent across years on the quality characteristics of solidness of head, core size, and overall quality score. 'Bronco' and 'Gideon'

Table 4. Late harvest (processing market) head characteristics of cabbage.

Hybrid	Head ht (inch) ^z	Head width (inch)	Head density (1 to 3) ^y	Core length (inch)	Core width ^x (inch)
1993					
Charmant	6.0 c ^w	6.4 c	2.3 ab	4.1 bc	1.3
Green Cup	6.3 bc	7.3 ab	2.0 abc	3.6 ab	1.3
Blue Pak	6.8 ab	6.7 abc	1.6 bc	4.1 abc	1.4
Bravo	6.5 bc	6.6 abc	2.0 abc	3.3 ab	1.4
Gourmet	6.8 abc	6.5 bc	1.3 c	4.6 c	1.3
Fresco	7.4 a	7.3 ab	2.4 ab	3.8 abc	1.2
Royal Vantage	6.8 ab	7.1 abc	2.8 a	3.3 a	1.4
Cheers	7.0 ab	7.3 a	2.0 abc	4.2 bc	1.2
Probability	***	***	***	***	NS
1994					
Charmant	5.1 b	5.7 c	2.8 ab	2.9 b	1.1
Gourmet	5.8 ab	6.2 abc	1.7 c	4.0 c	1.1
Green Cup	5.3 ab	6.5 ab	3.0 a	2.4 ab	0.9
Blue Vantage	5.5 ab	6.2 abc	2.3 bc	2.9 b	1.1
Royal Vantage	6.0 a	6.9 a	3.0 a	2.0 a	1.0
Bravo	5.1 b	6.0 bc	2.5 ab	2.7 ab	1.0
Blue Pak	5.4 ab	5.8 bc	3.0 a	2.0 a	0.9
Cheers	5.7 ab	6.7 a	3.0 a	2.6 ab	1.0
Probability	***	***	***	**	NS
1995					
Charmant	6.3 bcd	6.6 bc	2.8 ab	3.1 a–d	1.0
Fresco	6.9 ab	7.1 abc	3.0 a	3.5 b–e	1.0
Gourmet	6.8 abc	7.7 a	2.0 c	4.0 e	1.0
Green Cup	6.1 cd	7.0 abc	2.5 abc	2.9 ab	1.1
Blue Pak	6.9 ab	6.5 bc	3.0 a	2.8 ab	1.1
Blue Vantage	7.5 a	7.2 ab	2.3 bc	2.7 a	1.1
Cheers	6.4 bcd	7.4 ab	3.0 a	3.7 de	1.1
Gideon	6.3 bcd	6.3 c	3.0 a	3.4 b–e	1.1
Bravo	6.0 d	6.8 bc	3.0 a	3.3 a–e	1.1
Royal Vantage	6.7 a–d	6.8 bc	3.0 a	2.8 ab	1.0
Bronco	6.2 cd	6.6 bc	3.0 a	3.0 abc	1.2
Fortress	6.8 a–d	7.5 a	2.0 c	3.8 cde	0.8
Probability	***	***	***	***	NS
1996					
Gourmet	7.2 ab	7.6 a	1.6 b	4.4 c	1.1 ab
Blue Pak	7.0 ab	6.8 b	2.5 a	3.1 a	1.2 b
Fresco	7.7 a	7.7 a	2.5 a	3.9 bc	1.1 ab
Royal Vantage	7.1 ab	7.0 ab	2.6 a	3.3 a	1.1 ab
Fortress	6.6 b	7.3 ab	2.5 a	4.1 bc	1.0 a
Gideon	7.4 a	7.1 ab	3.0 a	3.5 ab	1.2 b
Probability	*	***	***	***	***
1997					
Royal Vantage	7.1 ab	8.2 a	2.9 ab	3.7	1.1 a
Cheers	7.8 a	8.8 a	2.4 abc	3.9	1.3 bc
Gourmet	7.2 ab	8.1 a	2.0 c	4.3	1.1 a
Blue Vantage	7.6 a	8.2 a	2.3 bc	3.6	1.2 abc
Bronco	7.0 ab	7.1 b	3.0 a	4.0	1.3 c
Blue Pak	6.4 b	6.9 b	2.8 ab	3.8	1.2 ab
Probability	*	**	**	NS	**

^z1.0 inch = 2.54 cm.

^yVisual estimate of head density. The higher the number the more dense the head.

^xWidth was measured at the base of the core (the widest point).

^wValues in the same column and year followed by the same letter are not significantly different at the 0.05 level. Mean separation by protected LSD (0.05) or by the GLM-PDIFF procedure of SAS.

NS, **, ***Nonsignificant or significant at $P \leq 0.01$ or 0.001, respectively.

Table 5. Results of sensory evaluations for shredded cabbage and coleslaw from varieties grown in 1993.

Variety	Shredded cabbage ^z			0-h slaw ^z			24-h slaw ^z		
	Appearance	Texture	Flavor	Appearance	Texture	Flavor	Appearance	Texture	Flavor
Blue Gem	6.1 ± 0.4 ^y	7.0 ± 0.4	5.7 ± 0.5	6.4 ± 0.7	6.2 ± 0.5	6.0 ± 0.6	6.0 ± 0.4	5.6 ± 0.7	5.5 ± 0.6
Blue Pak	6.9 ± 0.4	5.4 ± 0.7	5.5 ± 0.4	6.2 ± 0.4	6.2 ± 0.6	6.1 ± 0.6	5.9 ± 0.6	6.7 ± 0.4	5.9 ± 0.5
Bravo	6.0 ± 0.4	5.7 ± 0.4	5.3 ± 0.3	6.2 ± 0.5	5.5 ± 0.5	3.9 ± 0.7	7.2 ± 0.3	5.9 ± 0.4	5.1 ± 0.5
Charmant	5.8 ± 0.4	7.1 ± 0.3	6.7 ± 0.5	5.9 ± 0.4	7.0 ± 0.4	6.9 ± 0.3	6.7 ± 0.2	6.7 ± 0.3	6.2 ± 0.4
Cheers	6.3 ± 0.4	6.3 ± 0.2	6.1 ± 0.4	6.1 ± 0.2	4.4 ± 0.6	3.6 ± 0.8	5.4 ± 0.4	5.4 ± 0.6	5.0 ± 0.8
Copenhagen Market	6.0 ± 0.4	6.7 ± 0.5	5.4 ± 0.8	5.5 ± 0.5	6.2 ± 0.4	5.5 ± 0.3	5.0 ± 0.5	4.0 ± 0.6	3.9 ± 0.6
Fresco	5.7 ± 0.3	5.9 ± 0.1	5.3 ± 0.4	7.6 ± 0.3	5.3 ± 0.5	6.1 ± 0.3	5.3 ± 0.5	5.7 ± 0.6	5.4 ± 0.6
Gourmet	7.9 ± 0.4	6.2 ± 0.5	5.9 ± 0.4	6.6 ± 0.4	5.5 ± 0.5	6.0 ± 0.4	5.5 ± 0.3	6.3 ± 0.3	6.7 ± 0.5
Grand Slam	6.4 ± 0.4	6.2 ± 0.6	6.6 ± 0.5	7.2 ± 0.4	5.9 ± 0.4	6.0 ± 0.5	6.8 ± 0.3	5.8 ± 0.5	5.6 ± 0.7
Green Boy	6.4 ± 0.5	6.1 ± 0.4	5.3 ± 0.5	7.1 ± 0.3	7.1 ± 0.4	7.1 ± 0.3	5.6 ± 0.3	6.3 ± 0.4	6.4 ± 0.7
Green Cup	6.9 ± 0.2	6.1 ± 0.6	5.9 ± 0.4	5.4 ± 0.4	6.0 ± 0.5	5.8 ± 0.6	6.0 ± 0.4	6.3 ± 0.4	6.0 ± 0.8
Hinova	7.1 ± 0.3	6.4 ± 0.6	6.3 ± 0.5	6.1 ± 0.6	6.7 ± 0.3	7.1 ± 0.3	7.3 ± 0.4	7.0 ± 0.7	5.6 ± 0.8
Little Rock	5.9 ± 0.6	5.9 ± 0.5	5.6 ± 0.4	6.0 ± 0.7	5.9 ± 0.3	6.3 ± 0.4	6.4 ± 0.3	6.4 ± 0.3	5.1 ± 0.5
Morris	5.0 ± 0.4	6.4 ± 0.5	5.7 ± 0.4	5.2 ± 0.5	4.7 ± 0.7	4.5 ± 0.7	5.9 ± 0.5	5.4 ± 0.7	5.0 ± 0.9
Rocket	6.0 ± 0.5	7.1 ± 0.3	7.1 ± 0.3	6.4 ± 0.3	5.9 ± 0.5	6.7 ± 0.4	6.2 ± 0.5	5.9 ± 0.4	6.0 ± 0.3
Royal Vantage	6.1 ± 0.2	5.6 ± 0.5	5.3 ± 0.6	6.0 ± 0.5	6.4 ± 0.6	6.4 ± 0.6	5.4 ± 0.4	5.4 ± 0.6	4.1 ± 0.6
SCB 8101	7.2 ± 0.3	6.9 ± 0.5	5.9 ± 0.5	7.8 ± 0.2	7.2 ± 0.5	7.2 ± 0.5	7.4 ± 0.3	6.4 ± 0.5	6.3 ± 0.5
Solid Blue 780	7.4 ± 0.4	4.6 ± 0.5	5.8 ± 0.6	6.6 ± 0.4	6.0 ± 0.5	6.2 ± 0.4	4.6 ± 0.3	4.9 ± 0.6	4.5 ± 0.7
Solid Blue 790	6.8 ± 0.5	5.0 ± 0.6	5.7 ± 0.7	7.7 ± 0.4	6.2 ± 0.6	6.1 ± 0.7	5.8 ± 0.5	5.3 ± 0.5	5.6 ± 0.5
Stonehead	7.4 ± 0.4	6.4 ± 0.6	5.7 ± 0.5	5.4 ± 0.6	7.2 ± 0.3	6.8 ± 0.5	5.7 ± 0.5	7.3 ± 0.3	7.1 ± 0.5
Superelite	4.4 ± 0.4	5.0 ± 0.6	4.6 ± 0.6	4.0 ± 0.4	6.5 ± 0.7	5.8 ± 0.3	5.4 ± 0.6	5.1 ± 0.6	5.9 ± 0.4

^zCabbage was taste-tested after shredding (shredded cabbage), preparation of coleslaw (0-h slaw), or after 24 h of refrigerator storage of slaw at 4 °C (24-h slaw).

^yMean values (± standard error) from a nine-point hedonic rating scale (1–4 = poor, not acceptable; 5–6 = fair but acceptable; 7–9 = good) scored by 10 evaluators.

cabbage heads were the most solid, although most hybrids produced fairly solid heads. ‘Gourmet’ had low head density. ‘Royal Vantage’ and ‘Green Cup’ had the smallest cores. ‘Gourmet’ had large cores. Overall appearance scores showed ‘Royal Vantage’, ‘Gideon’, ‘Bronco’, and ‘Fresco’ to be the best looking hybrids. ‘Gourmet’ had the poorest appearance.

Later maturing hybrids, such as ‘Hinova’ and ‘Fortress’, did not always form a marketable head. Although it varied depending on the season, hybrids listed by seed companies with relative maturities of greater than 97 d (transplant) or 115 d (direct seed) generally had trouble forming marketable heads. This was not because of frost or cold, but because late in the season (late August and September) the cabbage plant just quit growing.

SENSORY EVALUATIONS. A large variation was found in the performance of cabbage varieties in sensory characteristics. The varieties which scored highest for sensory evaluation of shredded cabbage (in descending order) were: ‘Gourmet’, ‘Stonehead’, ‘Solid Blue 780’, and ‘SCB 8101’ for appearance and color; ‘Puma’, ‘Charmant’, ‘Rocket’, and ‘Blue Gem’ for texture; and ‘Rocket’, ‘Charmant’, and ‘Grand

Slam’ for flavor (Table 5).

For 0-h coleslaw, the best varieties were: ‘SCB 8101’, ‘Solid Blue 790’, and ‘Fresco’ for appearance and color; ‘Puma’, ‘Stonehead’, ‘SCB 8101’ and ‘Green Boy’ for texture; and ‘SCB 8101’, ‘Green Boy’, and ‘Hinova’ for flavor (Table 5). The top performing varieties for 24-h coleslaw were: ‘SCB 8101’, ‘Hinova’, and ‘Bravo’ for appearance and color; ‘Stonehead’, ‘Hinova’, ‘Charmant’ and ‘Blue Pak’ for texture; and ‘Stonehead’ and ‘Gourmet’ for flavor (Table 5). The 24-h coleslaw sample gives an indication of the keeping quality of the prepared salad. Those ranked higher retained better color, texture, and flavor in storage. This characteristic is meaningful in the restaurant and institutional trade where shelf life is important.

The cabbage varieties rated highest in sensory evaluations were ‘SCB 8101’, ‘Stonehead’, ‘Hinova’, ‘Green Boy’, and ‘Charmant’. These are not the same hybrids that had high yields and appearance in the field evaluations. In order to give the consumer the best quality hybrids, more sensory evaluation information is needed.

Conclusions

Using variety trials we identified many cabbage hybrids that are well

adapted to the northern plains and some that should not be grown here. We also determined quality characteristics for the cabbage hybrids tested. Despite differences in weather over the five years of the study, cabbage hybrids were fairly consistent as to relative yield and quality characteristics. Many cabbage hybrids grow well in North Dakota. Of the hybrids tested, the best adapted to North Dakota conditions included ‘Gideon’, ‘Bronco’, and ‘Royal Vantage’ for fresh market, and ‘Fresco’, ‘Cheers’, ‘Bravo’, and ‘Bronco’ for the processing market. In coleslaw and shredded cabbage sensory evaluations in 1993, ‘SCB 8101’, ‘Stonehead’, ‘Hinova’, ‘Green Boy’, and ‘Charmant’ were the top performers.

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