

Storage of Chinese Cabbage

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STORAGE OF CHINESE CABBAGE

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Abstract

Chinese cabbages were harvested in early October 1988 for the second year of a three year project investigating the effects of variety, crop maturity, fungicide spray and store environment on long term storage and subsequent shelf life.

Heads were assessed after 15 to 18 weeks of cool storage at 2.5°C, 50% RH, and subsequently during a 72 hour period of shelf life.

Results indicate that choice of variety is important to maximise storage potential. Despite promising results with Treasure Island in 1988, China Pride was the best variety in 1989. Kingdom 65 and RS 1446 also performed well when handled correctly.

Results over two years suggest that a post harvest spray application of Rovral (iprodione) will improve storage quality to some extent and that Controlled Atmosphere storage in 3% CO₂, 3% O₂ can also be beneficial.

Harvesting heads as soon as they reach full head density is essential since immature and overmature heads have been shown to store less successfully than those at optimum maturity.

Objective

To define optimum storage conditions for Chinese cabbage, with special reference to varietal choice, store environment and the subsequent quality during a period of shelf life.

Introduction

Over recent years Chinese cabbage has rapidly developed a niche in the UK vegetable market. Production is now estimated at around 500 ha. Since the crop is sensitive to frosts, late crops are limited to harvests before mid November. Supplies thereafter and throughout the winter period are mostly met by imports.

Trials work in 1987/88 investigated the optimum conditions for storage including factors such as the choice of variety, benefits of a controlled atmosphere and/or fungicide sprays and the optimum stage of maturity at harvest to maximise storage life.

Results to date indicated that; i) the two varieties Jade Pagoda and Treasure Island have particularly good storage potential; ii) the use of controlled atmospheres is of limited value; iii) a fungicide spray does enhance storage life; iv) harvesting heads either immature or overmature is detrimental to maximum storage life. Trials in 1988/89 were undertaken to confirm these findings in a different season.

Materials and Methods

The crops were grown at Luddington EHS to commercial standards using normal husbandry practices. Seed was sown between 28 June and 15 July (according to the mean days to maturity for each variety) and planted out between 22 July and 9 August. Crops were harvested in late September and early October as each variety reached maturity.

Trial 1 - Effect of fungicide spray, store environment and variety on storage

Treatments

Harvest date

Varieties:	1) Jade Pagoda	(3/10/88)
	2) RS 1446	(5/10/88)
	3) China Pride	(7/10/88)
	4) Treasure Island	(28/9/88)

Fungicide: 1) Rovral spray (1 g/l, 50% a.i. iprodione) at loading
2) No spray

Store environment:

- 1) CA (3% CO₂: 3% O₂) at 2.5°C, 95% RH
- 2) Air at 2.5°C, 95% RH.

Removals from store:

- 1) 16/17 January (16 weeks)
- 2) 30/31 January (18 weeks)

Trial 2 - Effect of variety and head maturity on storage

Treatments

Varieties: 1) Nestor
2) Kingdom 65

Harvest maturity:

- 1) Slightly immature, i.e. slightly loose
- 2) Optimum maturity, i.e. firm dense heads
- 3) Slightly overmature, i.e. very firm, very dense heads,
outer leaves starting to senesce.

Harvests were as follows:

	Harvest 1	Harvest 2	Harvest 3
Nestor	7 October	14 October	21 October
Kingdom 65	3 October	11 October	19 October

All heads were sprayed with Rovral at loading.

Bins were stored at 2.5°C, 95% RH.

Removals from store:

- i) 9 January
- ii) 23 January

Each treatment was replicated three times.

Store assessments (both trials)

On loading into store, two sets of 10 heads were pre-weighed into each bin. At each store removal one set of these heads was re-weighed and weight loss recorded. At each removal an additional sample of 10 heads was randomly selected and the 20 assessed for disease status, using a 1-5 scale (where 5 = excellent). Heads were weighed, trimmed and the number and weight of marketable and unmarketable heads recorded.

A sample of 5 Class I heads was selected, bagged and used for shelf life assessments.

Shelf life assessments

Class I heads from each variety were harvested in early October, trimmed, bagged and assessed for quality during a 72 hour period under shelf life conditions of 20°C and 50% RH to establish the quality pre-storage. Disease, turgidity and butt condition were assessed and scored on a 0-9 scale (where 9 = excellent, 6 = just unmarketable) at 24 hour intervals.

Weight loss was similarly assessed. After 0 and 72 hours, samples of heads were split open and the internal stalk, flower head and any internal rotting assessed. A diary of observations on external appearance, colour etc was also made during shelf life.

Similar shelf life assessments were made over 96 hours on the replicated treatments at each store removal.

Statistical analysis

Three replicated bins were used for each treatment. Store environments were not replicated but stores were filled to capacity (27 bulk bins). Analysis has been undertaken by Mr A Mead at Institute of Horticultural Research, Wellesbourne.

Results

Trial one - Effect of variety, fungicide spray and store environment on storage

Variety

Differences between the four varieties in this trial were quite marked and were manifest in a range of different quality parameters. In many instances varietal response interacts with store environment and fungicide effects.

In contrast to results in 1988 (see previous report), Treasure Island was shown to have developed higher levels of disease in store at both removals than some of the other varieties. In particular, heads in the Air store were worse affected (Table 1). China Pride received high scores for visible disease (i.e. very little present) out of store, particularly on those plots which had received a Rovral spray.

Table 1 Disease, scored out of store pre-trimming (1-5, where 5 = excellent) (week 18)

Variety	No Rovral		Rovral spray		Variety mean
	Air	CA	Air	CA	
Treasure Island	2.68	3.57	3.48	3.07	3.20
Jade Pagoda	3.30	2.95	3.30	3.57	3.28
China Pride	3.25	3.23	3.95	3.80	3.56
RS 1446	2.92	3.62	3.53	3.78	3.46
Mean	3.19		3.56		
Mean	Air	3.30	CA	3.45	
SED (between variety means)		30 df		0.128 *	
SED (between fungicide trts)		30 df		0.091 ***	
SED (between store environments)		30 df		0.091 ns	
SED (other comparisons)		30 df		0.257 **	

In addition to more visible disease, Treasure Island overall produced a lower percentage of marketable heads than the variety China Pride at the first removal (Table 2) In confirmation of disease scores China Pride also produced a high percentage of marketable heads from both store removals (Tables 2 and 3).

Table 2 Percentage of marketable heads (by number) - 16 weeks

Variety	Mean
Treasure Island	71 (58.2)
Jade Pagoda	79 (63.6)
China Pride	86 (70.2)
RS 1446	78 (63.5)

SED 30 df 4.15 (p = 0.058)

Figures in brackets are angular transformations.

Table 3 Percentage of marketable heads (by number) - 18 weeks

Variety	Mean
Treasure Island	67 (55.2)
Jade Pagoda	61 (51.1)
China Pride	76 (62.7)
RS 1446	62 (51.9)
SED 30 df	3.17 **

Figures in brackets are angular transformations.

The number of heads unmarketable due to rots and disease was correspondingly lower on China Pride (Table 4). In addition to rots in store, black speckling contributed to the outgrading of a small percentage of Treasure Island heads.

Table 4 Percentage unmarketable due to rots (18 weeks)

Variety	No Rovral	Rovral	Mean
Treasure Island	30 (32.7)	21 (26.4)	26 (29.6)
Jade Pagoda	40 (39.0)	35 (36.1)	38 (37.5)
China Pride	35 (36.1)	8 (11.5)	22 (23.8)
RS 1446	43 (39.9)	34 (33.2)	39 (36.5)
Mean	37 (36.9)	25 (26.8)	
SED (between varieties)		30 df	3.66 **
SED (between fungicide trts)		30 df	2.59 ***
SED (other comparisons)		30 df	5.18 *

Figures in brackets are angular transformations.

The mean marketable headweight out of store varied little between varieties. Treasure Island appeared to respond to the use of a fungicide spray with a significantly higher headweight than unsprayed plots (Table 5). Overall mean headweights for all varieties were 150-200g lighter at the second store removal (Table 6). Again Treasure Island showed a response to fungicide from the first removal but the response was not repeated by other varieties.

Table 5 Mean marketable headweight out of store (grams). Removal 16 weeks

Variety	No Rovral	Rovral	Mean
Treasure Island	1299	1526	1413
Jade Pagoda	1354	1441	1398
China Pride	1404	1401	1402
RS 1446	1338	1276	1307
Mean	1349	1411	
SED (variety means)		30 df	53.8 ns
SED (fungicide means)		30 df	38.1 ns
SED (other comparisons)		30 df	76.1 *

Table 6 Mean marketable headweight out of store (grams). Removal 18 weeks

Variety	No Rovral	Rovral	Mean
Treasure Island	1227	1263	1245
Jade Pagoda	1242	1315	1279
China Pride	1193	1217	1261
RS 1446	1256	1267	1205
Mean	1229	1265	
SED (variety means)		30 df	40.5 ns
SED (fungicide means)		30 df	28.6 ns
SED (other comparisons)		30 df	40.5 ns

The level of trimming required was also influenced by variety. After 16 weeks storage, in only the air store was the level of trimming higher on Treasure Island than on other varieties (Table 7). After 18 weeks Treasure Island in both stores required heavier trimming than the variety Jade Pagoda and RS 1446 (Table 8).

Table 7 Percentage trimming per head (16 weeks)

Variety	Air	CA	Mean
Treasure Island	34.1	28.4	31.3
Jade Pagoda	30.8	29.8	30.3
China Pride	26.4	30.6	28.5
RS 1446	28.3	29.0	28.7
Mean	29.9	29.5	

SED (between varieties) 30 df 1.69 ns

SED (between store environments) 30 df 1.20 ns

SED (between variety + store comparisons) 30 df 2.39 (*) p=0.052

Table 8 Percentage trimming per head (18 weeks). Mean of all treatments

Variety	Air	CA	Mean
Treasure Island	39.6	37.2	38.4
Jade Pagoda	35.6	33.3	34.4
China Pride	34.5	34.2	34.9
RS 1446	29.7	35.4	31.9
Mean	34.8	35.0	

SED (variety means) 30 df 1.77 *

SED (store environments) 30 df 1.255 ns

SED (other comparisons) 30 df 1.77 ns

The varieties were assessed for shelf life characteristics immediately after harvest (early October). Differences were apparent even at this time. Jade Pagoda lost significantly more weight than other varieties, whilst China Pride showed less deterioration of the butt (Table 9). Jade

Pagoda developed the least disease during shelf life, whilst Treasure Island showed most deterioration. The poor turgidity of Jade Pagoda is in line with the high weight loss recorded. Treasure Island, however, despite low weight loss during shelf life, was also less turgid than China Pride and RS 1446.

Assessments on internal stalk and flower development indicate the stage of maturity of each variety. Well developed stalks and flowers are not desirable. Jade Pagoda received a low score for both flower and stalk development indicating it to be one of the more mature varieties. Treasure Island showed less flower development than other varieties but also had more internal rot. RS 1446 developed similar levels of internal rots but scored highly for internal stalk, hence was less mature (Table 9).

Table 9 Pre-storage assessment of varieties after 72 hours shelf life

Variety	% wt loss	Disease score	Butt score	Turgidity score	Stalk	Flower	Rot
		scored 9-0, where 9 = excellent					
Treasure Island	1.96	8.47	5.77	7.10	6.83	6.37	8.10
Jade Pagoda	4.09	8.80	5.80	6.73	6.00	6.33	8.87
China Pride	2.11	8.70	6.70	8.03	6.70	7.57	9.00
RS 1446	1.83	8.43	5.68	7.92	7.47	7.65	7.67
SED (14 df)	0.515 ***	0.143 ns	0.168 ***	0.141 ***	0.234 ***	0.301 ***	0.255 ***

After both 16 and 18 weeks storage Jade Pagoda was still losing more weight during shelf life than the other varieties (Table 10).

Table 10 Percentage weight loss after 72 hours shelf life (18 weeks)

Variety	Air	CA	Mean
Treasure Island	0.71	0.39	0.55
Jade Pagoda	1.00	1.66	1.33
China Pride	0.45	0.65	0.79
RS 1446	0.57	1.00	0.55
Mean	0.68	0.93	

SED (between varieties) 29 df 0.183 ***

SED (between store environments) 29 df 0.132 ns

In addition, at both store removals the turgidity of Jade Pagoda was lower than most other varieties. In contrast, the variety RS 1446 after storage for both 16 and 18 weeks had a high turgidity (Table 11).

Table 11 Turgidity scores of varieties after 72 hours shelf life (scored 9-0, where 9 = excellent)

Variety	Removal from store	
	16 weeks	18 weeks
Treasure Island	7.60	7.97
Jade Pagoda	7.12	7.43
China Pride	7.68	8.18
RS 1446	7.93	8.38
SED (30 df)	0.101 ***	0.131 ***

All heads placed into the shelf life room were trimmed to Class I quality and so were virtually free from disease upon. After 16 weeks storage variety and fungicide treatment interactions were emerging but no variety was consistently better than another. After 18 weeks storage Treasure Island consistently developed more disease than other varieties (Table 12).

Table 12 Disease scores (scored 0-9, where 9 = excellent) after 72 hours shelf life (18 weeks)

Variety	Disease score
Treasure Island	7.40
Jade Pagoda	8.20
China Pride	7.88
RS 1446	8.15
SED (30 df)	0.173 ***

The condition of the butt on the Chinese cabbage is important since it often provides the source of entry for pathogens and becomes a vulnerable place for rots to develop. Normal browning of the butt is also unsightly and may be used as a criterium for freshness. Treasure Island appeared to show more deterioration of the butt than other varieties (Table 13).

Table 13 Butt scores (scored 0-9, where 9 = excellent) after 72 hours shelf life (16 weeks)

Variety	Air	CA	Mean
Treasure Island	6.30	6.57	6.43
Jade Pagoda	6.57	6.80	6.68
China Pride	6.23	7.10	7.15
RS 1446	7.00	7.30	6.67
Mean	6.53	6.94	
SED (between varieties)			0.248 * (30 df)
SED (between store environment)			0.176 * (30 df)
SED (other comparisons)			0.351 ns

The flower and stalk assessments mirrored pre-storage assessments in that RS 1446 showed least stalk extension and Jade Pagoda most extension after both 16 and 18 weeks storage (Table 14).

Table 14 Internal stalk extension (scored 9-0, where 9 = no extension), after 96 hours shelf life (18 weeks)

Variety	Air	CA	Mean
Treasure Island	5.77	5.77	5.77
Jade Pagoda	4.17	5.03	4.60
China Pride	4.10	7.20	7.10
RS 1446	7.00	5.60	4.85
Mean	5.26	5.90	
SED (between varieties)			0.161 *** (30 df)
SED (between store environments)			0.114 *** (30 df)
SED (other comparison)			0.227 *** (30 df)

After 16 weeks storage, Treasure Island showed the most advanced flower development and RS 1446 and China Pride the least (Table 15). Treasure Island and Jade Pagoda similarly received low scores after 18 weeks storage, whilst RS 1446 scored highly (Table 15).

Table 15 Internal flower head development (scored 9-0, where 9 = no developments), after 96 hours shelf life

Variety	Weeks in store	
	16	18
Treasure Island	5.32	5.37
Jade Pagoda	5.88	5.80
China Pride	6.23	6.35
RS 1446	7.00	6.87
SED (30 df)	0.135 ***	0.107 ***

As indicated in pre-storage shelf life assessments, Treasure Island consistently developed more internal rotting than the other three varieties though on this variety levels were still very low (Table 16).

Table 16 Internal disease scores (9-0, where 9 = excellent), after 96 hours shelf life

Variety	Weeks in store	
	16	18
Treasure Island	8.12	7.97
Jade Pagoda	8.82	8.70
China Pride	8.75	8.85
RS 1446	8.77	8.55
SED (30 df)	0.117 ***	0.089 ***

Fungicide

As in 1988 there were some marked responses in store to the use of a Rovral fungicide spray. After both 16 and 18 weeks storage there was less visible disease (high disease score) on those Chinese cabbage which had received the fungicide treatment (Table 1). From the second removal the benefit was particularly marked on China Pride in both stores and on RS 1446 and Treasure Island in the air store.

The percentage of marketable heads after trimming was also affected. After 16 weeks, differences were not significant (Table 17) but after 18 weeks storage the use of the fungicide spray significantly increased the number of marketable heads out of store (Table 18). This improvement was most marked on the variety China Pride. The level of trimming required was not affected by fungicide treatment.

Table 17 Percentage of marketable heads (by number) (16 weeks)

Variety	No Rovral		Rovral spray		Variety mean
	Air	CA	Air	CA	
Treasure Island	65(54.4)	78(64.5)	77(61.1)	63(52.8)	71(58.2)
Jade Pagoda	72(58.0)	80(63.5)	72(57.9)	90(75.0)	79(63.6)
China Pride	87(68.7)	83(66.3)	80(68.1)	93(77.7)	86(70.2)
RS 1446	52(46.1)	88(70.7)	80(63.9)	92(73.4)	78(63.5)
Mean	76(61.5)		81(66.2)		
Mean	Air	73(59.8)	CA	83(68.0)	
SED (between variety means)	30 df		4.15 ns (p=0.058)		
SED (between fungicide trts)	30 df		2.94 ns		
SED (between store environments)	30 df		2.94 **		
SED (other comparisons)	30 df		8.30 ns		

Figures in brackets are angular transformations. Statistical analysis relates to this transformed data.

Table 18 Percentage of marketable heads (by number) (18 weeks)

Variety	No Rovral		Rovral spray		Variety mean
	Air	CA	Air	CA	
Treasure Island	55(47.9)	75(60.1)	68(56.0)	70(57.0)	67(55.2)
Jade Pagoda	55(48.0)	58(49.8)	57(48.8)	72(57.9)	61(51.1)
China Pride	57(48.9)	72(57.9)	80(64.6)	95(79.5)	76(62.7)
RS 1446	42(40.0)	72(58.1)	55(47.9)	77(61.8)	62(51.9)
Mean	61(51.3)		72(59.2)		
Mean	Air	59(50.3)	CA	74(60.2)	
SED (between variety means)	30 df		3.17 **		
SED (between fungicide trts)	30 df		2.24 ***		
SED (between store environments)	30 df		2.24 ***		
SED (other comparisons)	30 df		6.33 ns		

Figures in brackets are angular transformations.

Table 19 Disease scores after 72 hours shelf life (16 weeks)

Variety	No Rovral	Rovral	Mean
Treasure Island	7.53	7.57	7.55
Jade Pagoda	7.73	7.90	7.82
China Pride	6.87	7.90	7.80
RS 1446	7.70	7.97	7.42
Mean	7.46	7.83	
SED (between varieties)		(30 df)	0.165 * (p=0.055)
SED (between fungicide trts)		(30 df)	0.116 **
SED (between fungicide + variety comparisons)		(30 df)	0.233 *

In terms of shelf life quality the effects of the fungicide treatment in reducing rots were reflected in the disease scores during shelf life from the first removal. Overall, sprayed plots developed less disease than unsprayed plots. Most of this improvement was, however, seen on the variety China Pride (Table 19). At the second removal no significant differences in disease levels during shelf life were noted, although the butt scores on China Pride were again significantly improved on sprayed plots. There were no consistent differences in levels of internal stalk, flower development and disease.

Store environment

Any effects of controlled atmospheres on the levels of visible disease out of store were not apparent at either store removal (Table 1) but there was a significant difference in the number of marketable heads (Tables 17 and 18). Controlled atmosphere storage using 3% CO₂ and 3% O₂ increased the percentage of marketable heads after both 16 and 18 weeks in store. There were no differences in the amount of trimming required. There is an indication that weight loss was reduced in the CA store after 18 weeks storage but the effect is significant only on the unsprayed plots (Table 20).

Table 20 Percentage weight loss after 18 weeks storage

Variety	No Rovral		Rovral spray		Variety mean
	Air	CA	Air	CA	
Treasure Island	9.11	3.64	1.53	6.40	5.17
Jade Pagoda	10.00	4.33	6.89	4.87	6.55
China Pride	8.76	5.07	7.73	5.42	6.75
RS 1446	14.72	5.86	7.78	5.66	8.47
Mean	No Rovral 7.68		Rovral 5.81		
Mean	Air	8.32	CA	5.17	
SED (between variety means)			(29 df)		1.979 ns
SED (between fungicide trts)			(29 df)		1.329 ns
SED (between store environments)			(29 df)		1.344 *
SED (between fungicide + store)			(29 df)		1.881 *
SED (other comparisons)			(29 df)		3.801 ns

In contrast, shelf life results suggest that CA treatments may deteriorate more rapidly. Disease levels were higher throughout shelf life on CA treatments from both store removals (Table 21).

Table 21 Disease scores after 72 hours shelf life (scored 9-0, where 9 = excellent)

Store environment	Weeks in store	
	16	18
Air	7.85	8.17
CA	7.44	7.65
SED (30 df)	0.116 **	0.122 ***

The weight loss during shelf life was higher from CA treatments (Table 7) and turgidity scores lower. Turgidity assessments out of store, however, indicated the CA treatments to be the same or more turgid than air store counterparts (Table 22).

Table 22 Turgidity scores on entry into shelf life (scored 9-0, where 9 = excellent)

Store environment	Weeks in store	
	16	18
Air	8.33	8.64
CA	8.66	8.68
SED (30 df)	0.063 ***	0.046 ns

The condition of the butts also indicated a significant difference between treatments. The butts from air stored treatments deteriorated more than those from CA stored treatments from both store assessments (Table 13).

A comparison between pre-storage (Table 21) and post storage assessments of internal stalk and flower development (Tables 14 and 15) indicate that extension and growth has continued throughout the storage period. It would appear, however, that this development has been most advanced in the air stored treatments (Tables 14 and 23). Some store environment and variety interactions were also apparent since the response was sometimes only significant on the varieties Jade Pagoda and China Pride.

Table 23 Internal flower stalk development (scored 9-0, where 9 = no extension), after 96 hours shelf life (18 weeks)

Variety	Air	CA	Mean
Treasure Island	5.37	5.37	5.37
Jade Pagoda	5.63	5.97	5.80
China Pride	6.17	6.97	6.35
RS 1446	6.77	6.53	6.87
Mean	5.98	6.21	

SED (between varieties)	(30 df)	0.107 ***
SED (between store environment)	(30 df)	0.076 **
SED (other comparisons)	(30 df)	0.152 ns

Trial Two - Effect of head maturity on storage

Although this trial was assessed from two store removals, the results discussed below refer to a single storage period of approximately 100 days. Depending on the variety or stage of maturity this may refer to data collected from either the first or second store removal. It should more accurately reflect treatment performance without penalising early maturity treatments which would have been in store for a longer period than later maturing ones.

All treatments were assessed for shelf life quality at harvest. Even before a period in store differences were apparent.

Statistical analysis of the weight loss during shelf life is not possible but results do suggest that weight loss is higher from the immature heads and that there is little difference between the varieties (Table 24).

Table 24 Percentage weight loss after 72 hours shelf life. (Pre-storage)

Varieties	Stage of maturity			Mean
	Immature	Mature	Overmature	
Kingdom 65	3.51	2.48	2.37	2.79
Nestor	3.46	2.68	1.98	2.71
Mean	3.49	2.58	2.18	

Statistical analysis not available

Weight loss is also reflected in turgidity scores, in that immature heads were less turgid than the others during the latter part of the period in shelf life (Table 25). In addition Nestor was less turgid overall than Kingdom 65.

Table 25 Turgidity score 9-0 (where 9 = excellent) after 72 hours shelf life (Pre-storage)

Varieties	Stage of maturity			Mean
	Immature	Mature	Overmature	
Kingdom 65	6.87	7.73	8.07	7.56
Nestor	6.20	7.53	7.80	7.18
Mean	6.53	7.63	7.93	

SED (between variety means)	(10 df)	0.147 *
SED (between maturity means)	(10 df)	0.180 ***
SED (other comparisons)		0.255 ns

Even before storage the overmature heads (previously trimmed to Class I quality) developed more disease during shelf life (Table 26) and Kingdom developed more disease than Nestor. In contrast Nestor developed more butt deterioration than Kingdom 65 (Table 27).

Table 26 Disease scored 9-0 (where 9 = excellent) after 72 hours shelf life (Pre-storage)

Varieties	Stage of maturity			Mean
	Immature	Mature	Overmature	
Kingdom 65	8.67	8.47	8.00	8.38
Nestor	8.87	8.80	8.40	8.69
Mean	8.77	8.63	8.20	

SED (between variety means)	(10 df)	0.143 (p = 0.055)
SED (between maturity means)	(10 df)	0.175 *
SED (other comparisons)		0.248 ns

Table 27 Butt scores 9-0 (where 9 = excellent) after 72 hours shelf life (Pre-storage)

Varieties	Stage of maturity			Mean
	Immature	Mature	Overmature	
Kingdom 65	5.80	6.33	6.47	6.20
China Pride	5.40	6.13	5.87	5.80
Mean	5.60	6.23	6.17	
SED (between variety means)			(10 df)	0.124 **
SED (between maturity means)			(10 df)	0.152 ***
SED (other comparisons)				0.215 ns

The stage of maturity at harvest had a marked effect on the levels of disease as assessed on removal from store. There was also a strong interaction with the variety.

Both varieties showed more visible disease on the overmature heads but this effect was more pronounced on the variety Kingdom 65. On overmature treatments only, Kingdom 65 received significantly lower scores than Nestor (Table 28).

Table 28 Disease scored out of store (using a 1-5 scale, where 5 = excellent) (100 days storage)

Varieties	Stage of maturity			Mean
	Immature	Mature	Overmature	
Kingdom 65	4.03	3.92	3.12	3.69
Nestor	3.90	3.87	3.60	3.79
Mean	3.97	3.89	3.36	
SED (between variety means)			(10 df)	0.068 ns
SED (between maturity means)			(10 df)	0.083 ***
SED (other comparisons)			(10 df)	0.118**

In terms of numbers of marketable heads the overmature treatments did produce a significantly lower percentage than mature ones but this response was attributable to the performance of Kingdom 65. Overall there was no significant difference in the performance of the two varieties (Table 29).

Table 29 Percentage of marketable heads (100 days storage)

Varieties	Stage of maturity			Mean
	Immature	Mature	Overmature	
Kingdom 65	75 (60.3)	87 (69.2)	57 (48.9)	73 (59.5)
Nestor	75 (61.5)	85 (67.4)	67 (54.7)	76 (61.2)
Mean	75 (60.9)	86 (68.3)	62 (51.8)	
SED (between variety means)			3.51	ns
SED (between maturity means)			(10 df)	4.30 *
SED (other comparisons)			6.09	ns

Figures in brackets are angular transformations.

Nestor is characterised by producing very little rotting in store (Table 30) in contrast to Kingdom 65. Mature and overmature heads were exceptionally good. Most of the unmarketable heads which were outgrade were penalised for the presence of black speckling and other unusual sunken non-pathogenic lesions.

Table 30 Percentage of heads unmarketable due to rots (100 days storage)

Varieties	Stage of maturity			Mean
	Immature	Mature	Overmature	
Kingdom 65	8 (16.2)	10 (15.2)	40 (39.1)	19 (23.5)
Nestor	7 (11.9)	0 0	2 (4.3)	3 (5.4)
Mean	8 (14.1)	5 (7.6)	21 (21.7)	

SED (between variety means) (10 df) 3.70 ***

SED (between maturity means) (10 df) 4.53 *

SED (other comparisons) (10 df) 6.41 *

Figures in brackets are angular transformations.

Nestor necessitated a considerably higher percentage of the head weight to be trimmed off upon removal from store in comparison to Kingdom 65 (Table 31). Given the smaller head weight initially this probably represented the same number of outer leaves.

Table 31 Percentage trimmings per head out of store (100 days storage)

Varieties	Stage of maturity			Mean
	Immature	Mature	Overmature	
Kingdom 65	30.7	32.1	29.9	30.9
Nestor	33.4	41.5	38.1	37.6
Mean	32.1	36.8	34.0	

SED (between variety means) (10 df) 1.83 **

SED (between maturity means) 2.25 ns

SED (other comparisons) 3.18 ns

The small nature of Nestor is reflected in the marketable headweight out of store (Table 32). For both varieties overmature heads had a larger mean marketable weight than either mature or immature heads.

Table 32 Mean marketable headweight (grammes) out of store (100 days storage)

Variety	Stage of maturity			Mean
	Immature	Mature	Overmature	
Kingdom 65	1189	1447	1776	1471
Nestor	844	968	1279	1030
Mean	1017	1208	1528	
SED (between varieties)		10 df	84.1 ***	
SED (between maturities)		10 df	103.0 **	
SED (other comparisons)		10 df	145.7 ns	

During shelf life assessments following storage, immature heads appeared to lose more weight than mature or overmature counterparts (Table 33).

Turgidity scores similarly reflect this pattern (Table 34).

Table 33 Percentage weight loss after 72 hours shelf life (100 days storage)

Varieties	Stage of maturity			Mean
	Immature	Mature	Overmature	
Kingdom 65	0.42	0.34	0.42	0.39
Nestor	0.46	0.25	0.25	0.33
Mean	0.44	0.30	0.34	

Statistical analysis not available.

Table 34 Turgidity score 9-0 (where 9 = excellent) after 72 hours shelf life (100 days storage)

Varieties	Stage of maturity			Mean
	Immature	Mature	Overmature	
Kingdom 65	7.67	8.00	8.27	7.98
Nestor	7.07	8.07	8.40	7.84
Mean	7.37	8.03	8.33	
SED (between variety means)			0.156	ns
SED (between maturity means)			(10 df)	0.191 **
SED (other comparisons)			0.269	ns

More disease and rots developed on the overmature cabbage (Table 35) as in the pre-storage assessment.

Table 35 Disease scored 9-0 (where 9 = excellent) after 72 hours shelf life (100 days storage)

Varieties	Stage of maturity			Mean
	Immature	Mature	Overmature	
Kingdom 65	8.33	8.13	7.80	8.09
Nestor	8.27	8.07	7.27	7.87
Mean	8.30	8.10	7.53	
SED (between variety means)			0.182	ns
SED (between maturity means)			(10 df)	0.223 *
SED (other comparisons)			0.315	ns

Similarly Kingdom 65 again developed less butt browning and/or rotting than Nestor (significant after 0 and 96 hours only) and overmature heads were worse than mature heads which were in turn worse than immature heads (Table 36).

Table 36 Butt condition scored 9-0 (where 9 = excellent) after 72 hours shelf life (100 days storage)

Varieties	Stage of maturity			Mean
	Immature	Mature	Overmature	
Kingdom 65	6.67	7.27	6.20	6.71
Nestor	6.93	7.40	6.60	6.98
Mean	6.80	7.33	6.40	

SED (between variety means)		0.133 ns (p = 0.07)
SED (between maturity means)	(10 df)	0.163 ***
SED (other comparisons)		0.231 ns

Internal stalk assessments confirm those made at harvest, that Kingdom 65 was more advanced in maturity than Nestor and that the immature harvest is less advanced than the later ones (Table 37). Comparison with pre-storage assessments indicate stalk extension had occurred during storage. Flower development followed a similar pattern (Table 38).

Table 37 Internal stalk extension scored 9-0 (where 9 = none present) after 96 hours shelf life (100 days storage)

Varieties	Stage of maturity			Mean
	Immature	Mature	Overmature	
Kingdom 65	6.80	4.80	5.00	5.53
Nestor	8.93	8.20	7.73	8.29
Mean	7.87	6.50	6.37	

SED (between variety means)	(10 df)	0.165 ***
SED (between maturity means)	(10 df)	0.202 ***
SED (other comparisons)	(10 df)	0.285 *

Table 38 Internal flower development score 9-0 (where 9 = none present) after 96 hours shelf life (100 days storage)

Varieties	Stage of maturity			Mean
	Immature	Mature	Overmature	
Kingdom 65	7.07	6.33	6.60	6.67
Nestor	9.00	8.87	8.60	8.82
Mean	8.03	7.60	7.60	
SED (between variety means)		(10 df)	0.070 ***	
SED (between maturity means)		(10 df)	0.086 ***	
SED (other comparisons)		(10 df)	0.122 *	

Discussion

Varieties

The trials were not designed to investigate the storage potential of a wide range of varieties. However results and observations of the six varieties listed in these trials are summarised as follows:

Treasure Island

In contrast to 1988, storage in 1989 was disappointing. Treasure Island experienced high levels of disease in store which resulted in both more trimming and a lower percentage of marketable heads. Although bacterial soft rots and basal rots were the main problem, this variety is also susceptible to black speckling. The poor storage quality is also reflected in the shelf life quality. Treasure Island is a difficult variety to grow in that it is prone to internal leaf necrosis. The shape is not ideal (mid-way between a tall and short barrel type) and good density is often difficult to achieve. The low turgidity scores seen in some of the shelf life assessments is probably attributable to the natural head growth.

Hence, despite the promising results in 1988, Treasure Island is not recommended as the first choice for storage. Highest yield was 78 per cent

of those heads loaded into store after 16 weeks, with no spray and CA storage.

Jade Pagoda

Jade Pagoda gave a very consistent performance . Internal stalk assessments indicated Jade Pagoda to be fairly mature at the time of harvest and indeed bolting was a problem in the field in autumn 1988. The heads required less trimming than some but consistently lost more weight during shelf life. As a result heads were less turgid. The shape (tall barrel) may be a problem for some market outlets although heads were generally nicely green and attractive. Highest yield was 90 per cent of those heads loaded into store after 16 weeks, a Rovral spray and CA storage.

China Pride

China Pride did not give an outstanding performance in 1987/88 trials. In 1989 when stored in conjunction with a fungicide spray, yields out of store were very good. There was less visible disease on these heads too. Heads tend to retain their greenness well and this, in combination with the dense short barrel shape, make China Pride a very attractive product out of store. Highest yield was 95 per cent of those heads loaded into store after 18 weeks, a Rovral spray and CA storage.

RS 1446

This was the first time this variety had been used in trials at Luddington. Heads were similar in shape to China Pride although slightly less compact. Quality out of store was rather variable and much improved by the use of controlled atmosphere storage. Trimming losses were slightly lower than Treasure Island or China Pride and the heads turgid. Highest yield was 92 per cent of those heads loaded into store after 16 weeks, a Rovral spray and CA storage.

Kingdom 65

Kingdom 65 gave a reasonable yield out of store (87 per cent of those heads loaded into store at optimum maturity and after 14 weeks storage). Heads tend to be very pale in colour and are prone to black speckling.

Nestor

This variety did not prove very suitable for storage in 1989. Heads were not very dense and hence were lacking turgidity. The shape is midway between China Pride and Treasure Island. Of greater importance was the development of brown sunken patches on the midribs. Black speckling was also evident on this variety.

Fungicide treatment

The benefits from using a Rovral spray at harvest and loading into store were confirmed in 1989 although they were less marked than in 1988. A Rovral spray reduced the overall level of disease in store, and during shelf life and certainly after prolonged storage (18 weeks), increased the percentage of marketable heads out of store. The effect was more pronounced on some varieties, (e.g. China Pride) than others.

Whilst this is encouraging, the continued post harvest use of many chemicals is under threat from consumer concern. Residue samples have been collected and data could be made available at cost if a body were willing to apply for off-label approval for Rovral as a post harvest spray on Chinese cabbage.

Store environment

In the 1988 trials CA storage showed slight benefits over air only after 17 weeks storage. In 1989 there were marked improvements after both 16 and 18

weeks storage, producing both a higher percentage of marketable heads and a reduction in internal stalk extension growth. Weight loss and hence desiccation during storage may also have been reduced. Unfortunately this improvement in performance was not extended into shelf life.

Head maturity at harvest

Results in 1989 confirmed those of 1988 in that heads harvested immature lost excessive weight and so were less turgid, whilst those harvested overmature developed more disease and produced a lower marketable yield out of store. Harvesting heads when just dense enough (optimum maturity) is likely to produce the best results in store. Leaving mature crops in the field and delaying harvest for storage until a later date is unlikely to produce satisfactory results.

Conclusions

1. China Pride was the best storing variety in 1989, producing an average of over 75 per cent marketable heads after 18 weeks in store. In addition, it is a reliable variety to grow. Kingdom 65, when harvested at the correct stage also performed well. RS 1446 also showed considerable promise.
2. Up to 40 per cent of the total weight may be removed during trimming. Headweights at loading must therefore be of an adequate size to withstand such losses and still remain above a minimum marketable headweight.
3. The use of a fungicide spray (Rovral) at harvest and loading improved the storage potential of Chinese cabbage. Varietal response to the use of this spray varied.

4. Controlled Atmosphere storage is of benefit, improving quality out of store after both 16 and 18 weeks storage.

5. Harvesting heads as soon as they reach the required density ensures maximum storage potential. Harvesting immature or overmature heads is detrimental to quality both in store and during subsequent shelf life.

Recommendations for future action

Further assessments of varieties for storage are needed. The use of Rovral appears to be of benefit but this should be verified in a third year of trials, together with investigations into the method of application. The use of Rovral would be of greater interest if it could be applied as a drench rather than a spray. Controlled Atmosphere storage does look promising and given the current concern over pesticide residues it should be pursued as a technique for improving the storage potential of Chinese cabbage. Further investigations into the optimum temperature and controlled atmosphere environment would also be of value.