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ONIONS DRY BULB: EVALUATION OF REGIMES DESIGNED TO ALLEVIATE THE NECESSITY FOR A SPROUTING SUPPRESSANT

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Authentication:

I declare that this work was done under my supervision according to the procedures described herein and that this report represents true and accurate records of the results obtained.

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ONIONS DRY BULB: EVALUATION OF STORAGE REGIMES DESIGNED TO ALLEVIATE THE NECESSITY FOR A SPROUTING SUPPRESSANT

SUMMARY

Two onion varieties, Sturon from sets and module-raised Hyton, a Rijnsburger variety, were grown commercially and either treated or not treated with maleic hydrazide before being harvested. They were dried in a commercial store following the ADAS guidelines for Stages 1 and 2. When dry and cured, samples were weighed into the three experimental stores at HRI Kirton, each of which underwent one of three different Stage 3 cooling regimes indicated below:-

A. Conventional slow cooling (taking 45 days) to drop to 5°C using ambient air when possible.
B. Rapid cooling (10 days) using refrigeration down to 1°C.
C. Rapid cooling (20 days) using refrigeration down to minus 2°C.

Samples were removed from store at monthly intervals January-August, and assessments made of weight loss, disease, quality, internal sprout development, number of skins, appearance of external shooting and shelf life.

The following main observations were made:-

1. Maleic hydrazide was persistent in stored bulbs and the amounts were similar between all three stores.

2. Under experimental conditions storage of minus 2°C used 2.5 times more electricity than 5°C storage, but only 1.3 times more than the 1°C storage regime.

3. Percentage weight losses in store were quite small but related to storage temperature and further reduced by the presence of MH.

4. From a commercial sample of each treatment graded out for marketing, waste was low for all treatments up to the April withdrawal when the 5°C storage without Maleic hydrazide declined rapidly whilst the bulbs stored at 1°C were good up to June thereafter they were unmarketable but the minus 2°C stored onions remained marketable even for the August withdrawal.

5. External shoot appearance in the later stages of the trial was slightly less with Sturon than Hyton, but drastically reduced by Maleic hydrazide (MH) and cold storage.

6. Development of the internal shoot followed a similar pattern, but was reduced much more by cold storage than by MH. However shoots developed faster in 1°C storage without MH than in 5°C storage with MH.

7. Internal disorders due to disease or physiological problems were low and unaffected by treatment, except that minus 2°C stored bulbs had an unacceptable level of cold/freezing related damage.

8. Bulbs from minus 2°C storage developed internal shoots faster than those from the other two stores when placed into shelf life conditions.

9. The trial must be repeated for a second year to verify the above observations but adapted to look at minus 1°C storage at which temperature the onions will not freeze and so should achieve the benefits of minus 2°C length of storage period, but with 1°C quality and internal bulb soundness.

INTRODUCTION AND OBJECT

For British growers to supply home-grown onions into the market place to meet a significant proportion of the year round demand then the crop has to be stored. Traditionally even when using cool storage of 1°C a chemical sprouting suppressant has been needed. Although some of the most recent selections of Rijnsburger onions have improved storability in the absence of chemical suppressants, these chemicals are still needed, especially as the industry is moving away from Rijnsburger varieties to onions such as Sturon which are considered to have a lower inherent long-term storage capability.

The original chemical sprouting suppressant used was the amine salt of maleic hydrazide which has been shown to have a question mark over its safety. The industry now uses the 'safe' potassium salt but the chemical has attracted media hype and its contiunued use may become an emotive issue. In such cases scientific data invariably loses out to emotion. Therefore, it is quite possible that the industry could lose maleic hydrazide in the short-term, if this was to happen in the absence of alternatives, British growers could lose a large proportion of their own market.

An alternative method of sprout suppression was known to exist and that is to store onions at -2°C hence it inclusion in the first year of this project which is aimed at producing a blueprint for long term onion storage without the use of maleic hydrazide.

MATERIALS AND METHOD

1. Site

HRI Kirton is located in the village of Kirton situated five miles south of the town of Boston on the A17 in the county of Lincolnshire. The facilities used included a propagation unit and a modern block of Venlo glass and the field designated 40Ac5 to raise and grow the crop of Hyton from transplants. The crop of Sturon was grown commercially from sets on a local farm (E A Dring Ltd at Langrick).

The onions were stored in three 40 tonne experimental stores, graded using facilities on site and subjected to shelf-life in a purpose built inner room where conditions similar to those on supermarket shelves could be maintained.

2. Test crops

i. Onions dry bulb variety Hyton raised from transplants.
ii. Onions dry bulb variety Sturon raised from sets.

3. Trial design and treatments

i. Varieties

Two as above grown in commercial blocks to ensure a minimum of 60 tonnes of each variety.

ii. Maleic hydrazide

Half of each block of each variety was sprayed with maleic hydrazide in accordance with commercial practice.

The onions were lifted commercially, but keeping the above treatments separate, put into a commercial store and taken through stages 1 and 2 of the onion drying and curing process.

NB. Stage 1 takes place during first 2-3 days following store loading and aims to get the onions surface dry - with all vents open air heated to 30°C is blown through the stack at a rate of $425m^3$/h/tonne. Stage 2 follows stage 1 and aims to dry the necks and get the outer scales dry and coloured golden brown. To achieve this air is blown at $170m^3$/h/tonne on recirculation but keeping the temperature between 25-30°C and the RH between 65-75% by venting and intermittent blowing.

At the end of stage 2 the onions were delivered in bulk to the experimental stores at HRI-Kirton.

On arrival, each treatment was put into 48 half tonne bulk bins and in 24 bulk bins of each treatment was buried four weighed and recorded nets of onions containing a minimum of 50 bulbs. The bins with weighed samples were labelled with the treatment code then eight of each treatment were labelled with one of the three stage 3 cooling and storage regimes (see iii below), and each of the eight bins of each treatment for each store was labelled for monthly removals from January to August. The stores were then loaded using the spare bins as guards. The bins were randomised within the store as much as possible but having regard to fairly easy unloading at monthly intervals and the need to keep to a minimum the time the stores were open each month. When the stores were loaded and closed they were blown as per end of stage 2 for two days to ensure the onions were crisp then the three cooling regimes were commenced.

iii. Stage 3 stack cooling rate and final storage temperature

a) The control store was cooled commercially as if by manual control using cool night air to cool the stack slowly aiming to be about 12°C by mid November and 5°C by early December.

b) The second store was cooled rapidly using refrigeration so that in ten days the stack was at 1°C.

c) The third store was treated exactly as the second so that the stack temperature was at 1°C after ten days but the refrigeration was maintained so that the stack was frozen at -2°C following a further ten days.

iv. Removal dates

On the second Tuesday of every month from January to August one bulk bin of each treatment was taken out of store the weighed samples removed and recorded, and the bulk bin put over a commercial grading line and assessed.

4. Husbandry

The field crops were grown commercially to a good standard. The crops in store were managed by an electronic computerised system, designed by Mavis Enderby Electronics Ltd, which was monitored daily and any irregularities or deviation from expected parameters reported to the station maintenance team. Manual back-up to the system was done daily during cooling and weekly once holding temperature had been reached.

5. Records

i. Maleic hydrazide levels into store and at final removal in August.

ii. Electricity inputs into each stage.

iii. Monitoring of store condition.

iv. At each removal;

a) Marketable class of onions.

b) Percentage weight loss of onions.

c) Number of bulbs with external shoots out of 50 and length of internal shoot on 3 x 10 bulbs.

d) Number of skins on 3 x 10 bulbs.

e) Number with internal disorders out of 50 bulbs.

f) Percentage waste by weight in bulk bin after grading.

g) Length of time in shelf life room to induce shooting or rotting.

Diaries of operations

i. Field diary of transplanted Hyton crop.

1.2.90 300 GPG 308 plastic trays were sown with six Hyton seeds per cell and, placed on stillages in an insulated unlit building maintained at 21°C.

12.2.90 Trays transferred to heated venlo glass at 10°C.

17.2.90 Heating reduced to frost protection only.

5.4.90 Onions transplanted: Five rows 305cm apart on a 1.83m bed, which had been prepared with two passes of the Lely Roterra. 90:45:135kg/ha; N:P_2O_5; K_2O had all been applied in the base.

12.4.90 Chlorbufam + chloridazon applied as 2.25kg/ha of Alicep product.

7.8.90 Maleic hydrazide applied as MSS MH 18 (22.5l/ha) to half the crop.

28.8.90 Crop lifted into bulk store to undergo storage stages 1 and 2, drying and curing. The crop treated with MH was kept separate from the untreated crop.

ii. Field diary of Sturon crop raised from sets

18.3.90	Sturon sets (set size 14-21mm diam) planted at a rate of 1.6t/ha on a 1.52m bed system with four rows per bed. Sets planted at 2cm depth and soil was firmed by rolling. Base fertiliser was 32:32:32kg/ha N:P_2O_5:K_2O. Immediately post planting propachlor as 9l/ha Tripart Sentinal plus pendimethalin as 2l/ha StompH applied in 900l water/ha.
1.4.90	Chlorbufam + chloridazon applied as 2.5kg/ha Alicep in 900l water.
8.4.90	30kg/ha nitrogen applied.
29.4.90	1kg/ha Alicep plus Ioxynil as 350ml Totril applied.
5.5.90	30kg/ha nitrogen applied.
17.5.90	700ml/ha Totril applied.
26.6.90	Chlorothalonil + metalaxyl as 1l/ha Folio 575 FW applied.
9.7.90	Chlorothalonil as 1l/ha Tripart Faber + 2kg/ha Copper applied.
17.7.90	Maleic hydrazide applied as 22.5l/ha MSS MH18 to half the trial crop.
13.8.90	Crop lifted into bulk store to undergo storage drying and curing stages 1 and 2. The crop treated with Maleic hydrazide was kept separate from the untreated crop.

iii. Storage Diary

12.9.90	Onions delivered in bulk bins from commercial stores to experimental store area. Four weighed samples were recorded netted and buried into each bulk bin and then each bulk bin was labelled with variety, MH treatment, storage regimes to be loaded into and month of removal. Each store was then loaded according to the statisticians design so that one bulk bin for treatment could be recovered from each store for each month of assessment. Guard bins made up the total per store to 64 bins.
13.9.90	Stores blown as per end of Stage 2 to crisp up the onions.
14.9.90	Bulbs from each treatment put into the shelf life room to assessrate of sprouting. Shelf life conditions were 20°C, 50% RH and a high light intensity. Also, samples of each treatment sent for MH analysis.
17.9.90	Cooling regimes for each store commenced and store conditions monitored 4 x daily until the end of the experiment any deviation

from predicted or final temperature was immediately reported to mechanisation staff to take remedial action.

16.1.91	January removal done for -2°C storage and placed in store at 0 to 0.5°C and positively blown for 2 days.
18.1.91	January removal done for +1°C store and placed with the bins from -2°C storage in a building at 5°C and blown for a further 2 days.
20.1.91	January removal from 5°C store placed with all other bins at ambient and blown for a further 2 days. NB. Stores were open for approximately 30 minutes to allow removal plus re-polythening the stack of boxes.
22.1.91	January assessments done: The four weighed and netted samples were recovered and re-weighed to record percentage weight loss in store. One sample was then put into shelf life room whilst from the other three samples 50 bulbs were counted out and cut in half to record internal disorders, and 10 from each 50 were assessed for length of internal shoot and number of skins. Other quality factors were also noted. As the samples from a bin were being assessed the rest of the bulk bin was passed over the commercial grading line and percentage waste of the treatment recorded.

13.2.91-19.2.91	February removals and assessments done as per January.
13.3.91-19.3.91	March removals and assessment done.
12.4.91-18.4.91	April removals and assessments done.
8.5.91-14.5.91	May removals and assessments done.
5.6.91-11.5.91	June removals and assessments done.
11.7.91-17.7.91	July removals and assessments done.
16.8.91-22.8.91	August removals and assessments done.

23.8.91	Samples from each treatment sent for Maleic hydrazide assessments.
22.11.91	Shelf life assessments terminated.

RESULTS AND DISCUSSION

1. Maleic hydrazide levels in treated and untreated onions at the start and end of the storage regime.

Samples of each treatment were sent for maleic hydrazide analytical determinations at the beginning and the end of the storage period. The results are given in Table 1 but should be treated with some caution as they are unreplicated and the first analysis was done by ADAS Labs, Cambridge but the second by Asplands and James Analytical Services of Chatteris. However, the pattern of the results are consistent, treated Sturon containing more MH than Hyton and treated containing considerably more than untreated. However, the results as they stand would suggest that metabolism of the maleic hydrazide may be quite slow even at 5°C storage. This result needs checking in subsequent trials.

Table 1: Assessments of Maleic hydrazide levels in onions going into store in September 1990 and out of store in August 1991.

Treatment	Maleic hydrazide in sample mg/kg September 1990	Maleic hydrazide in sample mg/ka August 1991
Hyton (No MH) stored at 5°C	1.90	0.62
Hyton (+ MH) stored at 5°C	6.33	11.00
Sturon (No MH) stored at 5°C	0.90	0.73
Sturon (+ MH) stored at 5°C	11.80	16.00
Hyton (No MH) stored at 1°C	1.90	0.61
Hyton (+ MH) stored at 1°C	6.33	14.00
Sturon (No MH) stored at 1°C	0.90	0.57
Sturon (+ MH) stored at 1°C	11.80	17.00
Hyton (No MH) stored at -2°C	1.90	3.10
Hyton (+ MH) stored at -2°C	6.33	12.0
Sturon (No MH) stored at -2°C	0.90	Non detected
Sturon (+ MH) stored at -2°C	11.80	23.00

2. Monitoring of store conditions during cooling and holding of onions at the required temperature

Cooling of the three stores commenced on 17 September 1990 and each store was monitored daily both by a commercial system and an experimental system for temperature and RH within and throughout the stack. An abbreviated summary of this data is presented in Table 2.

Store A, which had a target temperature of 5°C by the middle of December, achieved a temperature of 5.4 by 17 December at a cost of 1,816 units of electricity and required a further 7,000 units to maintain this temperature through to mid June.

Store B, which had a target temperature of 1°C within 10 days of commencement of cooling, achieved this in 12 days at a cost of 1,000 units of electricity and it required a further 16,500 units to maintain this temperature until mid June.

Store C had a target of 1°C in 10 days and -2°C as quickly as possible thereafter. The store achieved the holding temperature (-2°C) in 17 days at a cost of 1,700 units of electricity and required a further 21,000 units to maintain this temperature through until mid June.

Therefore although holding at 1°C achieved rapidly it proved twice as costly as holding after reducing to 5°C achieved slowly. -2°C storage was only 30% more costly than storage at 1°C.

Table 2. Cooling and holding temperature records for each store along with record of electricity used.

Day	Date	Store A Target temp = 5°C by 15.12.90 Temp (°C)	RH (%)	Elec. Units (No)	Store B Target temp = 1°C 10 days after loading Temp (°C)	RH (%)	Elec. Units (No)	Store C Target temp = 1°C 10 days after loading, then -2°C ASAP Temp (°C)	RH (%)	Elec. Units (No)
0	16.9.90	23.0	(62)		23.3	(69)		23.6	(66)	
2	18.9.90	21.6	(34)		19.9	(33)		18.7	(40)	
4	20.9.90	19.2	(56)		14.1	(49)		15.1	(56)	
6	22.9.90	18.5	(62)		8.9	(54)		9.9	(49)	
8	24.9.90	17.9	(65)	85	4.3	(62)	601	5.0	(54)	568
10	26.9.90	16.0	(59)	116	1.6	(76)	797	3.3	(73)	745
<u>12</u>	<u>28.9.90</u>	16.5	(66)	118	<u>1.1</u>	<u>(76)</u>	<u>973</u>	1.1	(73)	996
14	30.9.90	16.7	(70)	121	1.2	(81)	1181	-1.1	(74)	1270
<u>17</u>	<u>3.10.90</u>	17.2	(73)	124	1.3	(84)	1491	<u>-1.9</u>	<u>(79)</u>	<u>1693</u>
31	17.10.90	15.1	(60)	444	1.2	(88)	2446	-1.8	(86)	3192
62	17.11.90	9.8	(70)	938	1.0	(86)	4939	-2.0	(86)	6701
<u>92</u>	<u>17.12.90</u>	<u>5.4</u>	<u>(70)</u>	<u>1816</u>	0.9	(86)	6510	-1.8	(92)	8808
123	17.1.91	5.6	(81)	3044	0.9	(86)	8494	-2.1	(93)	11049
154	17.2.91	5.6	(76)	3983	1.7	(84)	9836	-2.1	(92)	13037
182	17.3.91	5.6	(85)	5564	1.9	(91)	11917	-2.1	(93)	15376
212	17.4.91	5.6	(94)	6582	1.0	(94)	13592	-2.1	(92)	17656
242	17.5.91	5.6	(96)	7711	0.9	(96)	15626	-2.1	(93)	20229
273	17.6.91	5.6	(99)	8863	0.9	(99)	17453	-2.1	(94)	22539

_____ indicates when each store achieved its holding temperature

3. Percentage weight loss in store

Table 3 shows the percentage weight loss for each variety over a 12 month storage period, meaned for all three stores. Weight loss was extremely low averaging about half a percent weight loss per month of storage. Hyton has a slightly higher weight loss than Sturon although this is more likely to be due to the fact that Sturon bulbs in this trial were larger than Hyton so Hyton would have a higher surface area to weight ratio, rather than their being any effect of per se.

Table 3 Effect of variety times removal date on percentage weight loss.

Removal month	Variety Hyton	Sturon	Mean
January	2.1	1.5	1.8
February	2.6	2.1	2.4
March	3.4	2.7	3.1
April	3.2	3.1	3.2
May	3.9	4.1	4.0
June	4.7	3.8	4.3
July	5.6	4.5	5.1
August	7.4	6.5	7.0
Mean	4.1	3.6	3.8

LSD all treatments = 0.49

LSD removal means = 0.35

LSD variety means = 0.16

NB Tables 4 & 5 do not have monthly means included as could be same as for above table

Table 4 shows the effect that an application of Maleic hydrazide has on percentage weight loss in store and the data suggests that weight loss can be reduced by up to 50% in extended storage and this was a consistent finding across all three stores.

Table 4 Effect of maleic hydrazide on percentage weight loss

Removal month	Maleic hydrazide (MH)	
	Plus MH	No MH
January	1.6	2.0
February	2.0	2.7
March	2.9	3.2
April	2.6	3.7
May	3.6	4.4
June	3.3	5.3
July	3.7	6.5
August	4.8	9.2
Mean	3.1	4.6

LSD all treatments = 0.49
LSD treatment means = 0.17

The effect of cooling regime and holding temperature on percentage weight loss was predictable, the higher the temperature the greater the weight loss as shown in Table 5.

Table 5 Effect of removal date and holding temperature on percentage weight loss

Removal month	Storage temperature 5°C	1°C	-2°C
January	3.1	1.3	1.1
February	3.9	1.6	1.5
March	4.6	2.4	2.2
April	5.1	2.7	1.8
May	5.5	3.5	3.0
June	6.1	4.4	2.3
July	7.6	4.6	3.0
August	10.7	6.5	3.7
Mean	5.8	3.4	2.3

LSD all treatments = 0.60

LSD treatment means = 0.20

4. Commercial assessments of individual bulk bins of treatments at monthly intervals

The bins were graded commercially by the farm staff at HRI-Kirton and all decisions concerning marketability were taken by the Farm Manager. No statistics can be applied to the results as only single bins were recorded for observation. However the trend and implications of the records taken are interesting. Presented in Table 6 is the percentage waste recorded for each bin and in Table 7 the marketed class of the produce.

Generally, Sturon had slightly higher percentage waste than Hyton. Maleic hydrazide had no effect on the per cent marketed from the 5°C store until April/May and had no appreciable effect on onions stored at 1°C or -2°C. Certainly onions stored at 5°C could be marketed until March, from 1°C until

May and -2°C until July without the need for maleic hydrazide. Therefore cool/cold storage appears to eliminate the necessity for maleic hydrazide and upon this evidence even appears to be more efficient.

The marketable class of the produce mirrored the results of waste. However quality of onions from the storage regimes will be looked at more closely in the next section of results.

Table 6 Percentage waste per month out of a bulk bin of onions from each treatment which had been commercially graded

Treatment	Percentage waste removal per month								
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Mean
Hyton (No MH) stored at 5°C	2.1	2.3	7.4	3.5	17.8	38.5	100	100	33.9
Hyton (+ MH) stored at 5°C	3.0	2.9	5.0	3.3	3.9	5.3	8.0	100	16.4
Sturon (No MH) stored at 5°C	2.9	3.8	3.3	7.8	12.9	15.7	100	100	30.8
Sturon (+ MH) stored at 5 dC	4.1	3.2	5.2	1.6	4.5	8.9	100	100	28.4
Hyton (No MH) stored at 1°C	2.2	2.5	3.6	3.0	6.5	6.4	100	100	28.1
Hyton (+ MH) stored at 1°C	2.7	2.6	3.6	2.6	3.9	3.8	100	100	27.4
Sturon (No MH) stored at 1°C	2.9	3.6	7.1	6.1	6.2	12.5	100	100	29.8
Sturon (+ MH) stored at 1°C	1.9	1.8	4.5	2.5	3.0	6.1	100	100	27.5
Hyton (No MH) stored at -2°C	2.2	2.6	4.7	3.0	2.7	4.5	7.0	12.1	4.9
Hyton (+ MH) stored at -2°C	1.8	2.3	5.0	4.0	4.2	3.9	7.9	33.6	7.8
Sturon (No MH) stored at -2°C	3.1	2.7	9.2	6.3	6.4	8.6	17.4	30.0	10.5
Sturon (+ MH) stored at -2°C	1.1	2.1	6.0	2.4	5.8	5.2	10.7	21.8	6.9
Mean	2.5	2.7	5.4	3.8	6.5	10.0	62.6	74.8	

Table 7 Class of onions marketed from bulk bins

Treatment	Class of marketed onions per month							
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Hyton (No MH) stored at 5°C	1	1	1	1	2	2	Un	Un
Hyton (+ MH) stored at 5°C	1	1	1	1	1	1	2	Un
Sturon (No MH) stored at 5°C	1	1	1	1	2	2	Un	Un
Sturon (+ MH) stored at 5°C	1	1	1	1	1	1	Un	Un
Hyton (No MH) stored at 1°C	1	1	1	1	1	1	Un	Un
Hyton (+ MH) stored at 1°C	1	1	1	1	1	1	Un	Un
Sturon (No MH) stored at 1°C	1	1	1	1	1	1	Un	Un
Sturon (+ MH) stored at 1°C	1	1	1	1	1	1	Un	Un
Hyton (No MH) stored at -2°C	1	1	1	1	1	1	2	2
Hyton (+ MH) stored at -2°C	1	1	1	1	1	1	2	2
Sturon (No MH) stored at -2°C	1	1	1	1	1	1	2	2
Sturon (+ MH) stored at -2°C	1	1	1	1	1	1	2	2

Un = Unmarketable

5. Quality aspects of bulbs out of storage treatments

a) Number of protective skins

There was no effect of treatment upon number of skins on the bulbs out of store although it must be emphasised that bulbs were analysed prior to going over a grading line and no assessment was made of any effect of treatment on the number of skins at the point of sale. It is hoped to make some assessments of these factors in subsequent years work.

However, as a general observation remarked upon by a number of people, the bulbs from minus 2°C storage looked rougher and more ragged than those out of the other two regimes.

b) Number of bulbs out of 50 with external shoots

Tables 8, 9 and 10 show the effects of variety, MH and storage regime on the number of bulbs out of 50 with external shoots in relation to removal date. The results are very much as would be anticipated. The later the removal date the greater number sprouted, maleic hydrazide suppresses the appearance of sprouts but so does cool and cold storage, in fact minus 2°C is more effective than maleic hydrazide. Perhaps surprisingly Hyton is more prone to sprouting than Sturon.

Table 8 Effect of variety and storage period on number of bulbs out of fifty that had external shoots

Removal month	Variety		Mean
	Hyton	Sturon	
January	0.0	0.0	0.0
February	0.0	0.15	0.03
March	0.5	0.0	0.3
April	1.7	0.6	1.1
May	1.4	0.7	1.0
June	2.3	0.9	1.6
July	5.2	2.1	3.6
August	8.3	4.7	6.5
Mean	2.4	1.1	1.8

LSD all treatments = 0.69
LSD removal means = 0.49
LSD variety means = 0.24

Table 9 Effect of MH on number of bulbs out of 50 that had external shoots

Removal month	Number of bulbs with external shoots Plus MH	No MH
January	0.0	0.0
February	0.0	0.1
March	0.1	0.4
April	0.1	2.2
May	0.1	2.0
June	0.0	3.2
July	0.3	6.9
August	0.4	12.6
Mean	0.1	3.4

LSD all treatments = 0.69

LSD MH means = 0.24

Table 10 Effect of removal date and storage regime on numbers of bulbs out of 50 with external shoots

Removal month	Storage temperature 5°C	1°C	-2°C
January	0.0	0.0	0.0
February	0.1	0.0	0.0
March	0.8	0.0	0.0
April	3.4	0.0	0.0
May	3.0	0.1	0.0
June	4.8	0.0	0.0
July	10.6	0.3	0.0
August	16.2	3.3	0.0
Mean	4.8	0.5	0.0

LSD all treatments = 0.85

LSD temp means = 0.30

c) Mean length of developing shoot inside the bulb

This measurement was taken on three times ten bulb samples per treatment per month. Tables 11, 12 and 13 deal with the effect of variety, MH and storage regime on the effective growth rate of the internal shoot. The consequence being that the longer the shoot the less the shelf life period prior to external shoots appearing.

Variety had little effect on shoot growth and as would be expected the use of MH slowed down shoot growth. 1°C storage slowed down shoot growth but not as much as maleic hydrazide whereas -2°C storage completely inhibited shoot growth until July.

Table 14 shows the interaction between MH and temperature. With MH at -2°C storage there is no shoot growth even in August whereas -2°C held bulbs without MH show some shoot growth in July and August also 1°C storage in absence of MH is not as good as 5°C with MH as determined by shoot growth.

Table 11 Effect of removal date and variety on the internal development of the onion shoot (lengths in mm)

Removal month	Variety		
	Hyton	Sturon	Mean
January	9.4	8.5	9.0
February	10.0	10.6	10.3
March	13.1	11.8	12.5
April	15.9	15.6	15.8
May	15.9	16.8	16.1
June	20.5	18.3	19.4
July	34.6	28.9	31.8
August	30.5	31.9	31.2
Mean	18.7	17.8	18.3

LSD all treatments = 2.7

LSD treatment means (month) = 1.0

LSD treatment means (variety) = ?

Table 12 Effect of removal date and maleic hydrazide on internal development of the onion shoot

Removal month	Maleic hydrazide (MH) Plus MH	No MH
January	5.8	12.1
February	7.1	13.5
March	8.9	16.0
April	11.9	19.7
May	9.9	22.3
June	12.4	26.4
July	20.4	43.1
August	18.1	44.4
Mean	11.8	24.7

LSD all treatments = 2.7

LSD MH treatment means = 1.0

Table 13 Effect of removal date and storage temperature on internal development of the onion shoot (length in mm)

Removal month	Storage temperature 5°C	1°C	-2°C
January	13.7	8.2	5.0
February	18.0	7.3	5.7
March	18.6	12.0	6.7
April	24.4	16.2	6.8
May	26.4	16.6	5.3
June	31.9	20.6	5.7
July	45.1	36.6	13.6
August	42.5	37.4	13.7
Mean	27.6	19.4	7.8

LSD all treatments = 3.4

LSD storage temp means = 1.2

NB 5.0 = no shoot growth taken as base plate of onions

Table 14 Interaction of removal date, MH and storage temperatures on shoot length (mm)

Removal month	MH and storage temperature					
	Plus MH			No MH		
	5°C	1°C	-2°C	5°C	1°C	-2°C
January	6.9	5.6	5.0	20.4	10.9	5.0
February	9.2	6.7	5.5	26.8	7.9	5.8
March	10.1	10.1	6.6	27.1	14.0	6.8
April	15.3	13.4	6.9	33.4	19.0	6.6
May	13.4	11.2	5.1	39.3	22.1	5.5
June	15.2	17.1	5.0	48.7	24.2	6.3
July	22.7	31.2	7.5	67.9	42.1	19.7
August	30.2	17.1	6.8	54.8	57.7	20.6
Mean	15.4	14.0	6.1	39.8	24.7	9.6

LSD all treatments = 4.8

LSD treatment means = 1.7

d) Number of bulbs out of 50 with internal disorders

Disease internal disorders were very low in this trial and did not increase with storage time. However, the main disorder found was freezing damage in the -2°C stored bulbs. In fact this was more of a problem than the results in Tables 15-17 would suggest as only severe damage was recorded as a disorder whilst many bulbs showed slight damage.

The results not surprisingly show that freezing damage was confined to -2°C storage, was unaffected by MH application but that Suron was slightly more susceptible than Hyton. The results show differences between individual months which most likely would have been caused by practical variations in the individual warming up process.

Table 15 Effect of removal month and variety on number of bulbs out of 50 with internal disorders

Removal month	Variety Hyton	Sturon	Mean
January	1.6	2.3	1.9
February	0.6	1.3	1.0
March	1.2	3.3	2.3
April	0.8	1.5	1.1
May	0.6	1.3	0.9
June	1.5	2.1	1.8
July	2.2	2.7	2.5
August	2.3	2.4	2.4
Mean	1.4	2.1	1.7

LSD all treatments = 0.93

LSD variety means = 0.33

LSD removal means = 0.66

Table 16 Effect of removal month and MH on number of bulbs out of fifty with internal disorders

Removal month	Maleic hydrazide Plus MH	No MH
January	1.9	2.0
February	1.1	0.8
March	2.2	2.3
April	1.1	2.2
May	1.0	0.9
June	1.5	2.1
July	2.4	2.5
August	2.3	2.4
Mean	1.7	1.8

LSD all treatments = 0.93

LSD Treatment mean = 0.33

Table 17 Effect of removal month and storage regime on number of bulbs out of 50 with internal disorders

Removal month	Storage temperature 5°C	1°C	-2°C
January	2.5	2.2	1.2
February	1.4	0.5	1.0
March	1.1	0.7	5.0
April	1.1	0.6	1.8
May	0.5	0.5	1.8
June	1.3	0.8	3.3
July	0.6	1.1	5.7
August	0.3	1.3	5.6
Mean	1.1	0.9	3.2

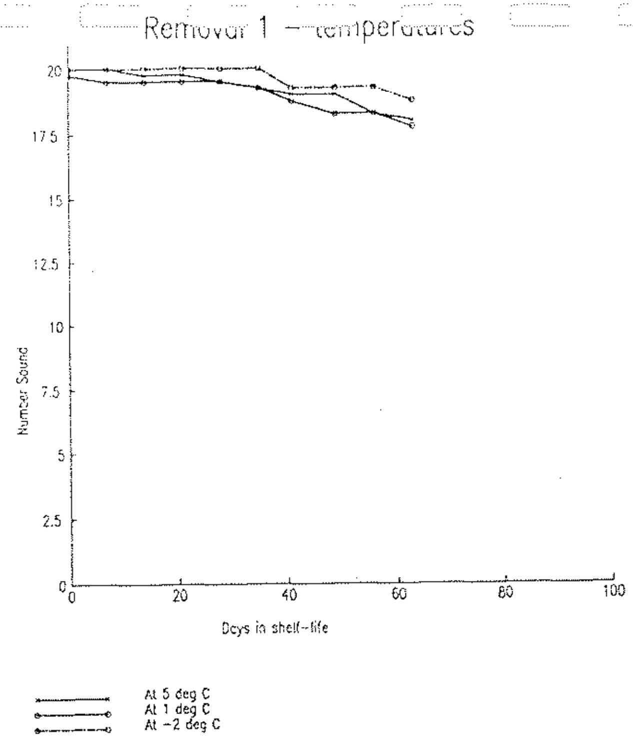
LSD treatments = 1.1

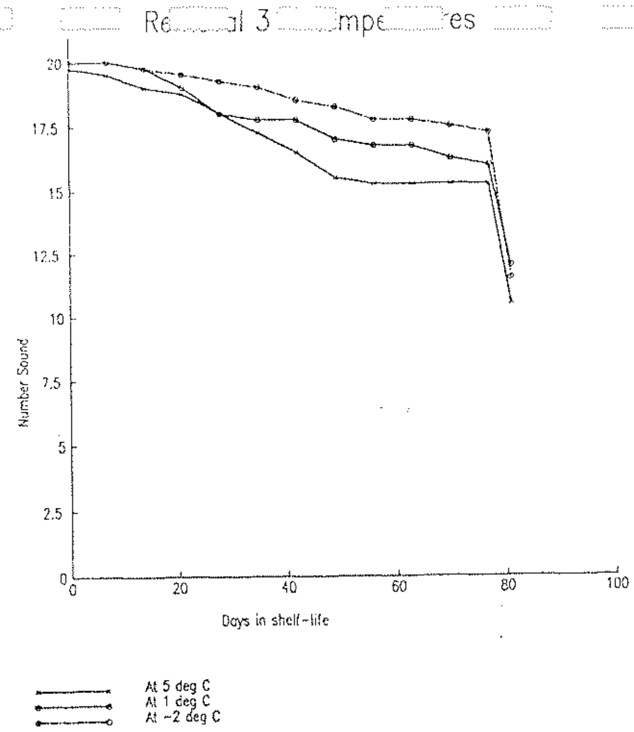
LSD treatment means = 0.4

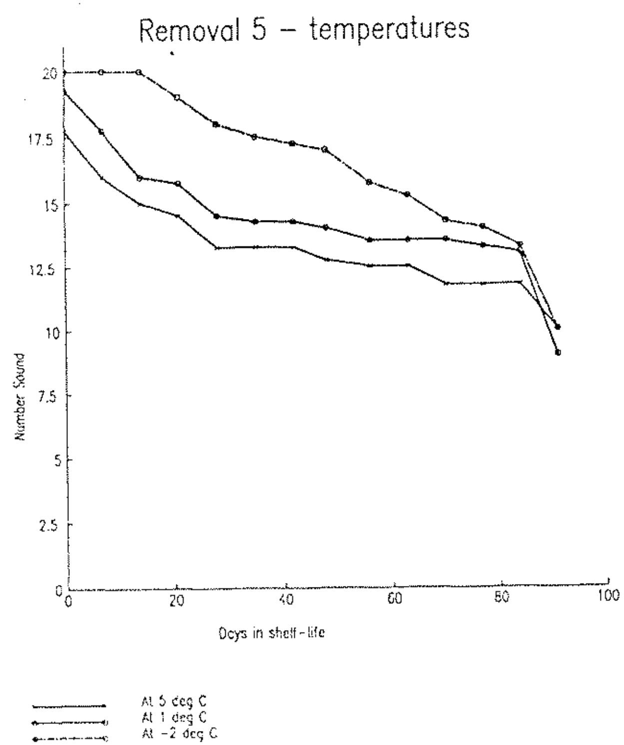
4. Shelf life observations

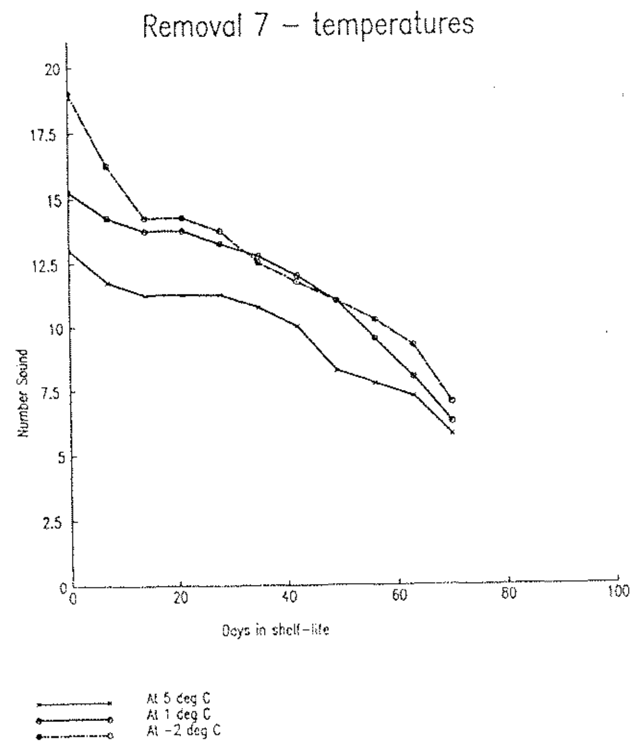
After each monthly removal a sample of each treatment of each store was put in a shelf life room set at 20°C, 50% RH and a high light intensity. At weekly intervals the samples were assessed for number of sprouted or rotted bulbs which were discarded, other reasons for downgrading the sample were ignored as the object of the exercise was to link internal sprout development with post-marketing sprouting.

Figures 1, 2 and 3 show the effects of variety, MH and storage regime on the decline in numbers of sound bulbs from the January, March, May and July removals.

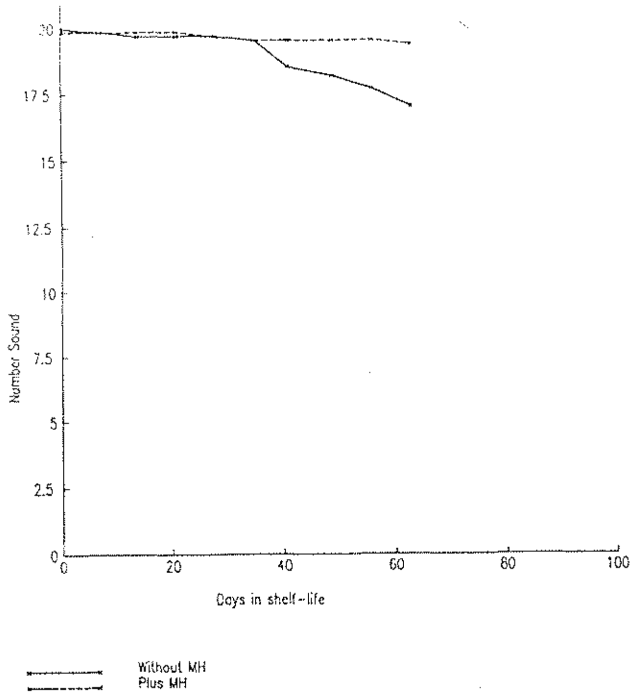

Removal 1 – temperatures
Number Sound
Days in shelf-life
At 5 deg C
At 1 deg C
At -2 deg C


Number Sound
Days in shelf-life
At 5 deg C
At 1 deg C
At -2 deg C

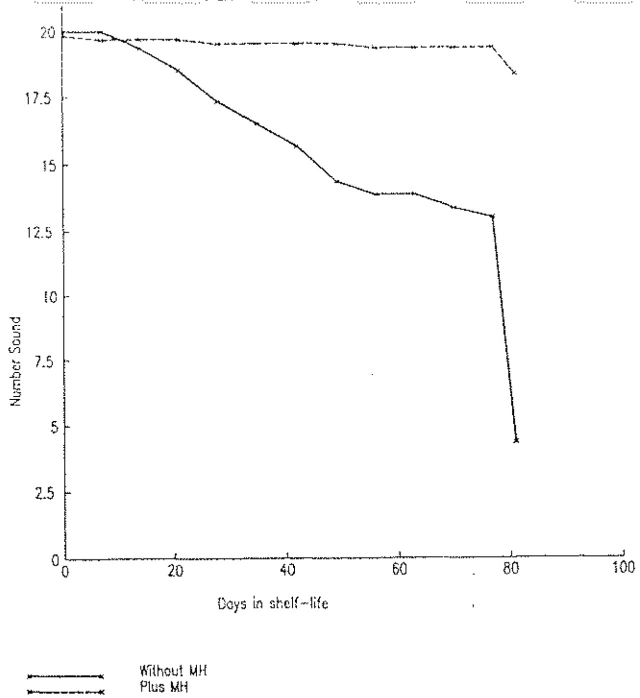

Removal 5 – temperatures
Number Sound
Days in shelf-life
At 5 deg C
At 1 deg C
At -2 deg C


Removal 7 – temperatures
Number Sound
Days in shelf-life
At 5 deg C
At 1 deg C
At -2 deg C

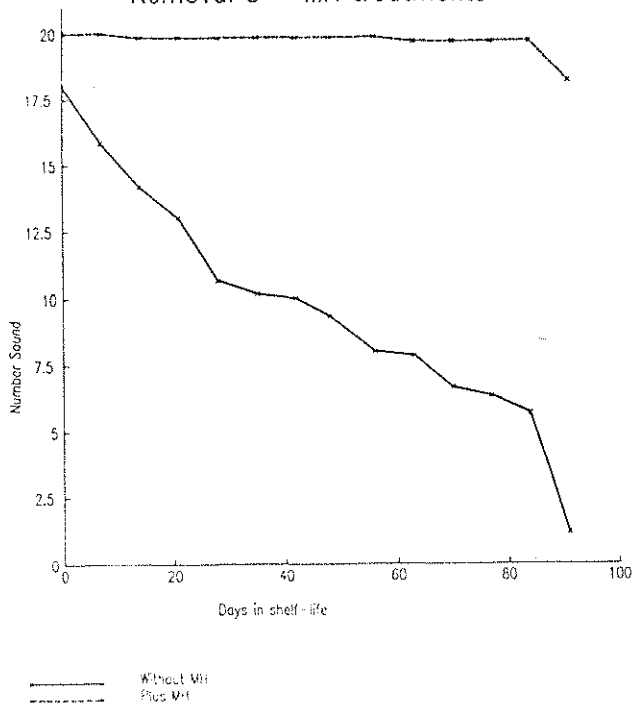
Remo[illegible] 1 – [illegible]trea[illegible]ts



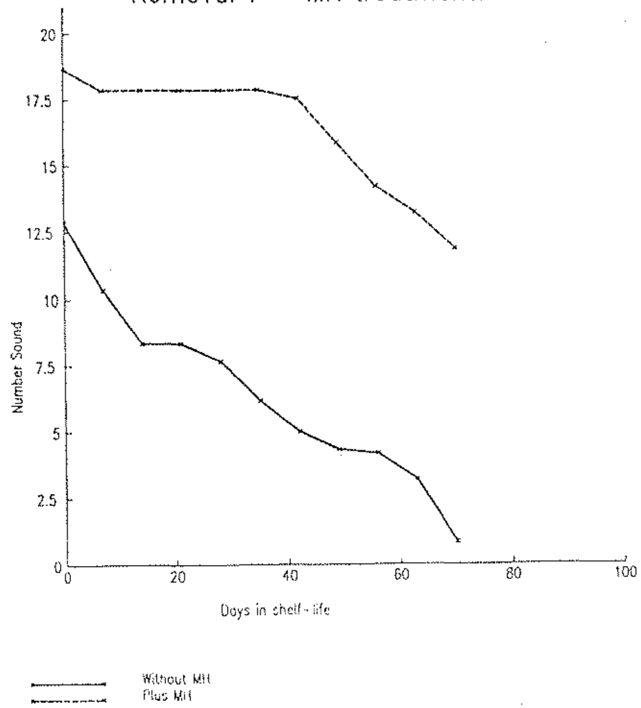
R[illegible]val [illegible] MH [illegible]men[illegible]



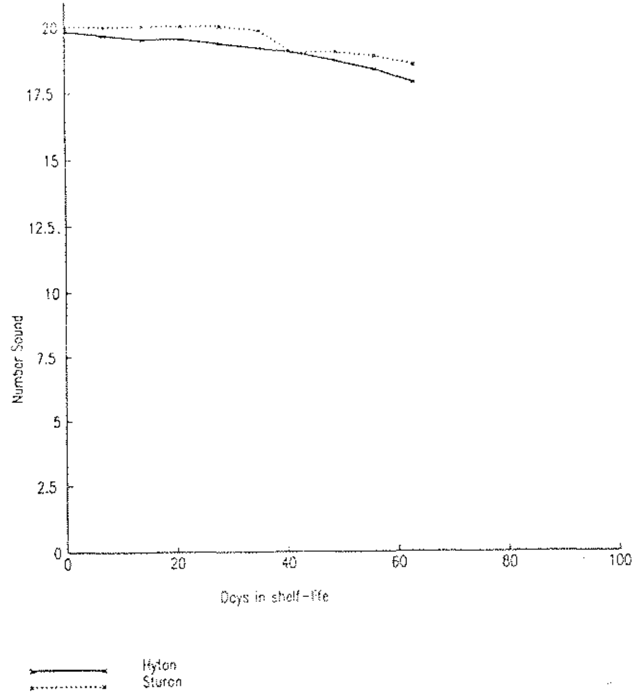
Removal 5 – MH treatments



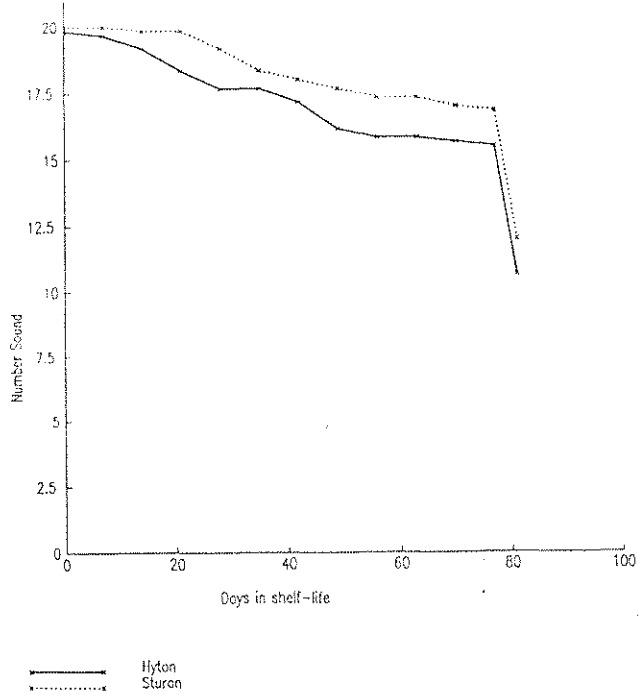
Removal 7 – MH treatments



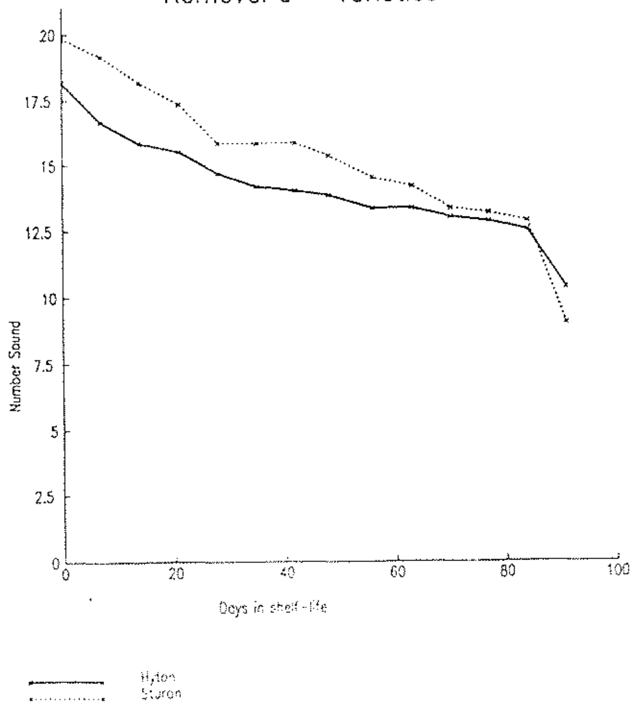
Removal 1 - varieties



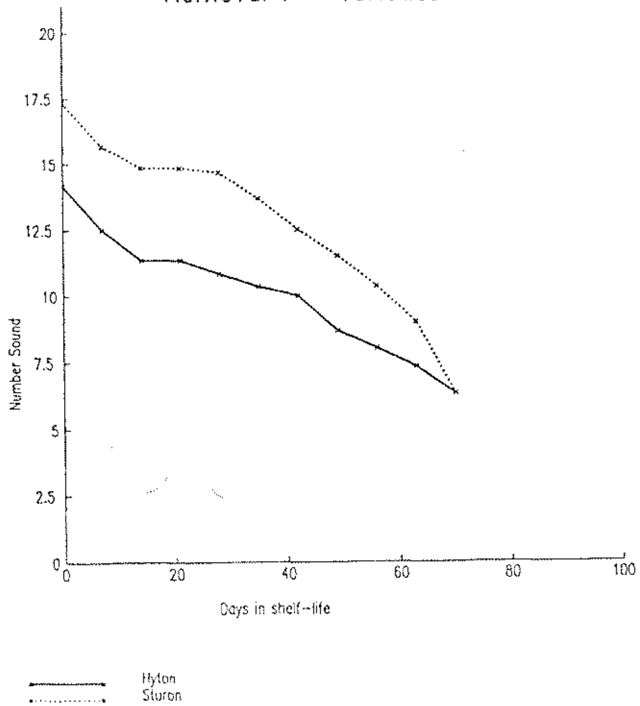
Removal 3 - varieties



Removal 5 - varieties



Removal 7 - varieties



There was only small but consistent differences for variety with Sturon having slightly better shelf life than Hyton. This is consistent with the slightly shorter internal shoot in Sturon.

Again with storage temperature there were only small but consistent differences between the three stores with storage at -2°C better than 1°C which was better than 5°C. However, this is not in keeping with the internal shoot data in Table 13 which would suggest the same order as was observed but would have anticipated much bigger differences. This suggests that shoot development from onions stored at -2°C is faster than those stored at 1° or 5°C when placed under shelf life conditions even though actual shoot length is less from -2°C stored bulbs.

MH had a large effect upon sprout development in shelf life and the effect was maintained for over a year after application.

Conclusions

1. MH was persistent in stored bulbs and the amounts were similar between the three stores.

2. Minus 2°C storage used 2.5 times more electricity than the 5°C storage but only 1.3 times more than the 1°C storage.

3. Percentage weight losses in store were quite small but related to storage temperature and were further reduced by the presence of MH.

4. From a commercial sample of each treatment graded out for marketing, waste was low for all treatments up to April then the 5°C storage without MH declined rapidly whilst the produce from 1°C was good up to June, thereafter it was unmarketable but the -2°C stored bulbs remained marketable up to August even in the absence of MH.

5. External shoot appearance in the later stage of the trial was slightly less with Sturon than Hyton but drastically reduced by MH and cold storage.

6. Development of the internal shoot followed a similar pattern but was reduced much more by cold storage than by MH. However, shoots developed faster in 1°C storage without MH than in 5°C storage with MH.

7. Internal disorders due to disease or physiological problems were low and unaffected by treatment except that -2°C stored bulbs had an unacceptable level of cold/freezing related damage.

8. Bulbs from -2°C storage developed internal shoots faster than bulbs from the other two stores when placed into shelf life conditions.

9. The trial must be repeated for a second year to verify the above observations but modified to look at -1°C storage at which temperature the onions will not freeze but should get the benefits of -2°C length of storage, but with 1°C quality and internal bulb soundness.

Recommendations for further work

The trial should be repeated but with the three cooling regimes amended to:-

A. Rapid cooling using refrigeration to +1°C
B. Rapid cooling using refrigeration to -1°C
C. Rapid cooling using refrigeration to -2°C

Acknowledgement

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