CONTRACT REPORT C98/FV45
ONIONS DRY BULB: EVALUATION OF REGIMES
DESIGNED TO ALLEVIATE THE NECESSITY
FOR A SPROUTING SUPPRESSANT
SECOND YEAR OF TRIAL 1991/2

UNDERTAKEN IN PART FOR THE
MAFF'S CHIEF SCIENTISTS GROUP
AND IN PART FOR
HORTICULTURAL DEVELOPMENT COUNCIL

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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 a true and accurate record of the results obtained.

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(signature)

Date 16-5-94

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RELEVANCE TO GROWERS AND PRACTICAL APPLICATION

APPLICATION

Although the results from this trial suggest that minus 1°C storage in the absence of maleic hydrazide (MH) is very nearly as good at sprout suppression as 1°C storage with MH, it also shows the risks of minus 1°C storage and the role of MH in preventing excessive weight loss which reduces quality in store. Therefore growers should store as near minus one as they safely can and continue to use MH for extended storage.

SUMMARY

Two onion varieties, Sturon from sets and transplanted Hyton, a Rijnsburger variety, were grown commercially and either case treated or not treated with MH 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 and placed in bulk bins then put into the three experimental stores at HRI Kirton, each of which underwent one of the three different Stage 3 cooling regimes indicated below:-

1. Rapid cooling (10 days) to drop to 1°C using ambient air when possible.

2. Rapid cooling (10 days) using refrigeration down to minus 1°C.

3. 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. As in the first year of the trial MH was found to be persistent in stored bulbs and the amounts were similar between the three stores.

2. Again very similar to last year's trial. Minus 2°C storage only used 1.35 times more electricity than the 1°C storage, whilst 1°C and minus 1°C used similar amounts of electricity with the minus 1°C using only 3.5% more.

3. Percentage weight losses in store were quite small but Hyton lost slightly more than Sturon, storage temperature also had an effect with bulbs at 1°C losing twice the weight as ones at minus 2°C with minus 1°C intermediate. MH did not have as large an effect on weight loss as in the previous year.

4. From a commercial sample of each treatment graded out for marketing, the crop at minus 2°C storage was considered unsuitable for marketing at the very first outtake in January due to unaccpetable levels of freezing damage. Both the other stores also had quite high levels of neck rot and it was considered possible that there was an

interaction between the presence of disease and freezing temperature to aggravate the freezing damage. Produce from the other two stores was deemed unmarketable in June, largely due to root regrowth and basal plate splitting.

5. The trial was terminated before external shoots appeared.

6. Development of the internal shoot followed a similar pattern to the previous year and was reduced much more by cold (-2°C) storage than by MH. However shoot development was similar in bulbs at minus 1°C storage without MH to those in 1°C storage with MH, and this treatment could go some way towards replacing the need for MH in the pre-May marketing period; however, the danger of freezing and the improved quality that MH can have in reducing weight loss means that it is unsafe at present to suggest this as an option.

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

8. The trial should be continued in a modified way for a third year to verify the above observation that minus 1°C storage can relieve the need for MH for pre-May marketing but with controlled relative humidity to try to lower the incidence of root regrowth.

EXPERIMENTAL SECTION

INTRODUCTION

For British growers to supply home-grown onions into the market place and 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 to prolong the storage period. Although some of the most recent selections of Rijnsburger onions have improved inherent storability 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 natural long-term storage capability.

The original chemical sprouting suppressant used was the amine salt of MH which has a question mark over its safety as amine radicles are carcinogenic. However, the industry now uses the 'safe' potassium salt, but, as the chemical has attracted media attention its continued use could become an emotive issue and in such cases scientific data invariably loses out to emotion. Therefore, it is quite possible that the industry could lose MH, and, 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.

In the first year of the trial (report issued January 1992) an alternative method of sprout suppression known to be possible, which was to store onions at minus 2°C, was tested against

1°C and 5°C storage with two varieties, both either treated or not with MH. Produce was withdrawn from stores at monthly intervals for assessment.

The following were the main findings of that trial:

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 minus 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 (ie minus 2°C) 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 bulbs from the other two stores when placed into shelf life conditions.

Therefore, for the second year's work it was decided to repeat the 1°C and minus 2°C treatments but to replace the 5°C with minus 1°C which, for the onion stored crop, would represent a sub zero but non-freezing temperature.

OBJECT

The object of this project is to investigate the potential to produce 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 Institute Field, to raise and grow the crop of Hyton from transplants. The crop of Sturon was grown commercially from sets on a local farm (G Thompson Farms, Holbeach St Marks).

The onions were stored in three 40 tonne experimental stores for various periods, 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, delivered to HRI Kirton where they were taken through Stages 1 and 2 of the onion drying and curing process.

NB. Stage 1 takes place during the first 2-3 days following store loading and aims to get the onions surface dry. This is done by keeping all vents open, and, air heated to 30°C, is blown through the stack at a rate of 425m^3/h/tonne. Stage 2 follows 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.

When the Hyton reached the end of Stage 2 the onions were unloaded to allow the trial to be set up. Each treatment was put into 48 half tonne bulk bins and in 24 bulk bins of each treatment was buried three weighed and recorded nets of onions containing 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 trial bins were randomised within the store 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) Store 1 was cooled rapidly using refrigeration so that in ten days the stack was at 1°C.

b) Store 2 was cooled rapidly using refrigeration so that in ten days the stack was at 1°C. The refrigeration was maintained until the stack reached minus 1°C.

c) Store 3 was treated exactly as store B so that the stack temperature was at 1°C after ten days, the refrigeration was maintained until the stack was frozen at minus 2°C.

iv. Removal dates

On the second Tuesday of every month from January to July 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. The August removal was aborted due to all treatments being unmarketable.

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 deviations from expected parameters reported to the station maintenance team. Manual back-up to the system was done daily during cooling and weekly once holding temperatures had been reached.

5. Records

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

ii. Electricity inputs into each store.

iii. Monitoring of store condition.

iv. At each removal, for each treatment;

a) Marketable class of onions.
b) Percentage weight loss of onions.
c) Number of bulbs with external shoots out of 3 x 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 in 3 x 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.

TRIAL DIARY

4.2.91 350 GPG 308 plastic trays sown with 4-5 onion seeds per cell (cv Hyton) trays put on stillages in single layer and germinated and grown in the dark at 21°C for 10 days.

14.2.91 Trays of onion seedlings transferred to heated Venlo glasshouse and kept at a minimum of 10°C for one week and then night frost protection only.

9.4.91 Onions transplanted: Five rows 305 cm apart on a 1.83 m bed which had been prepared with two passes of a Lely roterra. The multi-seeded transplants were planted by machine 30.5 cm apart in the row.

10.4.91 Chlorbufam + chloridazon applied as 2.25 kg/ha Alicep.

10.7.91 Stores sterilised prior to onion loading.

13.8.91 Half of Hyton crop sprayed with MH as Fazor.

29.8.91 MH treated and untreated onions cv Sturon delivered to HRI Kirton in bulk, put into bins and then into store for Stage 1 and Stage 2 drying. At end of Stage 2 onions held at this point until Hyton also at end of Stage 2.

5.9.91 Hyton crop harvested keeping the two treatments separate and put into a store for Stages I and II drying.

25.9.91 Stores unloaded to allow bulk bins to receive weighed sample nets and the treatments were sorted and labelled. Stores then reloaded and put on Stage 2 drying regime for two days to re-crisp onions. Samples taken for MH analysis.

27.9.91 Cooling regimes begun.

8.10.91 Stores at 1°C, Store 1 held at this temperature.

17.10.91 Store 2 at minus 1°C and held.

18.10.91	Store 3 at minus 2°C and held.
7.1.92	January bulk bin assessments removed and over next seven days warmed to ambient temperature.
14.1.92	January assessments.
4&11.2.92	February removal and assessments.
3&10.3.92	March removal and assessments.
7&14.4.92	April removal and assessments.
5&12.5.92	May removal and assessments.
9&16.6.92	June removal and assessments.
7&14.7.92	July removal and assessments. Samples also taken for MH analysis.

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 MH 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. However the following are consistent and indicate that little metabolism of the MH happened over the whole storage period at minus 1 and minus 2°C but some metabolism seems to have taken place at 1°C. The results show that this is a very persistent chemical especially at sub zero storage temperatures.

Table 1. Assessments of maleic hydrazide levels in onions going into store in September 1991 and out of store in July 1992

Treatment	Maleic hydrazide in sample mg/kg September 1991	Maleic hydrazide in sample mg/kg July 1992
Hyton (No MH) stored at 1°C	ND	ND
Hyton (+ MH) stored at 1°C	2.8	0.8
Sturon (No MH) stored at 1°C	ND	ND
Sturon (+ MH) stored at 1°C	8.6	4.2
Hyton (No MH) stored at -1°C	ND	ND
Hyton (+ MH) stored at -1°C	2.8	1.9
Sturon (No MH) stored at -1°C	ND	ND
Sturon (+ MH) stored at -1°C	8.6	6.1
Hyton (No MH) stored at -2°C	ND	ND
Hyton (+ MH) stored at -2°C	2.8	2.6
Sturon (No MH) stored at -2°C	ND	ND
Sturon (+ MH) stored at -2°C	8.6	7.0

ND = None Detected ie <0.1 mg/kg

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

Cooling of the three stores commenced on 26 September 1991 and each store was monitored daily both by a commercial system and a more elaborate experimental system, for temperature and RH within and throughout the stack. An abbreviated summary of this data is presented in Table 2.

Store 1, which had a target temperature of 1°C within 10 days of starting Stage 3, achieved a temperature of 1.3°C by day 12 using 821 units of electricity and required a further 18,309 units to maintain this temperature through to mid July.

Store 2, which had a target temperature of minus 1°C within 20 days of commencement of cooling, achieved this in 26 days using 1824 units of electricity and it required a further 17,962 units to maintain this temperature until mid July.

Store 3 had a target of minus 2°C in 30 days. The store achieved the holding temperature (minus 2°C) in 26 days using 2782 units of electricity and required a further 23,891 units to maintain this temperature through until mid July.

Store 2 took a little longer to cool to required temperature than desired due to an early malfunction. Interestingly, to cool to and hold at minus 1°C did not utilise an appreciably greater amount of electricity (3.5%) than to cool and hold at 1°C whilst storage at minus 2°C consumed 34% more electricity which is a figure very similar to that found for the previous years' trial.

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

Day	Date	Store 1 Target temp = Rapidly to 1°C			Store 2 Target temp = Rapidly to -1°C			Store 3 Target temp = Rapidly to -2°C		
		Temp (°C)	RH (%)	Elec. Units (No)	Temp (°C)	RH (%)	Elec. Units (No)	Temp (°C)	RH (%)	Elec. Units (No)
0	26 Sept	18.7	45	0	21.1	48	0	24.3	64	0
6	1 Oct	16.4	44	202	14.5	47	306	12.6	47	410
12	7 Oct	1.3	68	821	1.9	75	928	1.5	71	1108
19	14 Oct	1.1	82	1283	16	82	1358	-1.5	79	2020
26	21 Oct	1.0	77	1688	-0.9	75	1824	-2.7	70	2782
61	25 Nov	1.0	80	3547	-0.8	84	3881	-2.0	83	5559
89	23 Dec	1.2	84	4988	-0.6	88	5504	-2.5	83	7510
117	20 Jan	1.1	83	6477	-0.6	86	7109	-2.5	85	9387
142	24 Feb	1.0	84	8456	-0.6	86	9094	-2.4	85	11708
169	23 Mar	1.1	89	9998	-0.8	88	10826	-2.6	86	13668
198	21 Apr	1.1	85	11745	-0.9	87	12560	-2.4	84	15641
243	26 May	1.7	93	14415	-0.6	92	15283	-2.4	83	18523
269	22 June	1.3	97	16927	-0.8	92	17692	-2.5	84	21257
290	13 July	1.4	98	19130	-0.7	99	19796	-2.4	82	26673

______ indicates when each store achieved its holding temperature

3. Percentage weight loss in store

Table 3 shows the percentage weight loss for each variety at monthly intervals for the storage period expressed as means for all three stores. Weight loss was extremely low and very similar to those seen in 1990 averaging about half a percent weight loss per month of storage. Hyton had a slightly higher weight loss than Sturon again, as was seen in the previous trial (1990/91). In that year it was deemed due to the fact that Sturon bulbs were larger than Hyton to start with but, as in this year, the bulbs were of a more even size it may be that Sturon retains water more efficiently because of a better skin wrapping.

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

Removal month	Variety		
	Hyton	Sturon	Mean
January	2.1	1.4	1.7
February	2.0	1.6	1.8
March	3.0	2.4	2.7
April	3.9	2.9	3.4
May	4.5	2.6	5.5
June	5.6	4.6	5.1
July	5.9	5.1	5.5
Mean	3.9	2.9	

LSD all treatments = 1.9
LSD removal means = 1.4
LSD variety means = 0.7

NB Tables 4 and 5 do not contain monthly means as they would be the same as in the above table.

Table 4 shows the effect that an application of maleic hydrazide has on percentage weight loss in store and although the data suggests that weight loss could be reduced by the presence of maleic hydrazide it is not as dramatic as the 1990 trial which showed up to 50% weight loss reduction in extended storage with MH.

Table 4 Effect of removal date and maleic hydrazide on percentage weight loss

Removal month	Maleic hydrazide (MH)	
	Plus MH	No MH
January	1.6	1.9
February	1.9	1.8
March	3.2	2.3
April	2.7	4.0
May	3.5	3.5
June	4.8	5.4
July	4.3	6.7
Mean	3.1	3.6

LSD all treatments = 1.93
LSD treatment means = 0.7

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		
	1°C	-1°C	-2°C
January	2.2	1.7	1.4
February	2.2	1.7	1.6
March	2.5	3.3	2.4
April	4.7	2.9	2.5
May	4.3	4.0	2.2
June	7.0	5.1	3.2
July	9.3	4.2	3.1
Mean	4.6	3.3	2.3

LSD all treatments = 2.4

LSD treatment means = 0.9

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

The bins of onions 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.

Produce stored at minus 2°C was considered unmarketable when the stores were first opened in January due to a very high level of freezing damage. Losses from the two non freezing stores were generally similar and considerably higher than the previous year due mainly to neck rot, until June when all samples were considered unfit for sale, largely due to root regrowth, however up until that time (as Table 7 shows) quality of graded produce had been good.

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	Mean
Hyton (No MH) stored at 1°C	12.0	5.5	9.9	19.5	12.7	100	100	37.1
Hyton (+ MH) stored at 1°C	6.4	3.2	6.5	7.6	8.5	100	100	33.2
Sturon (No MH) stored at 1°C	6.7	6.4	5.7	5.4	5.7	100	100	32.8
Sturon (+ MH) stored at 1°C	4.1	6.6	4.4	4.7	4.2	100	100	32.0
Hyton (No MH) stored at -1°C	4.6	7.7	7.6	18.9	15.4	100	100	36.3
Hyton (+ MH) stored at -1°C	18.2	6.1	18.7	12.1	11.7	100	100	38.1
Sturon (No MH) stored at -1°C	6.6	4.5	6.8	8.3	6.4	100	100	33.2
Sturon (+ MH) stored at -1°C	7.0	6.3	5.1	4.3	5.1	100	100	32.5
Hyton (No MH) stored at -2°C	100	100	100	100	100	100	100	100
Hyton (+ MH) stored at -2°C	100	100	100	100	100	100	100	100
Sturon (No MH) stored at -2°C	100	100	100	100	100	100	100	100
Sturon (+ MH) stored at -2°C	100	100	100	100	100	100	100	100
Mean	38.8	37.2	38.7	40.1	39.1	100	100	

Table 7 Class of onions marketed from bulk bins

Treatment	Percentage waste removal per month						
	Jan	Feb	Mar	Apr	May	Jun	Jul
Hyton (No MH) stored at 1°C	1	1	1	1	1	Un	Un
Hyton (+ MH) stored at 1°C	1	1	1	1	1	Un	Un
Sturon (No MH) stored at 1°C	1	1	1	1	2	Un	Un
Sturon (+ MH) stored at 1°C	1	1	1	1	2	Un	Un
Hyton (No MH) stored at -1°C	1	1	1	1	1	Un	Un
Hyton (+ MH) stored at -1°C	1	1	1	1	1	Un	Un
Sturon (No MH) stored at -1°C	1	1	1	1	1	Un	Un
Sturon (+ MH) stored at -1°C	1	1	1	1	1	Un	Un
Hyton (No MH) stored at -2°C	Un	Un	Un	Un	Un	Un	Un
Hyton (+ MH) stored at -2°C	Un	Un	Un	Un	Un	Un	Un
Sturon (No MH) stored at -2°C	Un	Un	Un	Un	Un	Un	Un
Sturon (+ MH) stored at -2°C	Un	Un	Un	Un	Un	Un	Un

Un = Unmarketable

To check on the freezing problem 25 bulbs from each treatment were cut open immediately after each monthly take-out. In January 50% of bulbs kept at minus 2°C were frozen whilst none were of those kept at minus 1°C. By February the number frozen at minus 2°C had risen to 80% but still none were frozen at minus 1°C. The results of the rest of the outtakes stayed as for February.

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 when taken 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. Data is not presented.

b) Number of bulbs out of 50 with external shoots

There were no external shoots recorded until July and then numbers were so low that it was not possible to analyse or discern if there was any relationship to treatment. Data is not presented.

c) Mean length of developing shoot inside the bulbs as a percentage of the distance from the basal meristem to the neck.

This measurement was taken on three, ten-bulb samples per treatment per month. Tables 8, 9 and 10 deal with the effect of variety, MH and storage regime on the effective growth rate of the internal shoot. The presumed 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 but as would be expected the use of MH slowed down shoot growth. Minus 1°C storage slowed down shoot growth but not as much as maleic hydrazide especially at the later stages of the trial whereas minus 2°C storage completely inhibited shoot growth although it is possible that the meristems may have been damaged by freezing.

Table 11 shows the interaction between MH and temperature. With bulbs held at minus 2°C there is no shoot growth in any treatment whilst minus 1°C storage in absence of MH is nearly as good as 1°C with MH as determined by shoot growth, however, shoot growth suppression is further enhanced at minus 1°C in the presence of MH and there are other considerations which make the advent of minus 1°C in the absence dangerous and produces a lower quality product out of store.

Table 8 Effect of removal date and variety on the internal development of the onion shoot (% of distance from meristem to neck)

Removal month	Variety Hyton	Sturon	Mean
January	0	0	0
February	4.5	5.0	4.8
March	13.2	18.7	16.0
April	23.9	29.9	26.9
May	31.4	31.9	31.7
June	48.0	43.7	45.9
July	46.0	45.8	45.9
Mean	23.8	25.0	

LSD all treatments = 5.1

LSD treatment means (month) = 3.6

LSD treatment means (variety) = 2.1

Table 9 Effect of removal date and maleic hydrazide on internal development of the onion shoot (% of distance from meristem to neck)

Removal month	Maleic hydrazide (MH) Plus MH	No MH
January	0	0
February	1.9	7.5
March	14.1	17.9
April	19.3	34.4
May	15.5	47.8
June	37.6	54.1
July	24.3	67.5
Mean	16.1	32.7

LSD all treatments = 5.1

LSD MH treatment means = 2.1

Table 10 Effect of removal date and storage temperature on internal development of the onion shoot (% of distance from meristem to neck)

Removal month	Storage temperature		
	1°C	-1°C	-2°C
January	0	0	0
February	9.4	0	0
March	15.6	16.3	0
April	28.6	25.1	0
May	32.5	30.8	0
June	56.0	35.7	0
July	53.1	36.7	0
Mean	28.2	20.6	0

LSD all treatments = 5.1

LSD storage temp means = 2.1

LSD treatment means (variety) = 2.1

Table 11 Interaction of removal date, MH and storage temperatures on shoot length (% of distance from meristem to neck)

Removal month	MH and storage temperature					
	Plus MH			No MH		
	1°C	-1°C	-2°C	1°C	-1°C	-2°C
January	0	0	0	0	0	0
February	3.8	0	0	15.1	0	0
March	12.7	15.4	0	18.5	17.3	0
April	20.3	18.4	0	37.0	31.9	0
May	23.0	18.1	0	42.0	23.6	0
June	45.7	29.5	0	66.3	41.8	0
July	37.5	21.0	0	72.1	32.3	0
Mean	19.0	14.6	0	35.9	16.7	0

LSD all treatments = 7.3

LSD treatment means = 2.9

d) Number of bulbs out of 50 with internal disorders

In contrast to the previous year's work, when very few internal disorders were found, in this years trial the figures are relatively high. Table 12 shows that Hyton had more problems than Sturon and that the incidence of disease did progress with time. Table 13 shows that maleic hydrazide had no effect upon percentage of bulbs with internal disorders whilst Table 14, shows that storage temperature had a large effect on levels of internal disorders with the minus 2°C storage having very high levels due to freezing damage. However the two non-freezing temperatures also had high levels of neck rot which progressed to total bulb rot as the trial continued. It was considered possible that there might be an interaction between disease levels and freezing damage which would explain the very different level of freezing damage in the two years of the trial. Table 15 shows that Hyton had more neck rot in the unfrozen bulbs and more freezing damage in the frozen bulbs thus giving some substance to this hypothesis.

Table 12 Effect of removal month and variety on the percentage of bulbs out of 50 with internal disorders

Removal month	Variety		
	Hyton	Sturon	Mean
January	26.9	14.6	20.8
February	26.7	17.6	22.2
March	24.4	17.1	20.8
April	34.3	15.3	24.8
May	37.5	21.1	29.3
June	41.6	19.7	30.6
July	36.0	30.7	33.3
Mean	32.5	19.4	

LSD all treatments = 4.1

LSD variety means = 1.5

LSD removal means = 2.9

Table 13 Effect of removal month and MH on the percentage of bulbs out of 50 with internal disorders

Removal month	Maleic hydrazide	
	Plus MH	No MH
January	24.3	17.2
February	23.5	20.8
March	22.5	19.1
April	22.9	26.7
May	26.9	31.6
June	30.3	30.8
July	31.9	34.8
Mean	26.0	25.9

LSD all treatments = 4.1

LSD treatment mean = 1.5

Table 14 Effect of removal month and storage temperature on the percentage of bulbs out of 50 with internal disorders

Removal month	Storage temperature		
	1°C	-1°C	-2°C
January	11.6	10.0	40.7
February	9.7	9.2	47.6
March	7.5	14.1	40.8
April	14.2	14.3	45.8
May	11.4	14.9	61.4
June	11.9	18.1	61.9
July	20.3	17.7	62.1
Mean	12.4	14.0	51.1

LSD all treatments = 5.1

LSD treatment mean = 1.9

Table 15 Interaction of temperature and varieties and effects on internal disorders (neck rot in the case of 1°C and minus 1°C and freezing damage in the case of minus 2°C)

Variety	Temperature		
	1°C	-1°C	-2°C
Hyton	17.21	18.32	61.92
Sturon	7.52	9.76	41.01
LSD treatments = 2.6			

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 during storage with post-marketing sprouting.

Figures 1, 2 and 3 in Appendix 1 show the effects of variety, MH and storage regime on the decline in numbers of sound bulbs from the January, March and May removals. But only for the 1°C and minus 1°C storage temperature stores as the minus 2°C stored produce was unfit for shelf life evaluation.

Although bulbs rapidly became unmarketable due to skin discolouration (maximum 14 days) shelf-life was continued in order to further evaluate sprouting.

Hyton was slightly quicker to sprout than Sturon which is a little surprising as Table 8 shows that if anything Sturon was slightly ahead of Hyton in terms of shoot development going into shelf-life.

As expected the presence of MH had the greatest effect of depressing sprouting but on removals 1 and 3 there was no difference on the levels of sprouting during the normal shelf-life period of up to 14 days. At removal 5 the effect of MH was more striking.

Whether the bulbs were stored at 1°C or minus 1°C made no difference to subsequent shelf life.

CONCLUSIONS

1. As in the first year of the trial MH was found to be persistent in stored bulbs and the amounts were similar between the three stores.

2. Again, very similar to last year's trial, minus 2°C storage only used 1.35 times more electricity than the 1°C storage, whilst 1°C and minus 1°C used similar amounts of electricity.

3. Percentage weight losses in store were quite small but Hyton lost slightly more than Sturon, storage temperature also had an effect with 1°C losing twice the weight as minus 2°C with minus 1°C intermediate MH did not have as large an effect on weight loss as in the previous year.

4. From a commercial sample of each treatment graded out for marketing, the minus 2°C storage was considered unsuitable for marketing at the very first outtake in January due to unacceptable levels of freezing damage. Both the other stores also had quite high levels of neck rot and it was considered possible that there was an interaction between the presence of disease and freezing temperature to aggravate the freezing damage. Produce from the other two stores was deemed unmarketable in June mainly due to root regrowth and basal plate splitting.

5. External shoots did not appear in this trial as the trial was terminated early.

6. Development of the internal shoots followed a similar pattern to the previous year and was reduced much more by cold (-2°C) storage than by MH. However shoots development was similar in onions at minus 1°C storage without MH as those in 1°C storage with MH, and this treatment could go some way to replacing the need for MH in the pre-May marketing period, however, the danger of freezing and the improved quality that MH can give in reducing weight loss means that it is unsafe at present to suggest this as an option.

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

8. The trial should be continued in a modified way for a second year to verify the above observation that minus 1°C storage can relieve the need for MH for pre-May marketing but with controlled relative humidity to try to lower the incidence of root regrowth.

RECOMMENDATIONS FOR FURTHER WORK

The trial should be continued but with one cooling regime of -1°C but the stores held at three relative humidities.

1. Rapid cooling using refrigeration to -1°C and held at 90% RH.
2. Rapid cooling using refrigeration to -1°C and held at 70% RH.
3. Rapid cooling using refrigeration to -1°C and held at 50% RH.

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APPENDIX 1

FIG 1 : SHELF LIFE OF DIFFERENT VARIETIES

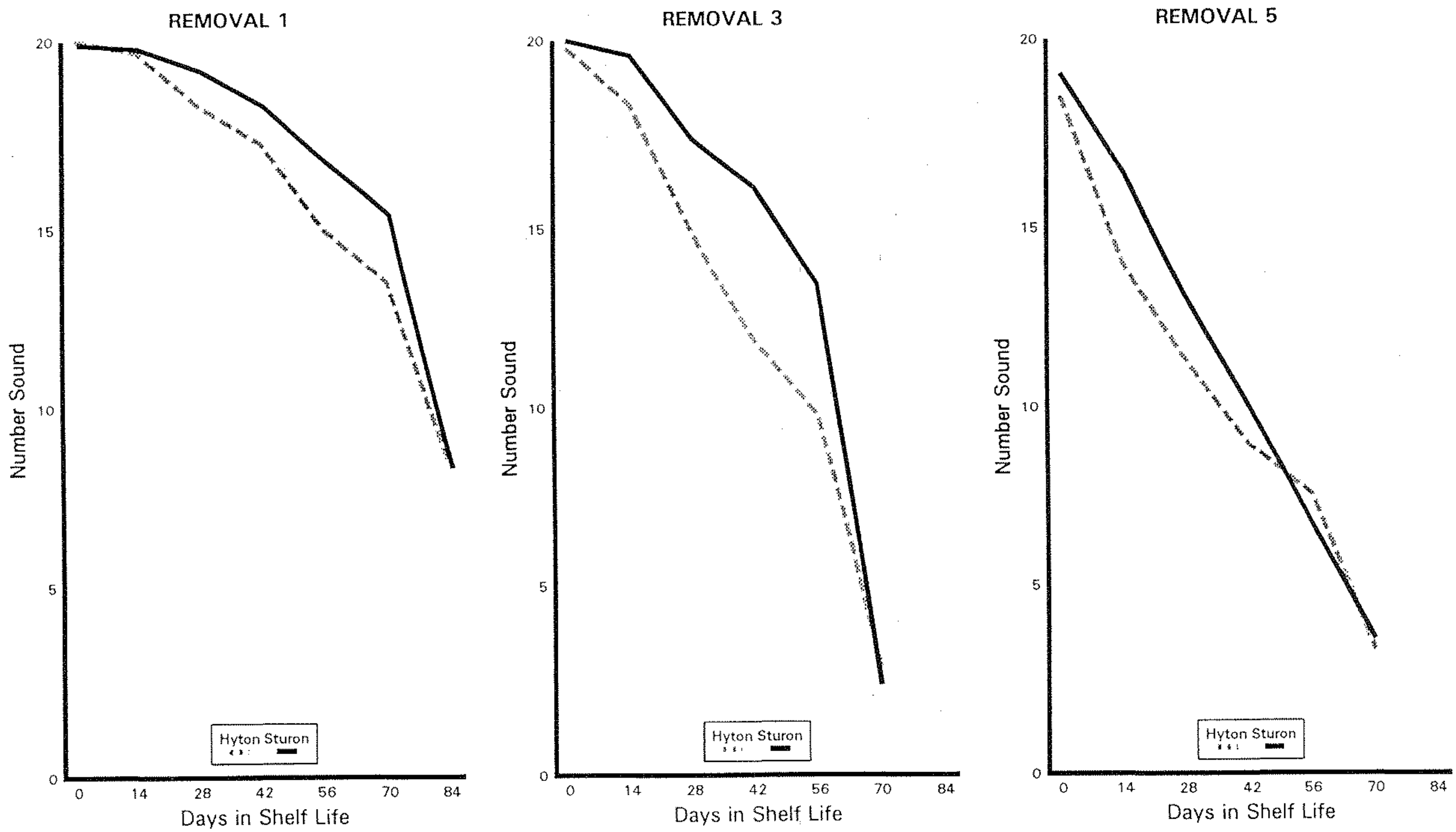

FIG 2 : SHELF LIFE OF ONIONS WITH OR WITHOUT MH TREATMENT

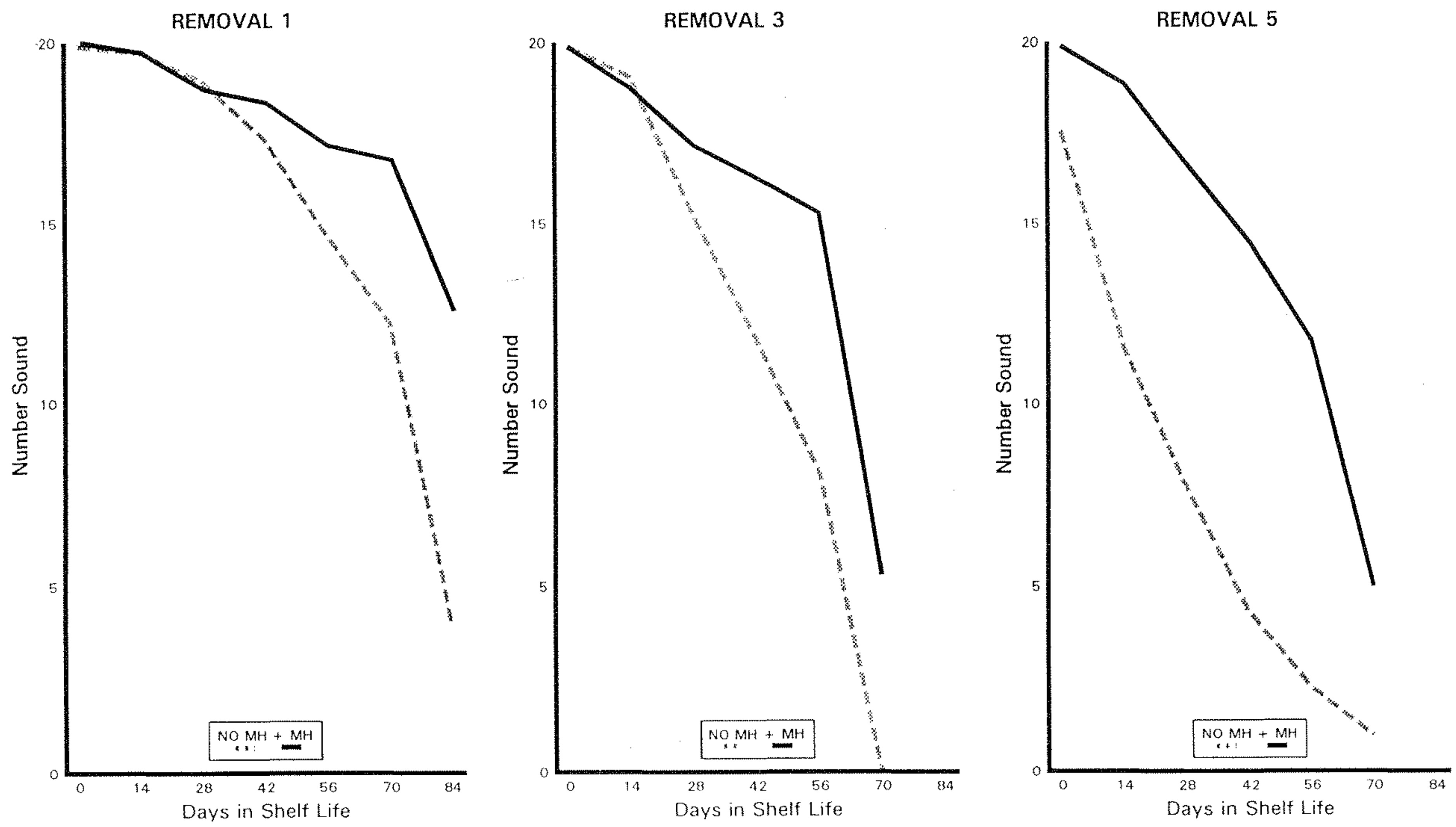

FIG 3 : SHELF LIFE OF ONIONS STORED AT DIFFERENT TEMPERATURES