CONTRACT REPORT FV45
ONIONS DRY BULB: EVALUATION OF REGIMES DESIGNED TO ALLEVIATE THE NECESSITY FOR A SPROUTING SUPPRESSANT

UNDERTAKEN IN PART FOR THE
MAFF'S CHIEF SCIENTISTS GROUP
AND IN PART FOR
HORTICULTURAL DEVELOPMENT COUNCIL
THIRD YEAR OF THE TRIAL

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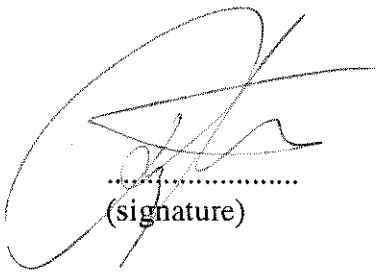
AUTHENTICATION

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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RELEVANCE TO GROWERS AND PRACTICAL APPLICATION

APPLICATION

The results of this trial support the application given in Year 2 Trial Report that growers should store as close as they safely can to minus 1°C but without dropping below minus 1°C and continue to use maleic hydrazide (MH) for extended storage.

SUMMARY

Three onion varieties, Sturon and Tasman from sets and transplanted Caribo, a Rijnsburger variety, were grown commercially and either treated or not treated with MH before being harvested. They were dried in either a commercial store or the HRI store on the Kirton site 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 Stage 3 cooling to minus 1°C and then held at one of three relative humidities (RHs).

Target RH's:-

1. 90% RH (This was in fact uncontrolled and was at least 90% RH see Table 2)

2. 70% RH (In the event the dehumidifier could only cope with keeping store 3 at about 50% RH and 70% RH was not achieved; instead store 2 was run at 85% RH)

3. 50% RH

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 in all three stores.

2. As in the previous two years, percentage weight loss was quite small, averaging about half a per cent weight loss per month. Sturon lost less weight than the Rijnsburger variety. The presence of MH also slightly reduced weight loss in extended storage with Caribo and Sturon but not with Tasman. Onions stored at 50% RH lost about 30% more weight than those stored at 90% target RH.

3. From a commercial sample of each treatment graded out for marketing, the Tasman variety was considered unsuitable for marketing after February due to exclusive rots. Both the other varieties also had quite high levels of neck rot although Sturon was less badly effected than Caribo. Only MH treated bulbs were considered marketable in June.

4. External shoots did not appear in this trial as it was terminated early. Caribo had more skins than Sturon but there was no treatment effect on skin retention.

5. Internal shoots grew faster in Sturon than Caribo and even at minus 1°C storage shoot growth was considerable in the absence of MH. Store RH had no effect on shoot growth, and no root regrowth was seen in this trial.

6. Shelf-life of produce kept until May was considerably worse if the crop had not been sprayed with MH.

EXPERIMENTAL SECTION

INTRODUCTION

For British growers to supply home-grown onions into the market place to meet a significant proportion of the year-round demand 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, this chemical is 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 had 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 stored onion crop, would represent a non-freezing temperature.

Storage temperature apart the second year's trial was very similar to the first year. Two onion varieties, Sturon from sets and transplanted Hyton, a Rijnsburger variety, were grown commercially and in 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 and refrigeration.

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-July 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 the previous 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 of ones at minus 2°C with bulbs at minus 1°C giving intermediate weight loss. 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 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, 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 as in the previous year and was reduced much more by cold (minus 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 bulbs grown for the pre-May marketing period; however, the danger of freezing when storing at minus 2°C and the improved quality (especially firmness) that MH can have in reducing weight loss, means that it is unsafe at present to suggest relying on minus 1°C 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.

Therefore in the third year it was decided to further investigate the minus 1°C storage regime and combine that with an investigation of lower relative humidities.

OBJECT

The object in year three of this project was to further 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 three 40t experimental stores two of which were modified by installing an MD300 Munter

Dehumidifier, a commercial grading facility, a scientific recording area and a shelf-life room.

2. Test crops

i. Onions dry bulb variety Caribo raised from transplants.
ii. Onions dry bulb variety Sturon raised from sets.
iii. Onions dry bulb variety Tasman raised from sets.

Tasman is the label used to describe a variety normally grown in Tasmania and which compete so strongly with our late stored varieties. The sets were raised in Holland.

3. Trial design and treatments

i Varieties
Three, 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 and the above treatments kept separate. The Tasman and Sturon were taken through Stages 1 and 2 of the onion drying and curing process by the farmer before delivery to HRI Kirton but the Caribo was delivered direct from the field to HRI Kirton where they were also taken through Stages 1 and 2 of the onion drying and curing process. All drying was done in bins.

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 Caribo reached the end of Stage 2 and the other two varieties had been delivered (10 October) the onions were unloaded to allow the trial to be set up. Each treatment was put into 32 half tonne bulk bins. 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 on 13 October.

iii. Stage 3 stack cooling rate and final storage temperature

All stores were 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.

iv. Removal dates

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

The field diary as supplied for the Sturon and Tasman sets is given below.

Previous cropping:		Winter wheat	
Cultivations:		November 91	ploughed
		12.3.92	Lely Roterra + American Roll
Fertiliser:	Base:	Mid January	500 kg/ha 0-20-30 giving 100 kg/ha $P_2 0_5$ and 150 kg/ha $K_2 0$
	Top:	24.4.92	86 kg/ha Nitram giving 30 kg/ha nitrogen
		11.5.92	64 kg/ha Nitram giving 22 kg/ha nitrogen
Planting/Drilling:		12.3.92	
Herbicides:		7.3.92	Pre-planting - diquat + paraquat as 2.5 l Parable/ha
		16.3.92	Pre-emergence - propachlor as 9 l/ha Ramrod + pendimethalin as 3.5 l/ha Sovereign 330 EC /ha
		11.4.92	Post-emergence - chlorbufam + chloridazon as 0.75 kg Alicep + ioxynil as 200 ml Totril
		19.4.92	Post-emergence - chlorbufam + chloridazon as 0.75 kg Alicep + ioxynil as 200 ml Totril
		2.5.92	Post-emergence - chlorbufam + chloridazon as 0.75 kg Alicep + ioxynil as 100 ml Totril
		9.5.92	Post-emergence - 4 lt Ramrod/ha
		11.5.92	Post-emergence - 375 ml Totril + fluroxypyr as 250 ml Starane/ha
		24.5.92	Post-emergence - clopyralid as 375 ml Dow shield/ha
		13.3.92	Post-emergence - clopyralid as 375 ml Dow shield/ha
Insecticides:		None	
Fungicides:		8.6.92	Chlorothalonil as 1 l/ha Bravo + mancozeb and metalaxyl as Fubol 1.5 kg + manganese sulphate 5 kg + Spraymate Bond.
		24.6.92	Bravo 1 lt + Fubol 1.5 kg + Bond
		2.7.92	Bravo 1 lt + Fubol 1.5 kg + Bond
Irrigation:		6.5.92	25 ml water applied
		14.6.92	25 ml water applied
Notes:		16.7.92	MH (18% formulation applied at 15 l/ha
		31.7.92	Harvested and put into labelled bulk bins for drying on-site

Onions of all three varieties were delivered by 5 October to HRI Kirton.

7+8.10.92	Trial set up, weighed samples put into bulk bins and labelled bins into store
9.10.92	Stores blown as Stage 2 to crisp up the onions
13.10.92	Cooling commenced
14.11.92	Minus 1°C temperature achieved
5.1.93	January outtake for warming up
12.1.93	January grading and recording
3.2.93	February outtake
10.2.93	February grading and recording
2.3.93	March outtake
11.3.93	March grading and recording
5.4.93	April outtake
13.4.93	April grading and recording
3.5.93	May outtake
11.5.93	May grading and recording

RESULTS AND DISCUSSION

1. Maleic hydrazide (MH) 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 from unreplicated samples. However, they are consistent and indicate that little metabolism of the MH happened over the whole storage period at minus 1°C.

MH breakdown was unaffected by relative humidity (RH) during the storage period.

Table 1. Assessments of maleic hydrazide (MH) levels in onions going into store in October 1992 and out of minus 1°C storage in June 1993

Treatment	Maleic hydrazide in sample mg/kg	Maleic hydrazide in sample mg/kg
Caribo (No MH) stored 90% RH	0.2	ND
Caribo (+ MH) stored 90% RH	5.9	5.0
Sturon (No MH) stored 90% RH	0.2	ND
Sturon (+ MH) stored 90% RH	6.4	4.7
Tasman (No MH) stored 90% RH	0.2	ND
Tasman (+ MH) stored 90% RH	6.9	5.6
Caribo (No MH) stored 70% RH	0.2	ND
Caribo (+ MH) stored 70% RH	5.9	4.8
Sturon (No MH) stored 70% RH	0.2	ND
Sturon (+ MH) stored 70% RH	6.4	4.7
Tasman (No MH) stored 70% RH	0.2	ND
Tasman (+ MH) stored 70% RH	6.9	5.3
Caribo (No MH) stored 50% RH	0.2	ND
Caribo (+ MH) stored 50% RH	5.9	5.1
Sturon (No MH) stored 50% RH	0.2	ND
Sturon (+ MH) stored 50% RH	6.4	5.2
Tasman (No MH) stored 50% RH	0.2	ND
Tasman (+ MH) stored 50% RH	6.9	5.6

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

The electrical inputs were monitored during the trial but not presented as all three stores were cooled to and held at the same temperature therefore electrical inputs were similar. The electricity used for dehumidification did not go through the store meters and so was not assessed. Cooling commenced on October 13 and the holding temperature of minus 1°C was achieved one month later. When the required temperature had been reached then the dehumidifier was switched on. It had been calculated by engineers that this machine could keep two of the stores of onions at regulated RH's one at 50% RH and another at 70% RH, it had been plumbed into stores 2 and 3 accordingly with an automatic switch from one store to the other but with an override to store 2 (50% RH) should both stores have required dehumidifying at the same time. In the event it took virtually continuous running to achieve 50% in

store 2 and that took seven weeks to achieve. Therefore as dehumidification rarely happened in store 3 it never got near its intended RH and was usually only a few percent lower than the uncontrolled, and these should be considered as the same treatment.

Table 2. Cooling and holding temperature and RH records for each store

Day	Date	Store 1 Target temp = -1°C Target RH = 90%		Store 2 Target temp = -1°C Target RH = 50%		Store 3 Target temp = -1°C Target RH = 70%	
		Temp (°C)	RH (%)	Temp (°C)	RH (%)	Temp (°C)	RH (%)
1	Oct 13	19.5	62	21.0	44	19.3	52
7	Oct 19	15.7	63	13.8	69	15.9	53
14	Oct 26	11.8	70	11.7	67	11.8	65
21	Nov 2	7.6	79	7.6	76	7.6	77
28	Nov 9	3.2	82	3.1	79	3.2	78
33	Nov 14	-0.9	83	-0.7	82	-0.9	76
49	Nov 30	-0.6	88	-0.7	67	-0.7	85
50	Dec 31	-0.9	90	-0.9	50	-0.7	86
110	Jan 30	-0.9	94	-1.0	52	-0.9	88
139	Feb 20	-1.1	94	-1.0	45	-1.0	88
170	Mar 31	-0.9	95	-1.0	49	-0.8	88
199	Apr 29	-1.0	97	-1.0	52	-0.9	92
229	May 29	-0.6	94	-0.9	58	-0.8	94
261	June 30	-0.8	93	-1.0	72	-0.9	96

____ indicates when each store achieved its holding temperature and RH

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 and 1991 averaging about half a percent weight loss per month of storage. For the third year running the Rijnsburger variety, in this case Caribo, had a slightly higher weight loss than Sturon which is thought to retain more water because of a better skin wrapping. Tasman lost a small but significantly greater amount of water than Caribo.

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

Removal month	Variety			
	Caribo	Sturon	Tasman	Mean
January	3.1	2.8	3.0	3.0
February	3.7	3.0	3.1	3.3
March	4.3	3.2	4.9	4.1
April	4.3	3.8	4.8	4.3
May	5.2	4.8	5.3	5.1
June	5.5	5.2	7.1	5.9
Mean	4.4	3.8	4.7	

LSD all treatments = 0.75
LSD removal means = 0.10
LSD variety means = 0.29

NB Tables 4 to 6 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 MH has on percentage weight loss in store and although the data shows that weight loss could be reduced by the presence of MH overall it is not as dramatic as the 1990 trial which showed up to 50% weight loss reduction in extended storage when MH was used7, but examination of the interaction between variety and MH in Table 5 shows that MH has little effect on Tasman but a large effect on the other two varieties. The reason for this is not known.

The possibility that Tasman contains a higher level of endogenous sprouting inhibitors is not borne out by internal shoot development data presented later.

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

Removal month	Maleic hydrazide (MH)	
	Plus MH	No MH
January	2.6	3.3
February	3.1	3.4
March	4.1	4.1
April	4.0	4.7
May	4.6	5.6
June	5.5	6.4
Mean	4.0	4.6
LSD all treatments = 0.57		
LSD MH treatment means = 0.23		

Table 5 Effect of variety times removal date times MH on percentage weight loss

Removal month	Variety x MH					
	Caribo + MH	Caribo No MH	Sturon + MH	Sturon No MH	Tasman + MH	Tasman No MH
January	2.7	3.4	2.0	3.5	3.1	2.9
February	3.2	4.2	2.9	3.1	3.7	2.9
March	4.2	4.4	2.8	3.6	5.3	4.4
April	4.0	4.7	3.3	4.3	4.7	5.0
May	4.4	6.1	4.2	5.4	5.2	5.5
June	4.9	6.2	4.4	6.0	7.3	7.0
Mean	3.9	4.8	3.3	4.3	4.8	4.6
LSD all treatments = 0.99						
LSD variety x MH means = 0.40						

Table 6 shows the effect of lowering RH on percentage weight loss and, not surprisingly, onion in 50% RH storage lost about a third more weight than those in the other two stores which had similar RH's. However, the increased weight loss was less than expected.

Table 6 Effect of removal date and holding relative humidities on percentage weight loss

Removal month	Target store RH %		
	90	70	50
January	2.8	2.9	3.2
February	3.0	3.0	3.8
March	3.7	3.9	4.8
April	3.6	3.8	5.7
May	4.3	4.2	6.8
June	5.6	5.2	7.1
Mean	3.8	3.8	5.2

LSD all treatments = 0.70

LSD RH treatment means = 0.25

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 Vegetable Chargehand. 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 7 is the percentage waste recorded for each bin and in Table 8 the marketable Class of the produce.

Most of the waste was caused by rots starting in the neck and progressing to whole bulb rots. The amount of waste appears to be unaffected by the relative humidity in store but there are differences between varieties with Tasman having very high levels of waste (averaging 48.7%), Caribo having less (but still averaging 30.7% waste) with Sturon least (but still an unacceptable 21% waste). The reason for these high levels of waste is not known but it is a little surprising as the treatments came from two sources and were dried in two separate stores.

In the case of Caribo and Sturon , the presence of MH appears to reduce the level of waste from 31.6 to 20.2 percent. The mean level of waste appears to be relatively stable until April and then rises rapidly.

In Table 8 it can be seen that although Tasman was graded out for actual percentage marketable (Table 7) it was deemed commercially unmarketable after February. Sturon had better quality than Caribo which was Class 2 from March onwards. Only MH-treated bulbs were marketable in June.

Table 7 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	Mean
Caribo (No MH) stored at 90% RH	22.0	23.5	18.5	15.8	42.5	100.0	37.1
Caribo (+ MH) stored at 90% RH	6.2	34.9	27.6	18.5	20.9	43.0	25.2
Sturon (No MH) stored at 90% RH	11.4	9.1	9.4	9.1	26.0	100.0	27.5
Sturon (+ MH) stored at 90% RH	11.9	8.1	9.8	9.8	23.5	43.2	17.8
Tasman (No MH) stored at 90% RH	27.8	58.5	28.9	28.9	25.0	100.0	46.8
Tasman (+ MH) stored at 90% RH	29.4	42.2	23.4	23.4	39.0	100.0	47.5
Caribo (No MH) stored at 70% RH	37.2	32.8	14.9	17.5	39.7	100.0	40.4
Caribo (+ MH) stored at 70% RH	4.0	13.5	29.3	27.8	10.1	45.6	20.9
Sturon (No MH) stored at 70% RH	10.2	6.3	5.6	6.0	33.0	67.0	21.4
Sturon (+ MH) stored at 70% RH	11.5	10.5	11.7	7.6	21.5	38.0	16.8
Tasman (No MH) stored at 70% RH	27.7	32.3	34.8	29.9	27.0	100.0	42.0
Tasman (+ MH) stored at 70% RH	26.3	42.1	33.1	26.0	21.7	100.0	41.5
Caribo (No MH) stored at 50% RH	23.1	24.6	14.6	14.8	31.6	100.0	34.8
Caribo (+ MH) stored at 50% RH	14.7	10.1	14.9	15.8	21.7	77.4	25.8
Sturon (No MH) stored at 50% RH	8.2	11.5	8.0	9.3	30.1	100.0	27.9
Sturon (+ MH) stored at 50% RH	12.4	16.6	8.1	15.5	24.6	39.8	19.5
Tasman (No MH) stored at 50% RH	28.8	48.2	30.2	34.2	50.0	100.0	48.6
Tasman (+ MH) stored at 50% RH	26.6	58.5	38.7	28.2	33.6	100.0	47.6
Mean	18.9	26.9	22.0	18.8	29.0	80.8	

Table 8 Class of onions marketed from bulk bins

Treatment	Class of onions marketed					
	Jan	Feb	Mar	Apr	May	Jun
Caribo (No MH) stored at 90% RH	1	1	2	2	2	UN
Caribo (+ MH) stored at 90% RH	1	1	2	2	2	2
Sturon (No MH) stored at 90% RH	1	1	1	1	1	UN
Sturon (+ MH) stored at 90% RH	1	1	1	1	1	2
Tasman (No MH) stored at 90% RH	1	1	UN	UN	UN	UN
Tasman (+ MH) stored at 90% RH	1	1	UN	UN	UN	UN
Caribo (No MH) stored at 70% RH	1	1	2	2	2	UN
Caribo (+ MH) stored at 70% RH	1	1	2	2	2	2
Sturon (No MH) stored at 70% RH	1	1	1	1	1	UN
Sturon (+ MH) stored at 70% RH	1	1	1	1	1	2
Tasman (No MH) stored at 70% RH	1	1	UN	UN	UN	UN
Tasman (+ MH) stored at 70% RH	1	1	UN	UN	UN	UN
Caribo (No MH) stored at 50% RH	1	1	2	2	2	UN
Caribo (+ MH) stored at 50% RH	1	1	2	2	2	2
Sturon (No MH) stored at 50% RH	1	1	1	1	1	UN
Sturon (+ MH) stored at 50% RH	1	1	1	1	1	2
Tasman (No MH) stored at 50% RH	1	1	UN	UN	UN	UN
Tasman (+ MH) stored at 50% RH	1	1	UN	UN	UN	UN

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 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. The only consistent difference was that Sturon averaged 2.0 skins whilst Caribo had 2.3 skins. 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 9, 10 and 11 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.

In earlier years of the trial variety had little effect on shoot growth but what effect there was showed the Rijnsburger variety to shoot slightly faster than Sturon. Surprisingly in this trial Sturon produced shoots considerably faster than either of the other two varieties (Table 9 and 12).

MH had a very large effect on sprouting suppression and considering that all three stores were at minus 1°C the sprouting growth in the absence of MH is very disappointing. Store RH had no effect on sprout growth.

Table 12 shows the interaction of variety, removal date and MH and shows that Tasman in the presence of MH does not commence growth until May although in the absence of MH sprout growth was very similar to Caribo.

Note that the January data has been omitted as it was inconsistent with the rest of the data.

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

Removal month	Variety			
	Caribo	Sturon	Tasman	Mean
February	2.8	19.7	3.2	8.6
March	2.9	16.5	6.9	8.8
April	7.0	17.8	11.0	11.9
May	17.0	22.6	15.7	18.4
June	24.9	35.7	24.7	28.4
Mean	10.9	22.5	12.3	
LSD all treatments = 2.65				
LSD treatment means (month) = 1.53				
LSD treatment means (variety) = 1.19				

Table 10 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
February	2.9	14.3
March	0.9	16.6
April	0.8	23.1
May	2.0	34.9
June	10.2	46.7
Mean	3.3	27.1
LSD all treatments = 2.17		
LSD MH treatment means = 0.97		

Table 11 Effect of removal date and store RH on internal development of the onion shoot (% of distance from meristem to neck)

Removal month	Target store RH %		
	90	70	50
February	8.6	10.1	7.0
March	8.4	9.0	8.8
April	11.9	11.3	12.6
May	19.1	19.6	16.5
June	29.3	24.1	31.9
Mean	15.5	14.8	15.9
LSD all treatments = 2.65			
LSD RH treatment means = 1.19			
LSD variety treatment means = 1.19			

Table 12 Interaction of removal date, MH and variety on shoot length (% of distance from meristem to neck)

Removal month	MH and variety					
	Plus MH			No MH		
	Caribo	Sturon	Tasman	Caribo	Sturon	Tasman
February	0.8	7.8	0.0	4.7	31.6	6.5
March	0.8	1.8	0.0	5.0	31.1	13.7
April	2.3	0.0	0.0	11.6	35.6	22.0
May	5.7	0.1	0.0	28.3	45.0	31.3
June	13.8	8.2	8.6	35.8	63.3	40.9
Mean	4.7	3.6	1.7	17.1	41.3	22.9
LSD all treatments = 3.75						
LSD MH treatment x variety means = 1.68						

d) Number of bulbs out of 50 with internal disorders

As commented earlier, there were high levels of waste due to rotting in the grade out and that was supported by the internal disorders data. In fact the number of rotting bulbs did not markedly increase with time and so it is presumed that it is an increase in the severity of rot that caused the increased percentage waste with time.

Also as indicated earlier, Sturon was less affected than the other two varieties (Table 13). There were slightly less rots in absence of MH than with it although it is suspected that the significance of this difference is a statistical quirk. Storage RH had no effect on internal problems.

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

Removal month	Variety			
	Caribo	Sturon	Tasman	Mean
January	16.6	5.7	15.7	12.7
February	21.1	6.1	14.3	13.8
March	21.5	7.1	18.3	15.6
April	20.2	10.9	17.1	16.0
May	24.9	6.1	20.5	17.2
June	19.8	7.8	16.8	14.8
Mean	20.7	7.3	17.1	
LSD all treatments = 3.13				
LSD variety means = 1.28				
LSD removal means = 1.8				

Table 14 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	12.1	13.3
February	15.0	12.7
March	18.7	12.5
April	16.1	16.0
May	16.1	18.3
June	18.0	11.6
Mean	16.0	14.0
LSD all treatments = 2.56		
LSD MH treatment mean = 1.04		

Table 15 Effect of removal month and store RH on the percentage of bulbs out of 50 with internal disorders

Removal month	Target store RH		
	90%	70%	40%
January	11.6	13.0	13.5
February	12.8	14.6	14.1
March	17.6	14.2	15.0
April	15.5	14.6	18.1
May	19.5	15.5	16.6
June	14.6	13.9	16.1
Mean	15.3	14.3	15.6
LSD all treatments = 3.13			
LSD RH treatment mean = 1.28			

6. Shelf-life observations

After each monthly removal a sample of bulbs from each treatment from each store was put in a shelf-life room set at 20°C, 50% RH and a high light intensity, aimed at simulating supermarket conditions. 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-market 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.

Tasman was not put into shelf-life as it was considered unfit due to such high levels of rots. Of the other two varieties (Fig 1) for the Jan and March removal there were no differences during the normal shelf-life period of up to 14 days and no consistent differences thereafter. At the May removal Sturon deteriorated faster during the first 14 days than Caribo.

As in both previous years MH had a very big effect on lengthening shelf-life (Fig 2) but for removal 1 and 3 in Jan and March MH had little effect on the first 14 days of shelf-life, but at removal 5 in May, MH was essential to achieve any appreciable store shelf-life from produce that had been held at minus 1°C.

Store relative humidity had no consistent effect on rotting or sprouting in shelf-life but the 50% RH treatments did look more tired and tatty.

CONCLUSIONS

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

2. As in the previous two years percentage weight loss was quite small averaging about half a per cent weight loss per month. Sturon lost less weight than the Rijnsburger variety. The presence of MH also slightly reduced weight loss in extended storage with Caribo and Sturon but not with Tasman. Onions stored at 50% RH suffered about 30% more weight loss than those stored at 90% target RH.

3. From a commercial sample of each treatment graded out for marketing, the Tasman variety was considered unsuitable for marketing after February due to excessive rots. Both the other varieties also had quite high levels of rot although Sturon less so than Caribo. Only MH treated bulbs were considered to be marketable in June.

4. External shoots did not appear in this trial as the trial was terminated early. Caribo had more skins than Sturon but there was no treatment effect on skin retention.

5. Internal shoots grew faster in Sturon than Caribo and even at minus 1°C storage shoot growth was considerable in the absence of MH. Store RH had no effect on shoot growth.

6. Shelf life of produce kept until May was considerably worse if the crop had not been sprayed with MH.

RECOMMENDATIONS FOR FURTHER WORK

The trial should be discontinued whilst a review of controlled atmosphere storage of onions is done as this is considered a potential way forward.

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APPENDIX 1

Fig 1 : Shelf Life of Onions of Different Varieties

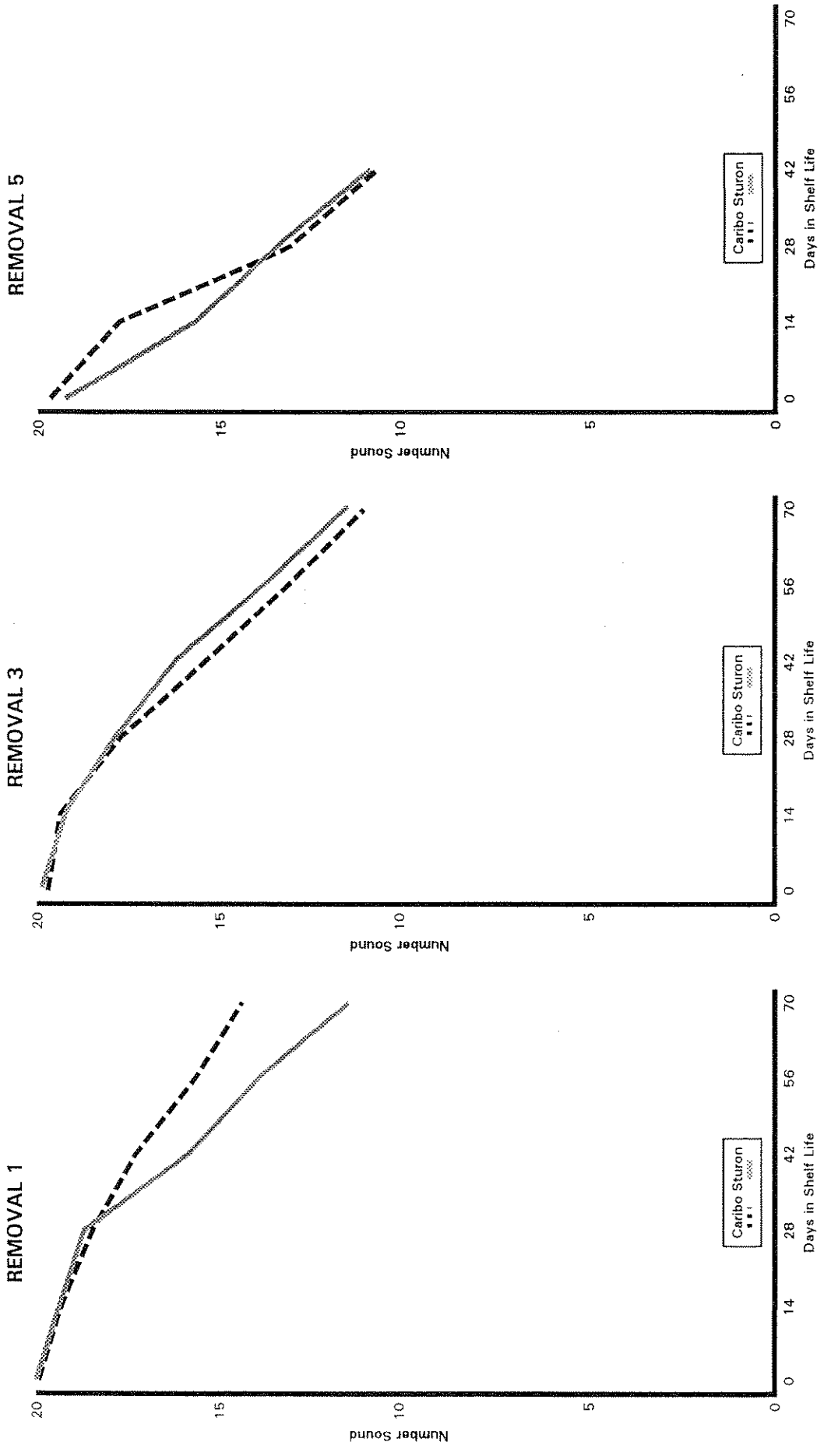

Fig 2 : Shelf Life After Storage at Different Humidities

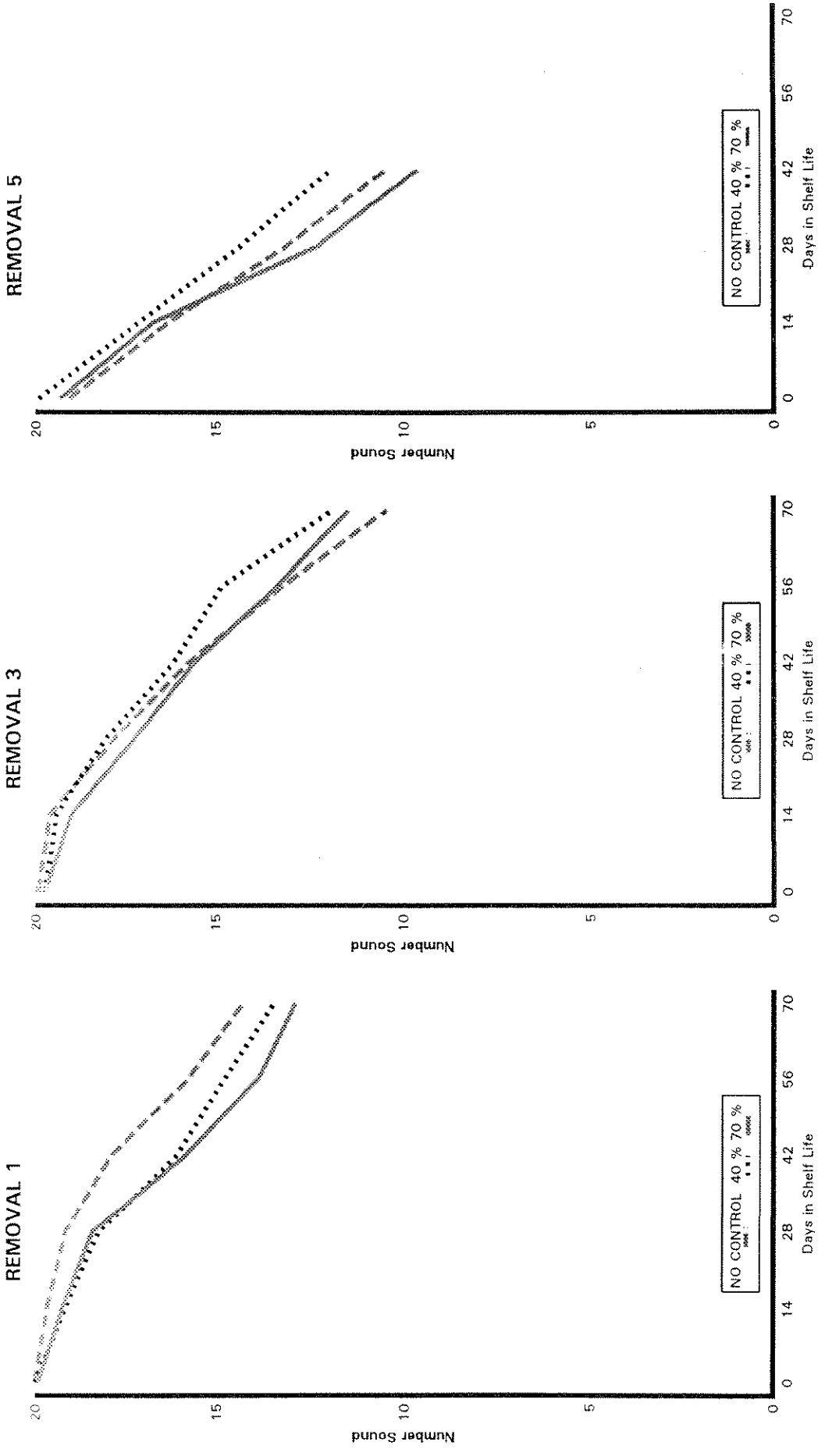

Fig 3 : Shelf Life of Onions With or Without MH