CONTRACT REPORT

FV125

CARROT
PRE-STORAGE ASSESSMENTS

Commercial in Confidence

CONTENTS

SUMMARY

Carrots, variety Narman, were established from 3 sowing dates (mid May, end May, early June) in 3 crops destined to be covered with black polythene and straw for winter storage.

Two sites were in commercial crops, one on sand and the other on silt soil. The third crop was established on a peat soil at ADAS Arthur Rickwood.

The objective was to identify the factors governing the storage potential of these crops and quantify the causes of deterioration at harvest the following May.

Measurements of yield, pest and disease incidence, mineral and sugar content of roots were taken in October prior to strawing down. Samples were also placed in a hot box at 28°C to encourage disease development and physiological breakdown in order to provide a predictive test. However this was not successful because soft rotting bacteria and potato sour rot caused rapid breakdown of the roots (within 5 days), swamping other problems which may have been present.

Pest and disease levels were monitored monthly throughout storage, and yield, pest and disease incidence, mineral and sugar analysis were recorded after storage the following May.

All sites and sowing date treatments gave a reduced marketable yield (5-20%) after field storage to May. On silt and peat soils the latest sowing (early June) gave the lowest reduction in marketable yield. On the sand site the second sowing date (late May) gave the lowest reduction in marketable yield.

Marketable yield reduction was caused by an increase in disease levels, principally by Violet Root Rot, Cavity Spot and Bacterial Soft Rot, which developed during April and May when soil temperatures increased. Disease incidence was minimal between October and March.

Analysis of mineral and sugar content of roots in October (before strawing down) and the following May show that dry matter content, total and reducing sugar levels drop significantly after winter storage. However, there were no significant differences between sowing date treatments.

INTRODUCTION

Approximately 30% of carrots grown in the UK are field stored (earthed up, under straw or under black polythene and straw) to provide a continuity of supply through the winter and spring months. This technique is well established and the industry has adopted the information provided by experimental work conducted in the 1980s at ADAS Arthur Rickwood.

However, under commercial conditions a range of apparently good crops chosen for winter storage in September or October can provide markedly different quality roots at harvest the following May, with no quantitive information on the causes of deterioration.

This project was carried out to evaluate the causes of deterioration (pest, disease or physiological) and to identify a means of "measuring" the potential of crops for field storage. This should enable only the best crops to receive the expensive covering of black polythene and straw.

MATERIALS AND METHOD

Carrots, variety Narman, were established on 3 sites (on sand, peat and silt soils) in East Anglia, each from 3 sowing dates. Sites comprised plots 16 m long in a randomised block design, sowing date treatments replicated 6 times. Target plant density was 130 plants/sq m (1.30 m plants/ha), actual plant density achieved is given in tables 1-3.

Treatments

Site-Soil Type	Sowing Date 1	Sowing Date 2	Sowing Date 3
Sand (Norfolk)	21 May	3 June	11 June
Peat (Cambridgeshire)	14 May	25 May	3 June
Silt (Cambridgeshire)	14 May	21 May	11 June

These trial sites received the same irrigation, herbicides and pesticides as the respective commercial crops. All were sprayed with Fubol 58WP against Cavity Spot within 6 weeks of drilling and all received a comprehensive spray programme for carrot fly based on ADAS carrot fly trap catches.

In the following October, before strawing down, yield was measured from a 2 m length of bed taken at random from each plot and the following assessments made.

1. Number and weight of roots in size grades

   < 19 mm, 19-25 mm, 25-32 mm, 32-44 mm, > 44 mm

2. 100 roots aggregated from the size grades 25 mm-44 mm were then assessed for:-

   a. Cavity spot - using the NIAB assessment chart at Appendix 1.

   b. Carrot fly in the categories < 5% (index 1), 5-25% (index 2), 25-50% (index 3), > 50% (index 4) of surface area affected.

   c. Any other disease problem was noted and scored index 1 - slight, index 2 - moderate, index 3 - severe. eg scab, crown rot and violet root rot.

3. A sub-sample of 10 roots from each sowing date on each soil type was sent to ADAS Analytical Chemistry at Cambridge for mineral analysis:

% dry matter
Total N at a % of dry matter
Luff - sch sugar as a % of dry matter (total sugar)
Reducing sugar as a % of dry matter
Total phosphorus % of dry matter
Total potassium % of dry matter
Total magnesium % of dry matter
Total calcium % of dry matter
Total sodium % of dry matter
Total boron in milligrams per kilogram

4. A further sub-sample of 10 roots per sowing date for each soil type were placed in plastic bags to prevent dehydration and placed in a hot box at 28°C for 5 days. These were then re-analysed by ADAS Analytical Chemistry for mineral content to compare with those listed in 3. Any disease development was also identified.

5. Soil temperature was recorded hourly at 10 cm depth from drilling to final harvest in May.

All plots were covered with black polythene and at least 25 tonnes per hectare of wheat straw by 7 November 1992. Plots were monitored monthly for pest and disease development by harvesting 100 roots, 25 from each of 4 rows across the bed, at random. Carrot fly, cavity spot, crown rot assessments were made after first washing the roots.

After storage in May 1993 yield, pest and disease levels and mineral content were measured again as in paras 1-3 above.

RESULTS

1. Yield

Tables 1-3 show the marketable yield (number of roots and weight per ha) obtained in October and May for each soil type and sowing date. At the October harvest date significant differences in yield between sowing dates on sand and silt soils were obtained. This was caused by variable establishment because of soil capping on the silt site for sowing dates 1 and 2 and low moisture levels at the third sowing date on the sand site.

However, it is the difference between the October and May harvest that provide a measure of how well crops stored in the field and the percentage marketable yield during field storage is also shown in Table 1-3.

Table 1, Sand Site, shows that all sowing dates lost yield (both weight and numbers of roots) from October to May. The yield from sowing date 2 was significantly reduced from October to May and the yield from sowing date 3 was reduced least.

Table 2, Peat Site, also shows that all sowing dates lost yield (both weight and number of roots) from October to May. Only for sowing date 1 was this reduction significant but the yield from sowing date 3, as with the sand site was reduced least.

Table 3, Silt Site, shows that all sowing dates lost yield (both weight and number of roots) from October to May but there were no significant treatment (sowing date) effect.

Table 1 Marketable Yield Sand Site

Treatment	Weight t/ha	Number of roots m/ha
SD 1 October	75.90	1.271
SD 1 May	62.20	1.017
% loss	18.05	19.980
SD2 October	83.70	1.411
SD2 May	67.90	1.142
% loss	18.87	19.060
SD3 October	41.31	0.713
SD3 May	35.12	0.687
% loss	14.92	3.650
Trial site mean	61.02	1.040
SED	14.34	0.253

SD = Sowing Date

Table 2 Marketable Yield Peat Site

Treatment	Weight t/ha	Number of roots m/ha
SD 1 October	79.11	1.215
SD 1 May	62.00	0.901
% loss	21.62	25.840
SD2 October	76.70	1.497
SD2 May	73.03	1.295
% loss	4.82	13.490
SD3 October	65.01	0.758
SD3 May	62.70	0.699
% loss	3.54	7.780
Trial site mean	69.76	1.061
SED	15.11	0.075

SD = Sowing Date

Table 3 Marketable Yield Silt Site

Treatment	Weight t/ha	Number of roots m/ha
SD 1 October	85.10	1.321
SD 1 May	75.30	1.090
% loss	11.52	17.490
SD2 October	52.70	1.102
SD2 May	50.00	1.043
% loss	5.12	5.350
SD3 October	40.10	0.672
SD3 May	36.50	0.616
% loss	8.98	8.330
Trial site mean	56.62	0.974
SED	15.72	0.320

SD = Sowing Date

2. Pest and Disease Assessments

Cavity Spot

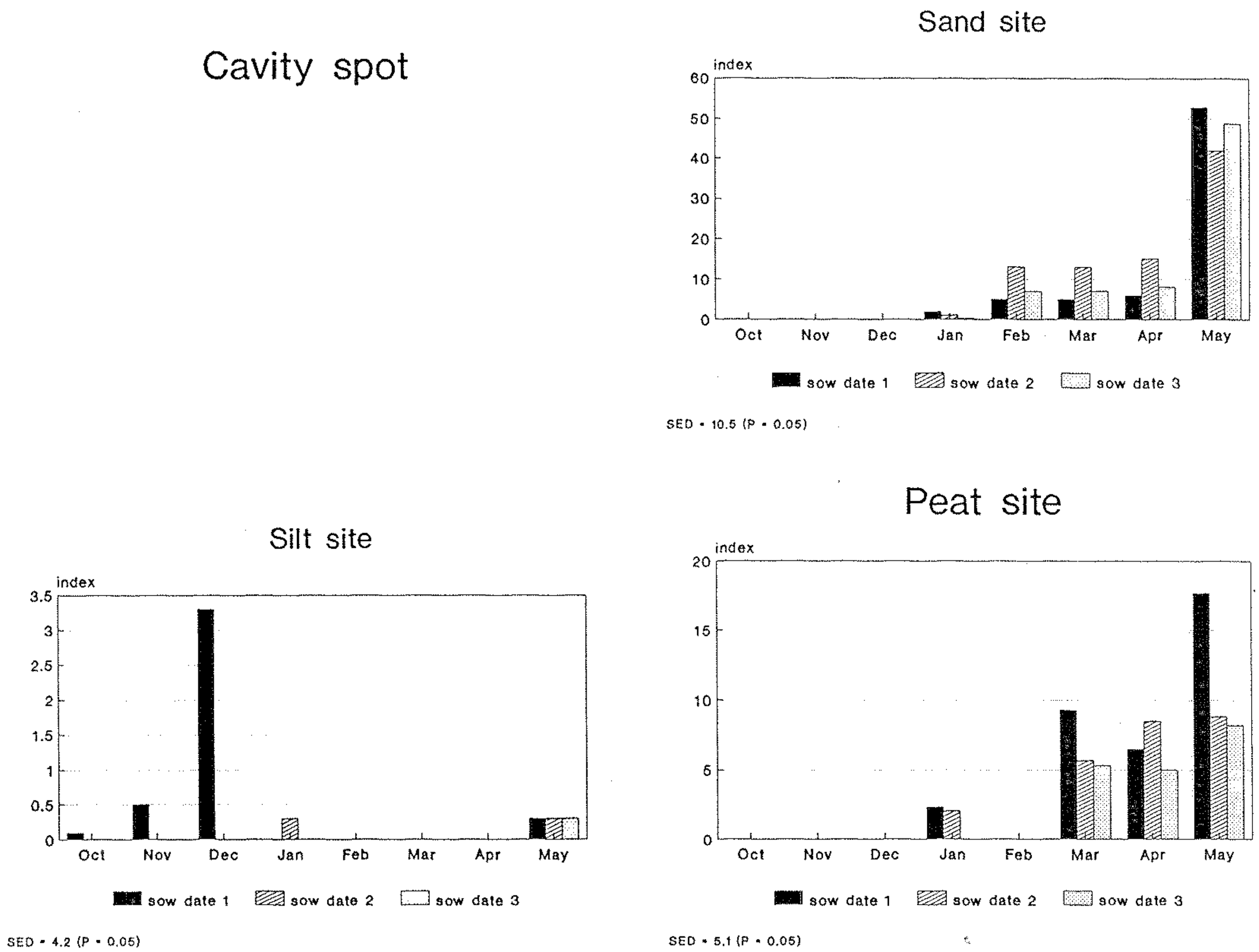
Assessments of cavity spot were made at both October and May harvests and monthly during field storage. The NIAB assessment chart (Appendix 1) was used to "score" 100 roots from each plot. For statistical analysis an index was calculated using the following formula:

$$\text{Index} = \frac{\begin{array}{l}(\text{score } 0 \times \text{number of roots}) \\ + (\text{score } 1 \times \text{number of roots}) \\ + (\text{score } 2 \times \text{number of roots}) \\ + (\text{score } 3 \times \text{number of roots}) \\ + (\text{score } 4 \times \text{number of roots}) \\ + (\text{score } 5 \times \text{number of roots}) \\ + (\text{score } 6 \times \text{number of roots})\end{array}}{6}$$

Figure 1 shows the level of cavity spot on all soil types as measured by the cavity spot index. From October to February the level of cavity spot remained low. From February to April cavity spot increased and substantially increased from April to May on both peat and sand sites but not at the silt site. Only the first sowing date on the peat site was significantly different from the other sowing dates. There were no other significant differences between treatments.

Figure 1

Cavity spot



Crown Rot (Figure 2)

Crown rot assessments were made on the same sampling basis as for cavity spot except that crowns were cut obliquely across the shoulder of the carrot so that any progression of rot down the root could be seen. Crowns were then scored for crown rot:

Score 0 = no crown rot, Score 1 = slight, Score 2 = moderate, Score 3 = severe.
As for cavity spot an index was calculated for Statistical Analysis.

From October until December all sites and sowing dates were free of any crown rot and from December until the final harvest in May levels remained low. Affected roots were sent to ADAS Plant Clinic at Cambridge to identify the cause of rotting. Bacterial soft rots were always present but from the silt site Sclerotinia and Fusarium were also recovered. There were no significant effects from sowing date treatments.

Violet Root Rot (Figure 3)

Violet root rot assessments were made on the same sample of 100 roots and given a score and an index calculated for Statistical Analysis:

Score 0 = No violet root rot
Score 1 = Slight, 5% of roots affected
Score 2 = Moderate, 25% of roots affected (unmarketable)
Score 3 = Severe, 50% or more of roots affected (unmarketable)

All sites were affected by violet root rot but this is "patchy" and with the exception of the October harvest the silt site remained free of this disease. The violet root rot index was higher on both peat and sand sites but there were no significant differences between sowing date treatments on any site.

Bacterial Soft Rotting (Figure 4)

Bacterial soft rotting was assessed in the same way as violet root rot and an index calculated for statistical analysis. All sites and sowing dates were free of bacterial rots until February. After which the index increased especially on peat and sand sites. The index was significantly greater for the first sowing date on peat and silt sites and first and second sowing dates were significantly greater than the third sowing date on the sand site.

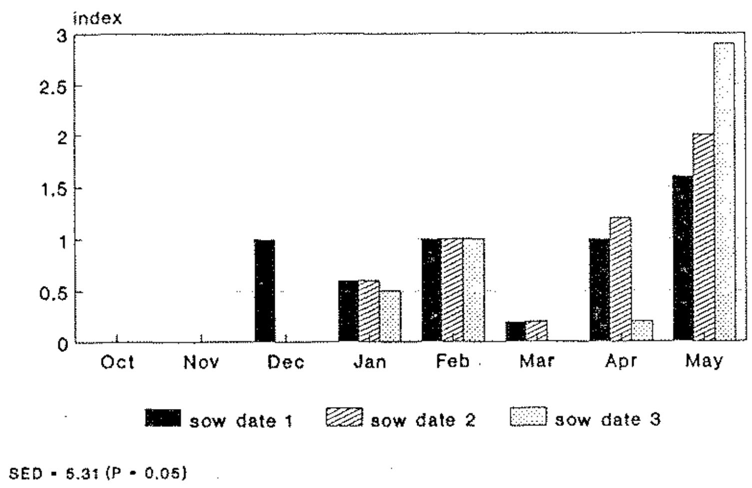
Common Scab (Figure 5)

Only the sand site was affected by common scab and this was similarly assessed and an index calculated as for violet root rot. The index declined from October to May (possibly due to subsequent bacterial soft rot) and was not significantly affected by sowing date.

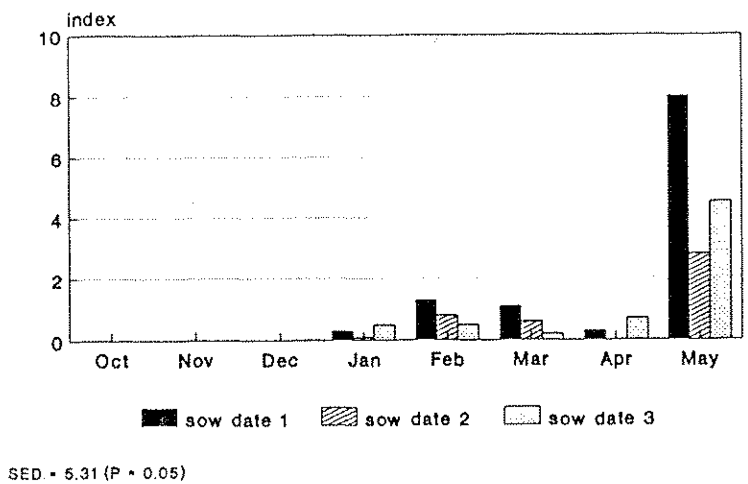
Figure 2

Crown rot

Sand site



Silt site



Peat site

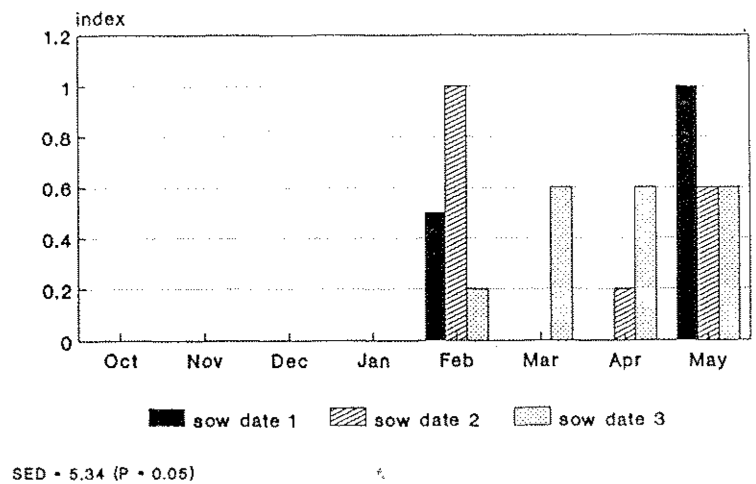


Figure 3

Violet root rot

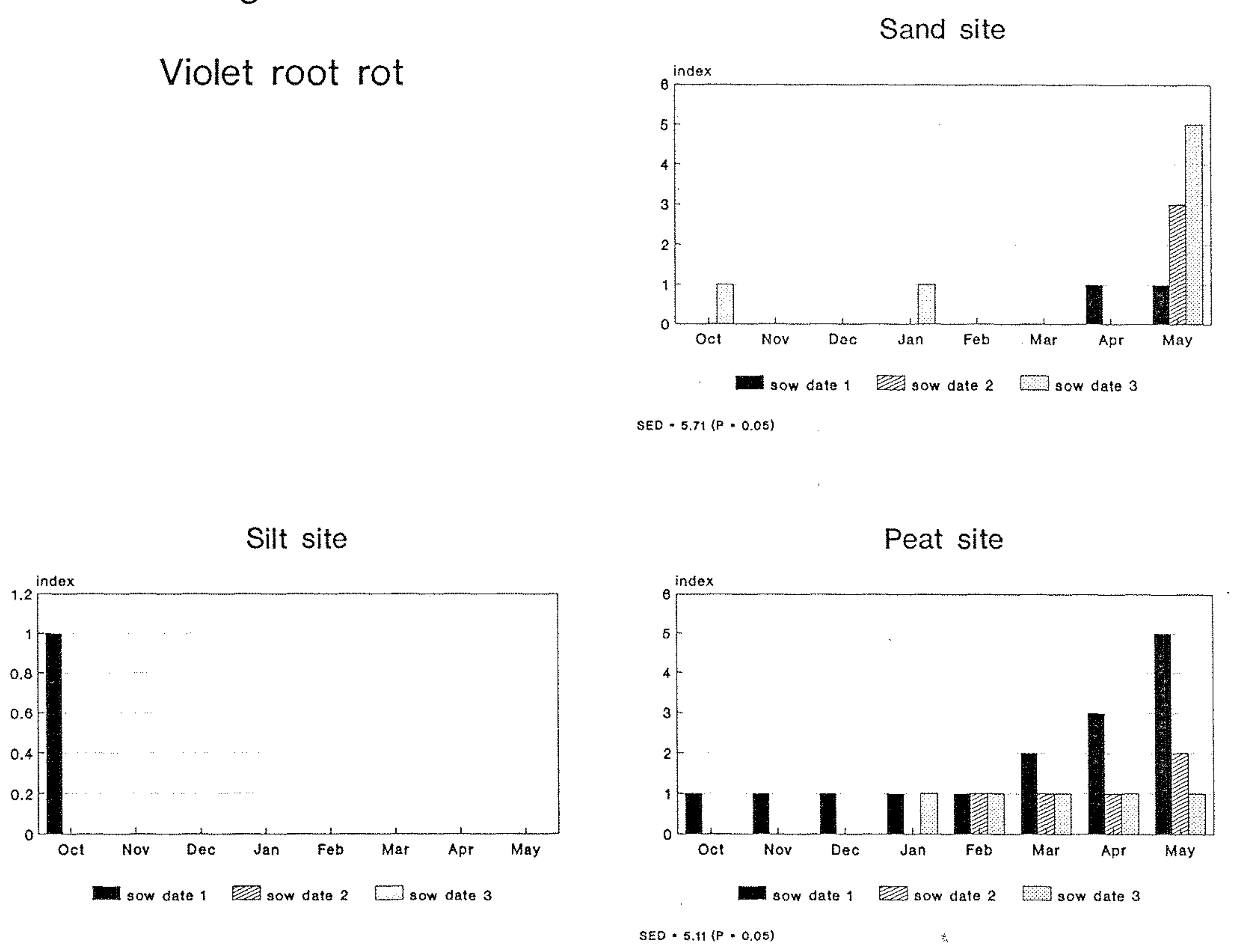
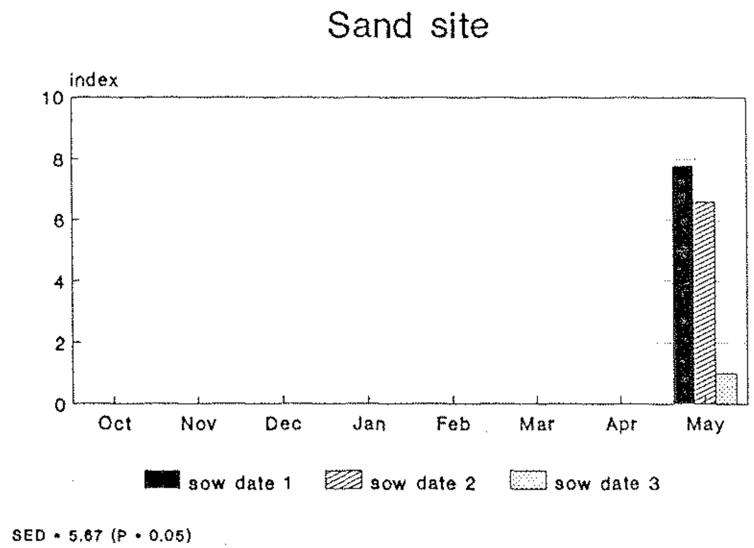
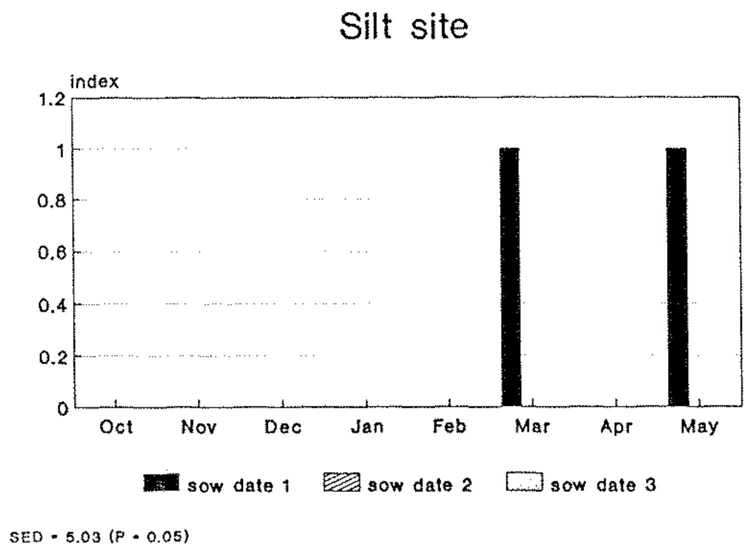


Figure 4

Bacterial soft rot





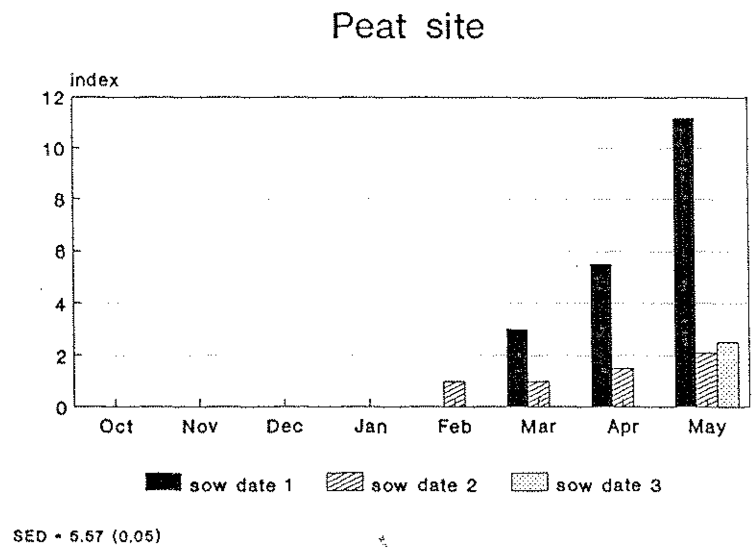
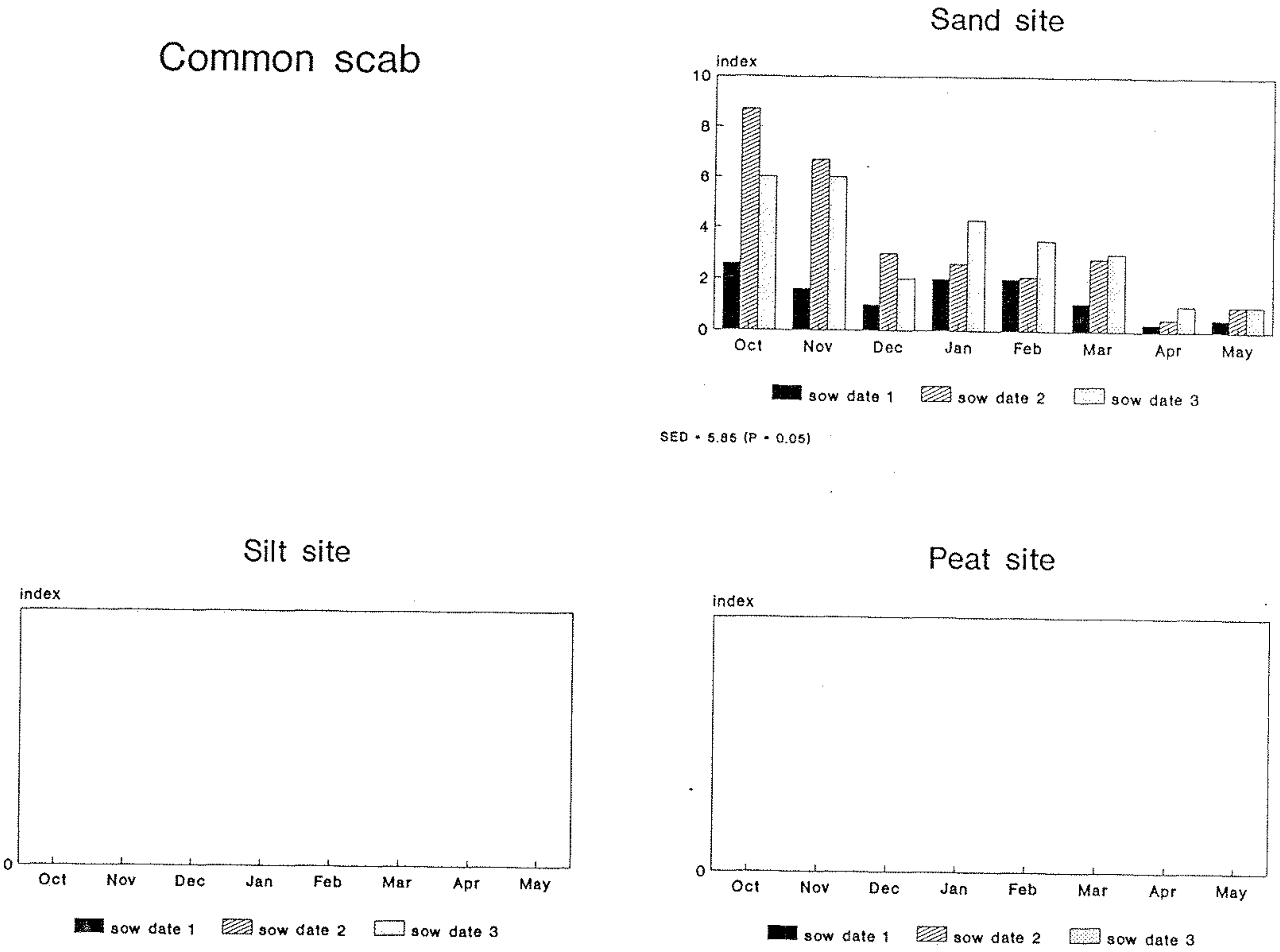


Figure 5

Common scab



Carrot Fly (Figure 6)

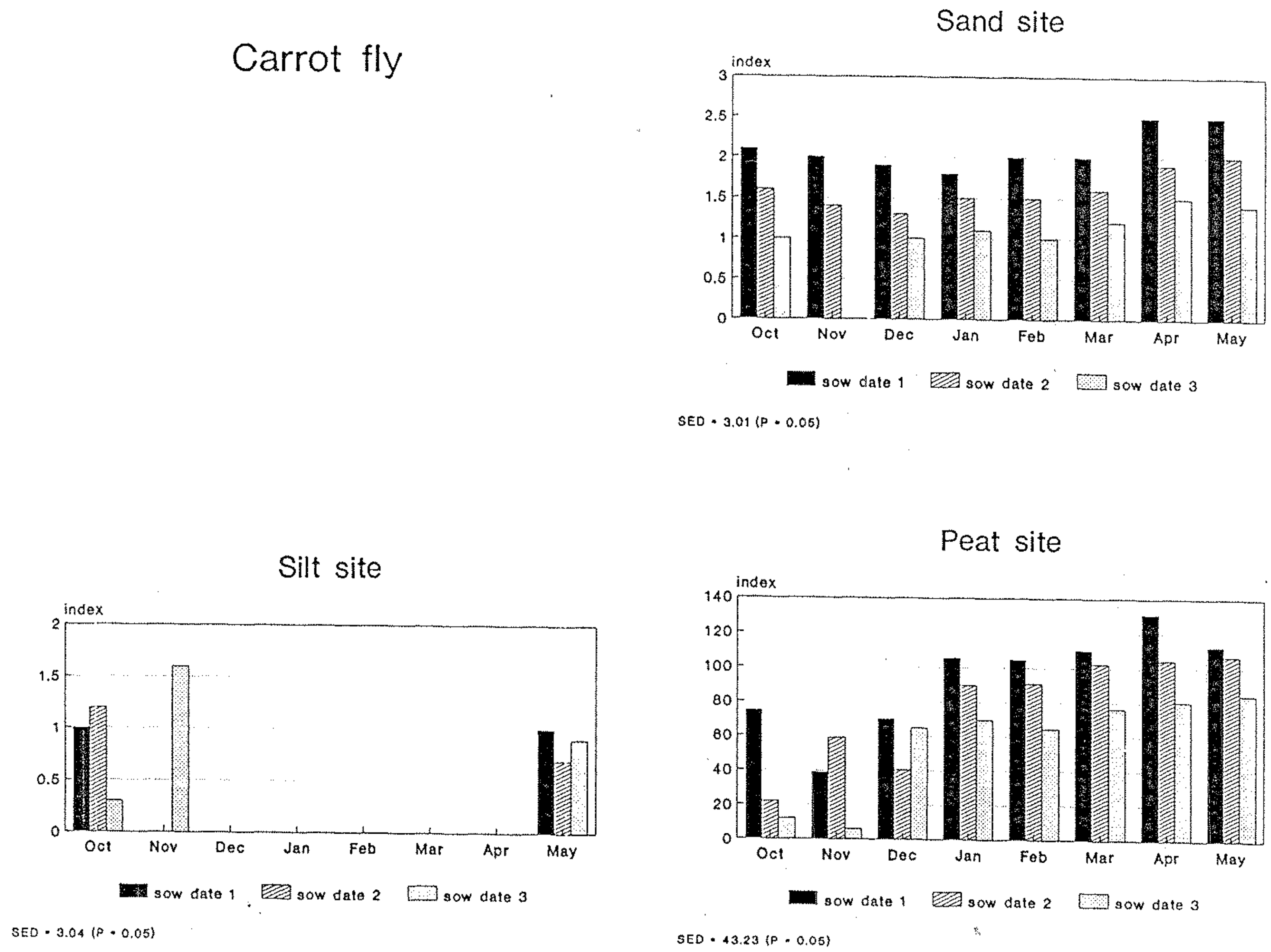
Treatments were scored monthly for carrot fly damage using the 100 root sample:

Score 0 = No carrot fly
Score 1 = < than 5% of the surface area of the root affected
Score 2 = 5-25% of the surface area of the root affected
Score 3 = 25-50% of the surface area of the root affected
Score 4 = > than 50% of the surface area of the root affected

Both sand and silt sites were almost free of carrot fly and the scores for these sites were less than for the peat site which sustained a severe second generation carrot root fly attack typical of a Cambridgeshire fen peat site. Cool moist weather conditions in 1992 favoured the development of particularly large numbers of 2nd generation carrot fly which proved difficult to control even with the most intensive spray programme. There were no significant differences between sowing date treatments.

Figure 6

Carrot fly



3. Soil Temperature

Soil temperature at a depth of 10 cm was recorded hourly throughout the duration of this experiment and the average temperature, maximum recorded and minimum recorded for each month is presented in Table 4.

At no time did any treatment freeze and the lowest temperature recorded was 2.6°C on the silt site.

In spite of a covering of black polythene and straw average temperature increased significantly in April and May on all sites.

Table 4 Soil Temperatures at 10 cm depth

	Sand			Silt			Peat		
	Av	**Max**	**Min**	**Av**	**Max**	**Min**	**Av**	**Max**	**Min**
May 1992	14.4	25.2	10.4	13.5	16.8	10.1	16.5	24.8	15.8
June 1992	17.8	24.5	14.8	17.2	19.5	16.6	17.5	22.2	15.2
July 1992	20.2	31.0	14.8	18.5	19.4	17.1	19.9	24.8	14.8
August 1992	22.1	30.2	21.4	17.9	19.5	15.8	19.5	22.8	16.2
September 1992	16.8	20.0	11.4	14.5	15.9	13.6	18.7	24.4	11.2
October 1992	11.8	11.8	4.6	11.5	16.3	8.2	11.7	15.8	8.1
November 1992	9.0	11.2	5.2	7.8	10.0	6.8	8.2	11.7	4.2
December 1992	7.2	6.2	4.0	6.6	8.6	3.2	5.3	5.6	4.3
January 1993	7.0	6.9	4.4	7.0	9.1	3.0	7.5	10.7	6.8
February 1993	7.0	6.8	4.8	4.8	6.2	2.6	6.9	7.5	4.9
March 1993	7.6	8.9	4.4	6.5	8.0	3.6	7.5	9.7	4.3
April 1993	7.8	10.8	6.2	7.1	8.2	3.8	8.8	11.4	5.9
May 1993 (until 14th)	12.2	17.1	10.0	-	-	-	13.2	18.7	9.4

4. Mineral Analysis

After the October harvests, hot box treatment and May harvest a sample of each sowing date treatment was sent to ADAS Analytical Chemistry at Cambridge for mineral and sugar analysis. The results are presented in Tables 5-7.

On all sites dry matter, mineral content and sugar levels were significantly reduced from October to May but there were no significant effects from sowing date treatments. Percentage dry matter was reduced by the hot box treatment (28°C) but this was not significant and there were no significant effects of sowing date treatment on mineral or sugar levels in the carrots tested. The hot box treatment therefore did not provide a method of predicting mineral levels in carrots after field storage.

TABLE 5 MINERAL ANALYSIS - SAND SITE

Treatment	% DM	% N	% LSS	% RS	% P	% K	% Mg	% Ca	% Na	Mg/kg Bo
SD1 OCT	10.9	0.105	5.095	2.695	0.031	0.320	0.012	0.070	0.010	29.40
SD2 H BOX	10.70	0.105	5.445	2.290	0.028	0.315	0.010	0.083	0.115	28.95
SD3 MAY	8.00	0.039	3.540	2.012	0.028	0.261	0.009	0.023	0.008	38.00
SD1 OCT	10.80	0.115	4.965	2.990	0.038	0.330	0.011	0.081	0.010	30.20
SD2 H BOX	10.45	0.125	5.370	2.470	0.030	0.330	0.010	0.081	0.010	33.15
SD3 MAY	8.01	0.050	3.466	1.860	0.026	0.260	0.009	0.006	0.009	35.34
SD1 OCT	10.25	0.105	4.600	2.760	0.033	0.310	0.011	0.030	0.010	30.60
SD3 H BOX	10.05	0.125	5.350	2.435	0.030	0.300	0.010	0.032	0.011	29.10
SD3 MAY	8.07	0.022	3.664	2.241	0.028	0.247	0.008	0.035	0.007	34.33
MEAN	9.69	0.0851	4.611	2.417	0.030	0.300	0.010	0.049	0.0095	32.12
SED SOW DATE	0.1540	0.0109	0.1354	0.1156	0.0023	0.0087	0.00012	0.049	0.0006	0.846
SED HARVEST DATE	0.1706	0.0115	0.1330	0.1066	0.0020	0.0073	0.00012	0.051	0.0007	0.773

SD = SOWING DATE
HB = HOT BOX TREATMENT
DM = DRY MATTER
N = NITRATE
LSS = TOTAL SUGAR MEASURED BY LUFF-SCHORLE METHOD
RS = REDUCING SUGAR
P = PHOSPHATE
K = POTASSIUM
Mg = MAGNESIUM
Ca = CALCIUM
Na = SODIUM
Bo = BORON

TABLE 6 MINERAL ANALYSIS - PEAT SITE

Treatment	% DM	% N	% LSS	% RS	% P	% K	% Mg	% Ca	% Na	Mg/kg Bo
SD1 OCT	11.50	0.117	5.748	3.198	0.118	0.338	0.013	0.034	0.117	39.23
SD2 H BOX	11.50	0.117	5.512	2.740	0.036	0.308	0.012	0.029	0.028	30.53
SD3 MAY	7.90	0.048	2.415	0.640	0.027	0.158	0.010	0.031	0.023	29.95
SD1 OCT	11.05	0.108	5.623	3.553	0.051	0.355	0.013	0.039	0.066	36.30
SD2 H BOX	11.57	0.123	5.583	2.957	0.033	0.305	0.012	0.030	0.029	30.05
SD3 MAY	7.40	0.097	2.335	0.660	0.030	0.287	0.010	0.031	0.020	30.65
SD1 OCT	11.05	0.110	5.500	3.163	0.763	0.347	0.012	0.030	0.151	38.60
SD2 H BOX	11.47	0.125	5.300	2.828	0.083	0.307	0.011	0.029	0.029	29.92
SD3 MAY	7.45	0.097	2.205	0.665	0.030	0.279	0.009	0.030	0.019	28.35
MEAN	10.10	0.1038	4.472	2.267	0.0548	0.298	0.117	0.032	0.054	32.62
SED SOW DATE	0.160	0.0087	0.1700	0.137	0.0431	0.0265	0.0006	0.013	0.0304	0.917
SED HARVEST DATE	0.153	0.0092	0.1558	0.118	0.0354	0.0285	0.0006	0.0012	0.418	0.964

SD = SOWING DATE
HB = HOT BOX TREATMENT
DM = DRY MATTER
N = NITRATE
LSS = TOTAL SUGAR MEASURED BY LUFF-SCHORLE METHOD
RS = REDUCING SUGAR
P = PHOSPHATE
K = POTASSIUM
Mg = MAGNESIUM
Ca = CALCIUM
Na = SODIUM
Bo = BORON

TABLE 7 MINERAL ANALYSIS - SILT SITE

Treatment	% DM	% N	% LSS	% RS	% P	% K	% Mg	% Ca	% Na	Mg/kg Bo
SD1 OCT	11.97	0.139	6.899	3.211	0.026	0.2800	0.01	0.036	0.043	31.35
SD2 H BOX	11.65	0.110	5.370	2.660	0.025	0.250	0.01	0.035	0.048	29.45
SD3 MAY	8.07	0.105	3.295	0.890	0.019	0.250	0.01	0.032	0.028	25.05
SD1 OCT	11.53	0.130	6.620	2.850	0.026	0.290	0.01	0.035	0.045	31.72
SD2 H BOX	11.05	0.105	5.130	2.790	0.023	0.240	0.01	0.035	0.038	25.35
SD3 MAY	8.30	0.105	3.027	0.880	0.019	0.265	0.01	0.030	0.027	22.90
SD1 OCT	10.60	0.125	5.965	2.630	0.026	0.295	0.01	0.040	0.028	30.65
SD2 H BOX	10.50	0.110	4.815	2.565	0.023	0.280	0.01	0.030	0.025	25.65
SD3 MAY	7.90	0.110	2.845	0.880	0.019	0.240	0.01	0.029	0.024	23.20
MEAN	10.175	0.1155	4.885	2.151	0.0228	0.2656	0.01	0.0336	0.0338	27.26
SED SOW DATE	0.173	0.0039	0.086	0.1069	0.0005	0.008	0.00	0.0015	0.0024	1.114
SED HARVEST DATE	0.166	0.0040	0.086	0.082	0.0005	0.008	0.00	0.0016	0.0026	1.265

SD = SOWING DATE
HB = HOT BOX TREATMENT
DM = DRY MATTER
N = NITRATE
LSS = TOTAL SUGAR MEASURED BY LUFF-SCHORLE METHOD
RS = REDUCING SUGAR
P = PHOSPHATE
K = POTASSIUM
Mg = MAGNESIUM
Ca = CALCIUM
Na = SODIUM
Bo = BORON

CONCLUSIONS

Sowing Date

The early sowing date (mid May) produced the highest marketable yield in October and after field storage the following May, on 2 out of 3 sites, in spite of higher levels of disease developing during the storage period.

Only when adequate seed bed moisture can be guaranteed is there merit in sowing later (early-mid June) to defer disease development during field storage.

Site/Soil Type

Yield was reduced after winter storage on all 3 soil types (sand, peat, silt) due to a combination of soil borne diseases and carrot fly. However, the combination was different for each site and assessments made in October did not predict storage potential.

Pest and Disease Levels

Levels of violet root rot and cavity spot increased on peat and sand sites and the level of bacterial rot increased on all sites during the storage period but particularly from April and May. Carrot fly was not a problem on silt and sand sites but a significant attack was sustained by carrots on the peat site and the damage index increased during the storage period.

There were no significant effects from any sowing date treatment on pest or disease levels.

Mineral Analysis

Percentage dry matter, % total sugar, % reducing sugar and mineral content were reduced on all sites and sowing date treatments at harvest in May following winter storage. However, there were no significant differences between site or sowing date treatments.

Hot Box Test

Carrots subjected to 28°C for 5 days in a hot box were severely affected by bacterial rotting and potato sour rot. Potato sour rot was not detected in any of the field assessments. This test did not prove to be suitable for assessing storage potential since there were no site or sowing date treatment effects.

RECOMMENDATIONS

1. This project provides evidence that sowing date influences the ability of carrot crops to store successfully in the field. Further detailed work is required to determine the optimum sowing date.

2. The Hot Box test using a temperature of 28°C did not predict storage potential because samples were "swamped" by soft rotting bacteria and potato sour rot.

   However, lower temperatures over longer periods could lead to a more successful test.

3. Temperature data indicates that there is a substantial rise in soil temperature during April and May coinciding with increased disease levels. There could be merit in the application of additional insulation to field stored crops in February/March to suppress this increase and possibly extend storage life of carrots.

ACKNOWLEDGEMENTS

The assistance of the following companies is greatly appreciated:

W H Knights & Sons
Crow Hall Farm
Gooderstone
KINGS LYNN
Norfolk

A Bartlett & Co
Great Acre Fen
CHATTERIS
Cambs

APPENDIX 1

(NIAB)

CAVITY SPOT (*Pythium Sp*) OF CARROTS