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RESEARCH REVIEW: BLOSSOM END ROT AND SKIN CRACKING IN SWEET PEPPER

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CONTENTS

A RESEARCH REVIEW FOR THE HDC PROTECTED CROPS PANEL SWEET PEPPER - BLOSSOM END ROT AND SKIN CRACKING

1. INTRODUCTION

The two most important fruit quality defects that affect glasshouse sweet peppers are Blossom End Rot (BER) and skin cracking.

BER can result in 15% or even more of some crops being unmarketable and nearly every crop is affected to some extent.

Skin cracking is usually less serious in that it does not in most cases render the fruit unmarketable but it can lead to down grading and reduces the value of the sample. Cracking also tends to reduce shelf life. This problem is also very widespread especially in crops picked ripe.

2. OBJECTIVES

There were two major objectives for the Review. Firstly, to undertake literature and database searches to obtain all available research data particularly from the UK and The Netherlands, and to visit The Netherlands to obtain information on current research and commercial practice. Secondly to formulate proposals for further R & D that might usefully be undertaken in the UK based on the increased understanding of the problems and work already completed.

3. SUMMARY

A number of factors have been identified as having an adverse effect on Blossom End Rot (BER) and skin cracking.

3.1 Blossom End Rot (BER)

BER is caused by a localised deficiency of calcium in the developing fruit, due to reduced calcium transport to the fruit via the transpiration stream and xylem tissue, as in tomatoes. Anything that reduces water and therefore calcium uptake by the roots or causes water loss from the leaves to exceed water uptake by the roots may result in BER.

The factors having an adverse effect on BER are:-

(a) High nutrient solution conductivity, particularly in excess of 3,000µs.

(b) Rapid increases in solution conductivity.

(c) Low calcium concentrations in the root environment (<140 mg/l Ca).

(d) High solution magnesium (>80 mg/l Mg) and sodium (>138 mg/l Na) concentrations.

(e) Low root zone temperatures, particularly early in season.

(f) Environmental factors

- high transpiration rates on hot sunny days
- excessive humidity at night reducing calcium transport
- sudden changes in rate of transpiration loss

(g) Removing fruit affected by BER too rapidly.

(h) Poor watering, leading to dry slabs/bags.

3.2 Skin Cracking:

Skin cracks result from the fruit expanding quicker than the skin is growing or is capable of stretching. They are initiated during the night when the fruit is expanding due to positive root pressure. The cracks are only generally visible to the eye in ripe fruit, which are the most susceptible due to the ripe skin being inelastic. However, cracks can begin to form 2-3 weeks after the fruit has set.

Skin cracking, and to a lesser extent BER, are genetically controlled. Progress is being made by the two main seed companies (Enza and Rijk Zwaan) marketing sweet pepper varieties, towards the breeding of varieties that are not susceptible to skin cracking.

The following factors have an adverse effect of skin cracking:-

a. Slow fruit growth rates, during spring/autumn.

b. Sudden changes in fruit expansion rates

c. Low solution conductivities (2000 µs or less)

d. Rapid changes in conductivity, particularly from high to low.

e. High humidities (over 80% RH) for long periods, particularly during the day.

f. Temperatures

   - 24 hour temperatures below 20°C.

   - Large differences between day and night temperatures.

g. Removing all fruit affected by BER too rapidly.

4. REVIEW OF RESEARCH AND DEVELOPMENT FINDINGS

4.1 REVIEW OF DUTCH RESEARCH

4.1.1 BLOSSOM END ROT

Blossom end rot (BER) known as 'neusrot' in Holland, continues to be a major quality problem affecting sweet peppers in Holland, generally accounting for losses of 5-8% in marketable yield. Although this is considerably less than experienced on some English nurseries growing long season mono peppers. Recent work at Naaldwijk has investigated the effect of environmental factors (temperature and humidity) as well as nutritional aspects on BER.

i. Calcium requirements of fruit:

BER is most likely to affect a pepper fruit during the period of fastest growth (generally when the fruit is one third to half its full size) when the demand for calcium is at its highest. As the fruit develops and expands its ability to transpire through the stomata decreases, as the number do not increase whereas the fruit size does. Hence as the fruit grows the uptake of calcium via the transpiration stream and xylem tissue (the exclusive transport route for calcium) decreases in relation to fruit size and the risk of BER is increased.

ii. Environment:

BER is induced by high transpiration rates which occur on hot sunny days with accompanying low air humidities, particularly when the crop has a high leaf area. This leads to the transpiration stream being directed to the leaf at the expense of the fruit.

During periods of high solar radiation and high temperatures fruit growth is rapid with a consequent increased demand for calcium. This occurs under precisely the conditions when the calcium is being diverted in the xylem flow towards the leaves at the expense of the fruit.

This situation lead research workers in the mid 1980s (van Uffelen 1985) to recommend reduced ventilation during the middle of the day during periods of high transpiration loss. Although this does have the desirable effect of raising humidities it inevitably leads to excessive temperatures which can render it impossible to work on the crop and increased incidence of fruit affected by sun scald.

A more positive approach is to reduce humidity at night with the objective of increasing the flow of calcium into the fruit thereby making full use of positive root pressure. This can be brought about by raising minimum ventilation temperatures and reducing minimum pipe temperatures.

Screens are used by some Dutch growers to increase day time humidity on hot sunny days, which will help slow transpiration losses from the leaf surface and theoretically reduce BER risks. Similarly, reducing green leaf area will assist in reducing transpiration stress although this is not recommended.

Thermal screens have been installed for 3 main purposes, to reduce heat losses in the winter, to raise humidities during the early stages of the crop and to reduce transpiration loss during periods of hot bright weather.

Unfortunately it is impossible to find a single screen material that is optimal for all these purposes. An impermeable product is better for use as a shade screen in summer. Further, some Dutch growers claimed that even when using a semi-permeable material, such as LS10 in hot weather this will inevitably reduce ventilation causing increased temperatures with adverse consequences for both crop and workforce.

Experience in Holland would suggest that screens, although of great value in other ways, are not the answer to the BER problem.

The use of fogging systems in the glasshouse to increase humidity and reduce temperatures on hot sunny days is not presently practised commercially in Holland, Although a number of growers apply water to the glasshouse roof to help reduce midday temperatures.

iii. Watering:

Recent work at Naaldwijk (Haghuis, 1990) has demonstrated the benefits of night water applications in decreasing the incidence of BER (Table 1). The application of water during the night is likely to have assisted the plant in translocating calcium to the fruit utilising the full benefits of the so called "root pump" action.

iv. Fruit Thinning:

Haghuis (1990) also investigated the effects of removing fruit affected on BER (Table 1)

Table 1: Effect of night water application and fruit thinning on yield and blossom end rot.

Treatment	Marketable Yield (kg/m^2)	Blossom End Rot (kg/m^2)
No night watering	16.0	3.5
With night watering	16.0	2.8
BER fruit thinned	8.4	2.7
BER fruit remaining	9.3	1.7

Removing fruit affected by BER rather than leaving them on the plant until they were ripe, increased the incidence of BER and decreased the marketable yield for the following harvested fruit. The removal of all fruit affected by BER is likely to unbalance the crops growth, leading to a flush of growth and fruit setting which is subsequently at increased risk from BER.

Present advice is that fruit affected by BER should not be removed from the plant until ripe or should be removed gradually to ensure that balanced plant growth is achieved.

v. Conductivity

High conductivity increases osmotic pressure in the root zone and decreases calcium transport in the xylem tissue. Work at Naaldwijk has clearly demonstrated the effect of high conductivity on BER. Trials in 1982 (van Uffelen,1985) recorded a 14 fold increase in BER on raising conductivity from 2,000 µs (0.5% fruit affected) to 4,000 µs (7.3% fruit affected) and in 1983 a 5 fold increase in BER on raising conductivity from 2,000 µs (1.1% fruit affected) to 5,000 µs (6.1% fruit affected). Similarly in 1987 (Bakker and van Uffelen, 1987) a 5 fold increase on raising conductivity from 1,500 µs (2% fruit affected) to 6,000 µs (11% fruit affected).

Dutch growers aim to maintain conductivities in the range 3,000-3,500 µs in the root environment, measured at 25°C. This is equivalent to 2,700-3,200 µs measured at 20°C, as standard by ADAS.

Present Dutch recommendations are to maintain a conductivity of 3,000 µs in the root environment. The target conductivity is higher than previously recommended, 2,500 µs at 25°C (Sonneveld and de kreij, 1986). The higher conductivity is achieved by increases in the target concentration of potassium to 270 mg/l (previously 200 mg/l), magnesium to 80 mg/l (previously 60 mg/l) and calcium 280 mg/l (previously 200 mg/l). Potassium to calcium ratios (1:1), and potassium to magnesium ratios (3:1) are the same, although the potassium to nitrogen ratio has increased to 1.3:1 from 1:1 in 1986 in the root environment.

v. Calcium:

Dutch recommendations aim to maintain calcium concentrations in the root environment in the region of 280 mg/l Ca, the minimum calcium concentration considered adequate is 140 mg/l Ca.

viii. Antagonistic cations:

The maintenance of a correct cation balance in the root environment will be increasingly important as growers move to recirculation systems, to minimise the antagonistic effects (particularly from magnesium and sodium) on calcium uptake and BER.

Present Dutch recommendations are to maintain magnesium in the root environment <80 mg/l Mg. As water concentrations in the UK are typically in the range 10-40 mg/l Mg, adjustments to nutrient feed inputs can be used to control concentrations.

Work at Naaldwijk in 1987 (van de Borg, 1988) investigated the effect of sodium and chloride on the yield and quality of pepper picked red) grown in a recirculation system, at 3 conductivities; 2,500 µs, 3,700 µs and 5,200 µs. The two higher conductivities were achieved by raising conductivity with feed (calcium and potassium nitrate) or by replacing feed with sodium chloride (NaCl). The highest yields of marketable peppers were obtained at a conductivity of 2,500 µs. Raising conductivity from 2,500 µs to 3,700 µs using feed reduced yield 4% (13.5 Kg/m^2) whereas raising conductivity with sodium chloride reduced yield 11% (12.5 Kg/m^2). Similarly, raising conductivity from 2,500 µs to 5,200 µs using feed reduced yield 16% (11.7 Kg/m^2), whereas raising conductivity with sodium chloride reduced yield 21% (11.1 Kg/m^2), Table 2. The average reductions in yield through raising conductivity with NaCl compared to feed was 0.8 Kg/m^2.

Table 2 Effect of conductivity raised by feed or sodium chloride addition on the yield and quality of peppers

Conductivity treatment (µs)	Marketable Yield (kg/m^2)	BER (kg/m^2)	Skin Cracking (%)
2,500	14 (100%)	0.3	23
3,700	13.5 (96%)	0.5	18
3,700 + Na Cl	12.5 (89%)	1.1	19
5,200	11.7 (84%)	0.9	18
5,200 + Na Cl	11.1 (79%)	0.7	15

The reductions in marketable yield were a result of increases in BER through sodium chloride addition, which averaged 0.7 Kg/m^2 at the two conductivity levels. The incidence of skin cracking decreased as conductivity increased, however the addition of sodium chloride had no effect upon skin cracking.

Van de Burg (1988) also studied the uptake of sodium and chloride by pepper plants (Table 3). The results are expressed as mg/l Na and Cl depleted from the recirculating nutrient solution.

Table 3 Uptake of sodium and chloride by pepper plants over two time periods

Time Period	Sodium <115	Sodium 290	Sodium 575	Chloride <125	Chloride 440	Chloride 875
	(mg/l in recirculating solution)					
	(mg/l taken up from solution)					
30 January to 30 March	9	18	32	14	53	84
31 March to 15 June	<2	2	7	11	18	32

Sodium and chloride uptake by the peppers was highest during winter (January to March period), although depletion rates were still relatively small. During spring (March to June period) there was essentially no sodium uptake at the low solution concentrations (<115 and 290 mg/l Na) from the recirculating solution. Although chloride uptake during winter and spring was higher than for sodium, depletion rates were still relatively low.

Mains water in the UK generally contains sodium concentrations in the range 30-70 mg/l and chloride 60-120 mg/l. Although there are notable exceptions to these ranges, such as in the Lea Valley area where water supplies can contain in the region of 235 mg/l Na, with sodium concentrations in excess of 500 mg/l Na being recorded in rockwool slabs.

Even at normal sodium and chloride concentrations in UK water supplies, concentrations are higher than the reported Dutch uptake rates by plants, such that both sodium and chloride can be expected to accumulate in recirculation systems.

Based on the work reported by van de Burg (1988), Dutch recommendations are that salt (sodium and chloride) concentrations should not be permitted to rise above 138 mg/l Na (6mmol/l) and 213 mg/l Cl (6mmol/l) due to adverse effects on BER. In practice, most Dutch growers allow solution to drain away from recirculation systems when sodium concentrations exceed 100 mg/l Na (4 mmol/l Na).

viii Guidelines to minimise BER problems

1. Maintain conductivity below 3,000 µs

2. Avoid sudden changes from low to high conductivity

3. Maintain calcium concentrations in the root environment above 140 mg/l Ca.

4. Maintain magnesium concentrations in the root environment < 80mg/l Mg, and sodium concentration <138 mg/l Na to minimise the antagonistic effect of these two cations on Ca uptake.

5. Use root zone warming in the early season.

6. Environmental control

   - minimise transpiration loss on hot sunny days
   - avoid sudden changes in transpiration loss rates.
   - slow transpiration rates at night to gain maximum benefits of root pump action.

7. Don't remove all fruit affected by BER at the same time, gradually remove, or remove when ripe.

8. Watering

   - ensure that slabs do not dry out, particularly during the night.

4.1.2 SKIN CRACKING

Skin cracking results from the fruit expanding quicker than the skin is growing. The cracks are initiated during the night when the fruit expands due to positive root pressure. Although the cracks are only generally visible to the eye on ripe fruit, they can begin to form 2-3 weeks after the fruit has set.

As the fruit expands transpiration through stomata and skin elasticity decrease, increasing the risk of skin cracking. Generally large fruit and thick walled varieties are most at risk.

Research at Naaldwijk has identified a number of factors which all contribute to the problem.

i. Growth rate

Steady plant growth during the season is important to reduce cracking, sudden changes in growth rate which lead to rapid fruit expansion increase skin cracking.

Slow growing fruit during the early season and in autumn is most at risk, largely as it spends a longer period on the plant.

ii. Conductivity

Work at Naaldwijk in 1982 and 1983 (van Uffelen, 1985) studied the effect of conductivity (maintained and changed during the growing season) on the incidence of skin cracks, Table 4.

Table 4. Skin crack scores for constant and changed conductivity regimes (0 = no cracks; 9 = very severe)

Conductivity Treatments	1982	1983 Harvest weeks 4-6	1983 Harvest weeks 7-9
Constant high, 4-5,000 µs	0.7	2.3	1.1
High early/low later	1.2	3.3	1.5
Low early/high later	0.8	4.1	1.3
Constant low, 2,000 µs	0.9	4.4	1.5

Conductivity changes were made when the first green fruit was firm in both years. In 1983 the incidence of skin cracks in harvest week 4-6 and 7-9 for red fruit was determined.

In 1982, changing from a high conductivity regime to a low conductivity regime increased the incidence of skin cracks. There was little difference between the other 3 regimes.

In 1983, the red fruit picked during weeks 4-6 was the most susceptible to skin cracks. Maintaining a high conductivity significantly reduced skin cracking scores (2.3) compared to a constant low conductivity (4.4). Changing from a low to high conductivity had little effect on skin cracking, the initiation of most cracks had obviously been prior to the first green fruit being firm. Changing from a high conductivity to low increased skin cracks (score 3.3) compared to the constant high (2.3), the change initiating further skin cracks during ripening at the lower conductivity. During harvest weeks 7-9, the low conductivity regime and changing from high to low conductivity had more skin cracks, than the constant high conductivity regime.

Further work in 1986 at Naaldwijk (de Kreij et al, 1990) investigated the effect of conductivity on skin cracking. Increasing conductivity from 1,500 µs to 6,750 µs surprisingly had no effect on skin cracking over the season. However, marketable yield was reduced 8% per 1000 µs conductivity rise in the range 2,500 to 6,500 µs (there were no yield reductions below a conductivity of 2,500 µs). Changing the conductivity regime 6-8 weeks after planting from 3,000 µs to 1,500 µs increased the incidence of skin cracks (16.1% of fruit affected) compared to maintaining a constant conductivity of 3,000 µs (12.6%).

At Naaldwijk in 1987 the effect of maintaining 7 conductivity regimes throughout the growing season on the incidence of skin cracks (variety Delphin, picked red) was evaluated in a rockwool recirculating system (Bakker and van Uffelen, 1987). Increasing conductivity from 2,200 µs to 6,000 µs decreased the percentage of fruit with skin cracks by 14% from 43% to 29% (Table 5). However, BER was increased 9%, from 2% to 11%.

Table 5 Effect of conductivity in the incidence of skin cracks.

	Conductivity (µs)						
	1,500	2,200	3,000	3,800	4,600	5,200	6,000
% fruit affected by skin cracks	45	43	40	36	34	29	25

Bakker and van Uffelen (1987) also investigated the effect of changing conductivity on the incidence of skin cracks, Table 6 (0 = no cracks; 5 = very severe). The conductivity regimes were changed from 6,000 to 1,500 µs 8, 11, 14 and 17 weeks after planting, and compared to constant conductivities maintained at 1,500 and 6,000 µs.

Table 6 Skin crack scores for constant and changed conductivity regimes averaged over three sampling dates (14/4, 26/5 and 27/7)

Conductivity treatment µs	Skin crack score (0 = no cracks; 5 = severe cracks)
Constant 1,500 µs	1.0
6,000 to 1,500 8 weeks after planting	1.4
6,000 to 1,500 11 weeks after planting	1.3
6,000 to 1,500 14 weeks after planting	1.2
6,000 to 1,500 17 weeks after planting	0.9
Constant 6,000 µs	0.8

Changing conductivity 8, 11 and 14 weeks after planting increase skin cracking compared with maintaining a constant low or high conductivity regime.

iii. Environment:

Screens;

In 1982, work at Naaldwijk (van Uffelen, 1985) evaluated the effect of using a screen over 3 time periods during the early season on the incidence of skin cracks, Table 7.

Table 7 Effects of using a screen on skin crack scores during the early season (0 = no cracks; 9 = very severe)

Screen Timing	Skin crack score
10 December 1981 to 28 March 1982	0.55
10 December 1981 to 20 February 1982	1.28
20 February to 28 March 1982	0.43

The presence of a screen during the period 20 February to 28 March appeared to be particularly important in reducing the incidence of skin cracks (score 0.43), compared to no screen from 20 February (score 1.28). It is possible that the screen helped maintain skin suppleness, as air humidities would have been lower without a screen. A screen would also lead to higher tissue temperatures leading to a faster growth rate.

Humidity; Work at Naaldwijk in 1987 (Bakker and van Uffelen, 1987)investigated the effect of variations in humidity (high humidities were achieved by use of a screen) until mid April, whereafter all environmental factors were maintained the same (variety Delphin, grown in a recirculating rockwool system).

High humidity during the day (89%) and over the 24 hour period favoured the occurrence of skin cracks,for fruit picked during April, Table 8. Over the three sampling dates the low day/night humidity regime consistently produced the lowest percentage fruit affected by skin cracks.

Table 8 Effect of humidity on the incidence of skin cracks on three sampling dates.

Day/night Humidity	Sampling Date 14/4	26/5	21/7		Mean
	(% fruit affected has skin cracks)				
High/high (89%)	91	47	41	=	60
Low/high	84	48	45	=	59
High/low	91	51	42	=	61
Low/Low (70%)	73	38	36	=	49

Dutch recommendations to reduce the incidence of skin cracks are that humidity during the day should not exceed 80%.

Temperature: The effect of temperature on skin cracks was investigated in work during 1983/4 and 1987. Van Uffelen (1985) reported work carried out in 1983/4 studying the effect of night temperature on the incidence of skin cracks. Night temperature below 15°C in 1983 and 1984 resulted in more skin cracks than regimes that maintained night temperatures above 15°C.

In 1987 a combination of 12 different temperature regimes were investigated. Regimes with a 24 hour temperature less than 19°C resulted in the most skin cracks, also the percentage of fruit with skin cracks increased when differences between day and night temperatures were at their greatest (average difference 7.5°C).

Recommendations are to maintain the 24 hours temperature above 20°C and to avoid large differences between day and night temperatures (Bakker and van Uffelen, 1987).

Growers need to take care that adequate night temperatures are maintained, so that in the mornings rapid and large temperature changes do not occur which increase skin cracking.

iv. Fruit thinning: Work between 1982 and 1984 (van Uffelen 1985) evaluated the effect of fruit thinning (ie removing at one time all fruit affected by BER) on skin cracking. Table 9.

Table 9 Effect of fruit thinning on skin crack scores for Trials in 1982, 1983 and 1984 (0 = no cracks; 9 = very severe)

	Year			
	1982	1983a	1983b	1984
No thinning	0.9	4.2	1.6	1.19
Half set fruits removed	1.0	-	-	
4 fruits per plant	-	4.7	1.9	1.36

a = Ratings in harvest weeks 4, 5,6
b = Ratings in harvest weeks 7, 8,9

In all 3 season's trials there was a trend for skin cracks to increase following fruit thinning, although difference were small.

v. Variety;

Skin cracking is to a large extent genetically controlled. Progress by the two main seed companies marketing sweet pepper varieties (Enza and Rijk Zwann) towards the breeding of varieties that are immune, or at least not susceptible to cracking, is fairly rapid.

vi. Guidelines to minimise skin cracking problems

1. Selecting a variety that is not prone to the problem is probably the most important factor.

2. Ensure steady plant growth through the season, sudden changes in growth rate which lead to rapid fruit expansion increase risks.

3. Maintain solution conductivities in the range 2,500-3,000 µs. Low conductivity (2,000 µs) in the Stockbridge EHS trial (1989) resulted in skin cracking problems during April and May, that were not evident at 3,000 µs and 4,000 µs.(see Section 4.2.1) Increases in conductivity above 3,000 µs although likely to decrease skin cracks will markedly increase BER risks.

4. Avoid sudden changes in solution conductivity, changes from high to low conductivity can be particularly damaging.

5. Screens early in the season (February-March) have been shown to decrease skin cracks probably because they raise daytime humidity when leaf area is still small.

6. Avoid high humidities (over 80% RH) for long periods, particularly during the day.

7. Maintain the 24 hour temperature above 20°C, and avoid large differences between day and night temperatures.

8. Don't remove fruit affected by BER all at one time, gradually remove or wait until ripe.

4.2 REVIEW OF UK RESEARCH

4.2.1 PEPPER NUTRITION TRIAL - STOCKBRIDGE EHS 1989

The trial aimed to investigate the effect of feeding 3 conductivity regimes (Low, 2,000-2,500 us; Medium, 3,000-3,500 us; High, 4,000-4,500 us) on the yield, quality and fruit size of 3 pepper varieties (Delphin, Madara, Bendigo) grown as a long season mono crop, picked red. Detailed monitoring of the two major quality problems affecting peppers, blossom end rot (BER) and skin cracking was also undertaken. Trial details are recorded in Appendix 1.

<u>Results</u>

Yield:

As conductivity increased there was a highly significant linear reduction in marketable yield throughout the growing season. Increasing conductivity from the low to medium regime decreased yield 4% (0.74 kg/m^2; 18.60 to 17.86 kg/m^2) and from the medium to high regime 9% (1.52 kg/m^2; 17.86 to 16.34 kg/m^2) overall the 3 varieties at the end of the season (Table 10). Marketable yield decreases at high conductivity were largely due to increased BER problems.

Table 10 Effect of Conductivity on Yield - mean of 3 varieties

Conductivity	Harvest date			
	To end May	June/ July	August to October	All Season
Low	5.76	5.92	6.91	18.60
Medium	5.55	5.55	6.95	17.86
High	5.36	4.47	6.50	16.34
SED	0.115	0.207	0.239	0.522
LSD (8 dl)	0.27	0.48	0.55	1.2

Quality:

High conductivity and to a lesser extent medium conductivity maintained quality to the end of May. Low conductivity signifcantly reduced % Class 1 fruit to the end of May, due to skin cracking problems. Class II fruit increased correspondingly at low conductivity. There were no notable differences in the amount of waste fruit (Table 11). From June until the end of the season the situation was reversed, % Class 1 fruit was reduced at high conductivity with no differences in % Class II fruit. At the end of the high and medium conductivities overall gave the same % Class 1 fruit (67%) and low conductivity 64%.

Table 11 Effect of Conductivity on Quality (% Class I and II fruit) and Waste (%) - mean of 3 varieties

Conductivity	Harvest date			
	To end May	June/ July	August to October	All Season
i) % Class 1:				
Low	56.8	71.1	63.7	63.9
Medium	70.9	70.2	60.4	66.6
High	78.5	64.9	58.1	66.6
SED	2.43	1.97	1.88	1.43
LSD	5.6	4.5	4.3	3.3
ii) % Class II:				
Low	36.5	19.6	25.2	27.0
Medium	22.4	19.1	26.9	23.1
High	15.0	16.2	26.3	19.7
SED	2.5	1.77	2.57	1.83
LSD	5.8	4.1	5.9	4.2
iii) % Waste				
Low	8.9	11.1	14.5	11.7
Medium	8.4	13.1	16.8	13.1
High	7.3	22.4	20.9	16.8

SED	1.0	1.41	0.95	0.58
LSD	2.3	3.3	2.2	1.3

Fruit Size (>75 mm):

High conductivity produced significantly more % class 1 fruit >75 mm to the end of May, as fruit from the low conductivity treatment was downgraded to Class II due to skin cracking problem. From June to the end of the season, there was a trend for increases in % Class 1 fruit >75 mm at low conductivity. At the end of the season all conductivities produced similar % large Class 1 fruit (40%), Table 12.

Table 12 Effect of Conductivity on % Large Fruit (>75 mm) - mean of 3 varieties

Conductivity	Harvest date			
	To end May	June/ July	August to October	All Season
Low	28.4	51.4	40.5	40.1
Medium	31.9	50.5	37.8	39.6
High	37.0	49.4	36.6	40.1
SED	1.63	2.05	2.25	0.82
LSD	3.8	4.7	5.2	1.9

Quality Defects:

The relative importance of the quality defects BER and skin cracking was monitored over the season.

Early in the season skin cracking was the major quality defect, which was exacerbated by low conductivity. Affected fruit were downgraded to Class II. Later in the season, BER was the most serious quality defect, particularly at high conductivity. Affected fruit were recorded as waste (Table 11).

The cumulative number of fruit (kg/m^2) affected by BER for all 3 varieties were counted on 25 May and 2 August (Table 13). For the period up to 2 August, raising conductivity from 2,000 to 3,000 us increased BER 40% (18 fruit/m^2 to 26 fruit/m^2), whilst raising conductivity from 3,000 us to 4,000 us increased BER over 250% (65 fruit/m^2) for the 3 varieties.

Table 13 Effect of Conductivity on Blossom End Rot - 3 varieties

	Harvest Period		
	To End May	(fruit/m^2)	To end August
Low	3		18
Medium	5		26
High	23		65

Conclusions

1. High Conductivity (4,000-4,500 µs) caused severe BER and significantly reduced marketable yield.

2. Low Conductivity (2,000-2,500 µs) increased skin cracking and reduced % Class 1 fruit in the early season (to end of May).

5. REPORT OF VISIT TO HOLLAND

5.1 ITINERARY

Tuesday, 11 September	Overnight ferry Harwich to Hook of Holland
Wednesday, 12 September	Visit to Delft Westerlee Auction
	Visit to Naaldwijk Research Station
Thursday, 13 September	Visits to Pepper Growers in the Westland
	Visits to Pepper Growers near Hertogenbosch
Friday, 14 September	Visit to Pepper Grower near Horst, Venlo
	Visit to Noord Limberg Experimental Station
	Return on overnight ferry to Harwich.

5.2 TECHNICAL NARRATIVE

5.2.1 Introduction

On leaving the ferry we drove to the Delft Westerlee Auction and examined several consignments of peppers. Green, red and yellow were the main colours with a few deep orange, possibly Solsa, and a small number of a pointed white variety.

Fruit quality was generally good apart from those packed in returnable crates for the domestic market, however, most Class I consignments showed slight thrips damage suggesting the widespread presence of WFT.

5.2 Visit to Naaldwijk Research Station

5.2.1 Introduction

Capital investments continue at a pace at Naaldwijk Research Station. The recently constructed office block and laboratories are undergoing a further extension and in addition to the 16 compartment house built for biological control experiments a further multi-compartment block has been constructed to undertake experiments on re-circulating hydroponic systems, and 2 further blocks are planned one of which is intended to undertake experiments on non-indigenous pests.

The "Long Term Plant Protection Plan" submitted to the Second Chamber of the Dutch Parliament in Spring 1990 aims at a 50% reduction in use of all chemicals over 10 years.

A further objective is to reduce energy input per unit of output by 50% by the year 2000 using 1988 as the base year.

Grodan had announced that they were setting up four plants throughout the Westland to act as collection points where used rockwool would be compressed into brickettes which would then be transported to a re-processing plant in Southern Holland for melting down and remanufacturing into fresh rockwool. The energy costs of this process in terms of both transport and re-melting must be high. A charge would be made to each grower for the disposal and this would be 25 Guilders per cubic metre, (approximately £8/m^3) plus transport currently disposal of rockwool in dumps costs 30 Guilders per cubic metre.

5.2.2 Blossom End Rot

Mr De Kreij explained the mechanisms of calcium transport in the plant stating that calcium flowed through the Xylem vessels and that problems often occurred when transport of photosynthates via the phloem became out of balance with the flows of water and minerals via the xylem into the fruit.

When a fruit is small water loss through transpiration is substantial as the fruit size grows transpiration is reduced and therefore the water flow carrying the calcium into the fruit is likewise reduced.
Mr De Kreij was doubtful whether night watering was beneficial. He argued that rockwool slabs contain approximately 12 litres of water per square metre and that maximum daily uptake in extreme conditions was only 6 litres of water per square metre and therefore there was no need for additional watering at night. Other evidence would contradict this view.

The following factors were identified as having an adverse effect on BER:

1. High nutrient solution conductivity, particularly in excess of 3000 µs.

2. Rapid increases in solution conductivity.

3. Low calcium concentrations in the root environment (< 140 mg/l Ca)

4. High solution magnesium (> 80mg/l Mg) and sodium (> 138 mg/l Na) concentrations.

5. Low root zone temperatures, particularly early in

season.

6. Environmental factors:

- high transpiration rates, both on hot sunny days and during the night.
- sudden changes in transpiration loss rates.

7. Removing all fruit affected by BER too rapidly.

8. Poor watering, leading to dry slabs/bags.

5.2.3 Skin Cracking - Janse

Skin cracks result from the fruit expanding quicker than the skin is growing and are initated during the night when the fruit expands due to positive root pressure.

It is almost certain that these expansion cracks can first appear on fruit 2 to 3 weeks after setting. However, they may not become visible to the naked eye until the fruit is much larger and/or skin elasticity decreases during ripening.

The slower a fruit develops the more susceptible it is to skin cracking. This is particularly common during spring or autumn. There are also great differences in varietal susceptibility to skin cracking. Varieties such as Mazurka have been found to have much increased resistance to skin cracking.

Experiments to assess the effect of increased conductivity have only indicated trends suggesting that the higher the conductivity the less the skin cracking however a replicated trial undertaken in 1987 (Bakker and van Uffelen, 1987) showed very positive effects.

The presence of Ammonium ions was found to improve shelf-life but made Blossom End Rot (BER) worse. Levels as high as 80 mg/l NH4-N were used.

The flavour was found to improve when the conductivity was raised but yield is reduced. Janse believed that plant breeding was the most likely solution to the skin cracking problem.

Cracking was found to relate positively to solution conductivity but there was only a trend. However significant yield reductions occurred at high conductivities largely due to the increase in Blossom End Rot.

A trial undertaken in 1988 showed that fruit thinning especially when done in the early stages of the fruit development results in increased cracking.

In 1991 it is planned to carry out an experiment using Mazurka which would be grown at a range of temperatures beginning from fruit set with a further series of regimes applied from when the first fruit ripened to red. Aspects such as flavour and shelf-life will be recorded as well as other quality factors.

The following factors have a negative effect on fruit shelf-life:

1. High solution conductivities

2. High glasshouse temperatures

however a replicated trial undertaken in 1987 (Bakker and van Uffelen, 1987) showed very positive effects.

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The following factors have a negative effect on fruit shelf-life:

1. High solution conductivities

2. High glasshouse temperatures

3. Larger day to night temperature differentials

4. Higher relative humidities

There is no doubt that there is considerable varietal variation in susceptibility to skin cracking. Representatives of both the seed companies we met confirmed that this was an important aspect in their breeding programme.

The following factors were identified as having an adverse effect on skin cracks:

1. Slow fruit growth rates, during spring/autumn.

2. Sudden changes in fruit growth rates.

3. Low solution conductivities (2000 µs or less)

4. Rapid changes in conductivity, particularly from high to low.

5. High humidities (over 80% RH) for long periods, particularly during the day.

6. Temperatures

- 24 hour temperatures below 20°C
- large differences between day and night temperatures

7. Removing all fruit affected by BER too rapidly.

5.2.4 Varieties

Mazurka will probably be the most widely grown variety in the Netherlands in 1991 and will be used as the standard variety in the green/red trials next year. However flavour is not one of its strong points.

Lambada (Rijk Zwaan) - was preferred by the researchers as it had better flavour, good early yield and was similar in quality to Mazurka.

Adele - was not included in the trials as it had a very poor shelf life, tended to be soft at picking stage and often ripened more on one side of the fruit than the other. It was not recommended.

Evident (De Ruiter) - gave the highest yield in the trial but had a large percentage of Class II. It is also very tall growing and open in habit and therefore fruit can be susceptible to sun scald.

E5596 (Enza) was the first new orange variety to compete successfully with Ariane.

Solsa - this is a dark orange variety with an apple flavour.

Arvis (E900) (Enza) - was the best yellow variety being preferred to Samanta (De Ruiter) which tended to have too large fruit.

Locas (1951) (De Ruiter) - tended to have very large fruit and will probably be better grown green rather than red.

The optimum fruit size in Holland was 75-85 mm and returns fell rapidly if 90 mm were exceeded.

5.2.5 Re-circulating Systems

The accumulation of sodium in closed hydroponic systems is a major problem with most water supplies in the Westland. Work at Naaldwijk 1987 (van de Burg 1988) studied the uptake of sodium and chloride by pepper plants. The sweet pepper has the lowest uptake compared with tomatoes and cucumbers, especially so in the later life of the crop. Van de Burg (1988) also studied the uptake of sodium and chloride by pepper plants (Table 14). The results of this work is discussed in 4.1.

The Denar Project was originally constructed to undertake demonstrations on low energy usage but the emphasis is now changing towards experiments on re-circulation.

It was found in 1988 that the amounts of water and fertiliser applied and used by a tomato crop grown in a run to waste rockwool system per hectare were as follows:-

Water applied	9,400 cubic metres
Drainage water	3,900 cubic metres
Fertiliser used	18,300 kilograms
Fertiliser lost through runoff drainage	9,300 kilograms

assuming that the water draining to waste contained 200mg/l N03-N, the loss of 3900 m^3 of drainage water would result in the loss of 780 kg/ha N.

In 1989 a re-circulation system was installed and the figures changed as follows:

Water applied	6,200 cubic metres
Drainage water to minimise sodium accumulation	700 cubic metres
Total fertiliser used	10,500 kilograms
Fertiliser lost in drainage water	1,500, kilograms

Assuming that the water draining to waste contained 200 mg/l N03-N, the loss of 700 m^3 of drainage water would result in the loss of 140 kg/ha N.

The adoption of a recirculation system , draining to waste only when sodium concentrations accumulated above 138 mg/l Na, reduced fertiliser loss from 51% of that applied in 1988 to 14% in 1989, and estimated nitrogen losses from 780 kg/ha N to 140 kg/ha N.

5.3 VISITS TO GROWERS IN THE WESTLAND - A. VAN DER HOUT, ENZA ZADEN

5.3.1 Fa Jena, Bwigoweg, Maasland

The crop on this nursery was of entirely yellow varieties grown as a second crop interplanted following early tomatoes. About 50 hectares of peppers are grown in this way in Holland.

The crop was sown on 1 May and inter-planted on 1 June, the tomatoes being removed at the end of June.

The main variety was Ariane but there was a smaller area of the new Enza variety E5596 which is orange/yellow, less tall than Ariane and a true F1. However, it is said to have a poorer flavour than Ariane.

The grower claimed to be using high conductivity ie 3,000-3,500 µs (at 25°C) in order to increase flower strength during the autumn period and offset the disadvantages of increased relative humidities, a dubious practice.

TSWV - about 60 plants had been lost out of a crop of 2 hectares and the infected plants had been distributed randomly through the crop. All thrips present in the crop were killed with an aerosol of Dichlorvos. Infected plants were removed as soon as they had been identified and the row marked.

The crop was grown on rockwool slabs drained to waste and provided the crop was healthy at the end of the season it was the practice to re-use the rockwool without steam or other sterilisation.

5.3.2 Gebr Spruit, Groeneweg, Naaldwijk

On this nursery the crop was sown on 15 November and planted early January. The main variety was Madara grown for harvesting green.

Despite the early sowing and the decision to pick green the height of the crop was not excessive with a gutter height of only 2 metres. The yield to date was 21 kilograms per square metre with a target of 25 kilograms by November.

The usual Dutch finned tube was installed down the middle of each double row but there was no underslab heating.

Hive bees were being employed to improve pollination although this seemed a doubtful advantage at this stage in the season.

The leaf miner Liriomyza hiudobrensis was readily apparent in the crop but claimed not to be a serious problem.

Conductivity in the slabs of 2,500 to 3,000 µs (25°C) was being used but many fruit appeared to have cracking problems.

The rockwool was re-used on this nursery. The old sleeves were removed, the slabs stacked and steam applied for one hour. Re-sleeving was done on the nursery. However if the old crop was not healthy, fresh rockwool was bought in.

5.3.3 Fa Gebr v.d.valk Harteveldlaan, Kwintsheul

On this nursery of 3 hectares the crops was grown red using Madara and Mazurka as the main varieties.

New Enza varieties under trial were as follows:

> Maestro (974) - claimed to be the best new variety available with yields as high as Mazurka. It can be grown with stem fruit only and its average vigour is good for early crops and shows no sign of Stip or skin cracking.
>
> 8576 - this variety was claimed to be quite promising but was more susceptible to Blossom End Rot than Maestro and generally looked inferior.

As with most other crops biological control had been used from the outset on this nursery but problems had developed with leaf miner, aphids, white fly and mildew and chemicals are now being used.

Labour cost - we were quoted the cost of a full-time skilled worker as between 40 and 45,000 Guilders per year. (approximately £13-15000 pa).

5.4 VISITS IN AREA NEAR HERTOGENBOSH WITH J CUPPEN (Rijk Zwaan)

5.4.1 Nursery - H Dings Elsendorp, Gemert

An 8,000 square metre glasshouse unit growing green/red peppers from a 6 October sowing. Crop was planted 25 November.

The main varieties were Mazurka and Evident. The new variety Lambada (RZ35-05) was on trial. It was claimed to be short jointed, easy to work and "blocky". It was claimed to be earlier than Mazurka, have a better flavour and be less susceptible to skin cracking and with almost no Stip, however Blossom End Rot remained a problem.

French fly have been a problem earlier in the life of the crop but Torque had given good control. Anthocorid bugs had come in naturally and given some pest control of aphids and thrips.

Marketing was through one of the two major auctions in the Venlo area.

5.4.2 Langenbom Nursery, Zeeland

A modern glasshouse unit of 30,000 square metres producing only peppers. The main varieties were Valetta and Mazurka. The former was selected for its very good early yield and suitability for early crops.

New varieties on trial were:

Polka (Rijk Zwaan) - a promising red/green variety short jointed, but difficult to twist and more suitable for a green crop.

Mazurka - gave the highest yield in the trial.

P1038 (Panam) (Sluis and Groot) - a short jointed variety but skin cracking a major problem early in the season.

The crop was sown on 7 October and planted during the last week of November. Underslab heating was used and a temperature of 20-21^{o}C targeted in the slab.

Moveable thermal screens had been installed, woven clear polythene in one house and LS10 in the other block. The main objectives were raising humidity early in the season, and fuel saving. However it had proved difficult to use the screens to reduce stress during peak radiation in summer.

Hortiplus glass had been installed in one block which gave significant fuel savings but at an additional cost of 3 Guilders per square metre. It was considered that the cost was justified as a 40% grant had been available from the government for the entire block. This type of glass coating however reduced light transmission by 10% and led to reduced condensation and therefore increased humidities.

The standard rockwool system was used with drainage to runoff. Each rockwool slab was used for three years and steamed in between. However following the introduction of the new Grodan system for re-cycling rockwool, one year life slabs will be purchased next time.

Thrips (WFT) were a problem on this nursery. Dichlorvos has been sprayed five times followed by three introductions of Amblysieus.

5.5 Visits with C Verberne, Dutch Advisory Service, Venlo

5.5.1 Tom Neits Nursery Near Horst

This nursery had 20,000 square metres of glasshouses half of which were 26 years old and the other half only 2 years. Both yellow and red peppers were grown.

The main varieties were Samanta (yellow) which was large fruited and suffered from the problem of shoulder cracking and Cubico which was a red variety also with very large fruit.

Part of the crop was grown in Agrifoam claimed to have the following advantages:

More stable nutrition than rockwool

Similar yields to rockwool

Can be steamed more frequently without breaking down (6-7 year life)

Its reduced waterholding capacity means it is easier to dry out at the end of the season.

Drying out can be completed using a machine to compress the material.

Disposal is free as there is a ready market for the used product or it can be re-cycled.

The water supply for this nursery was from a deep borehole and very pure water of only 100 µs was available.

Of the various systems employing rigid troughs the one used on this nursery at a cost of 5 Guilders per metre was as shown in the diagram below:

The woven material, similar to Mypex, failed to prevent root growth penetrating from the un-wrapped rockwool slab however this did not seem to prevent the feed solution draining down the trough. The roots looked active and very healthy.

A bulk system of liquid feed was employed said to cost between 25 and 50,000 Guilders depending on the complexity of the computer control. The principles of the system were identical to the systems installed at Naaldwijk and Noord Limburg Research Stations.

The watering system used was intermittent aiming at a similar run-off to that used for the standard rockwool system. The run-off water was then collected and sterilised using Ultra Violet Light in a machine supplied by Hanovia of West Germany but which contained British equipment. The machine on this nursery cost 20,000 Guilders and was said to be a proto-type and claimed to be maintenance free. Two sand filters were used to ensure that the drainage water was clean before passing over the UV light.

It was hoped that the equipment would control TMV, Pythium and Olpidium. Installed only one year ago it was difficult to tell whether the machine was effective or not. It was essential that the pH's should be kept below 5.8 to prevent deposits of calcium phosphate on the lamp, and acid at the rate of about .5 litre per day was added to the catchment tank. The throughput was about 2.5 cubic metres per hour.

We were told that there were about 90 pepper growers in the Venlo area and that these met regularly in small groups of 8 or 9. Most growers in the area train their plants on the three stem system. There are about 75 hectares of peppers in the area.

Although the grower claimed to be using biological control, Pirimor was being used to assist with aphid control and Potassium Cyanide had been used to control thrips and capsids. Cyanide had to be used three times to control capsids which appeared to be a new problem with sweet pepper growers. In the Westland liquid Vydate had been used but we were told to little effect. It is illegal to use either cyanide or liquid Vydate in the UK.

Labour Costs - we were quoted 22 Guilders per hour for "regular part time" labour and 10 Guilders for casual labour. The cost of a full-time experienced worker was 45,000 to 50,000 Guilders per annum total cost to the employer including tax and health insurance contributions.

5.6 PROEFTUIN NOORD LIMBURG (NEW VENLO RESEARCH STATION)

A whistle stop tour of this experimental station revealed a wealth of interesting experimental work. The station had been moved to a new site with a completely new glasshouse complex of top quality 4 metre Venlo Glasshouses with state of the art computer for control monitoring and data capture. A bulk liquid feeding system had been installed by Windmill with full computer control and even a small ozone injector was on trial.

In one of the pepper crops rockwool was being compared with Agrofoam in a recirculating system. Each plant was growing on 1 litre of substrate but the depth of slab was variable; 2.5, 5.0, 7.5 or 10 cm. It was found necessary to water the Agrofoam more frequently than the rockwool initially. During the early life of the crop drips were used to give each plant intermittent watering. Once a good root system was established the irrigation system was changed to one continous NFT type input per channel.

Rain water was used to improve the water quality but it was still found necessary to dump the solution 3-4 times per season due to the buildup of Sodium and Chloride. There were no disease problems in the recirculating system and it was considered that if the roots were strong and healthy there was no great disease risk.

A second experiment involved the use of rigid troughs costing 3 to 4 Guilders per trough each of which contained a non-wrapped metre long slab of rockwool. Watering was through a drip system with the run-off re-circulated. This crop was planted later and used direct fired Priva heaters as a major heat source simulating fairly low energy input systems.

In this trial various planting densities were being examined. Plants were trained with either 2 or 3 stems per plant and the spacing in the row was also variable. The highest density was 8 stems/m^2.

A fogging system was being used in one of the trials to raise the humidity in a cucumber crop but there was no work in progress to examine the use of fog for peppers. Although this was planned for 1991.

6. RECOMMENDATIONS FOR FURTHER INVESTIGATION

The following projects have been identified as requiring further investigation to improve our understanding and ability to minimise fruit quality defects in sweet peppers.

1. The potential for improved relative humidity control during the day and night to minimise BER problems, and to improve skin elasticity. Positive humidification is likely to be beneficial.

2. Variety testing to keep abreast of breeding programmes which are aiming to develop varieties less susceptible to skin cracking and BER.

3. Recirculation systems for sweet pepper production - system comparisons, including continuous water application systems.

4. The benefits of night water applications in reducing BER problems.

APPENDIX 1

PEPPER NUTRITION TRIAL - STOCKBRIDGE EHS 1989

Materials and Methods

Sowing Date:	23 November 1988
Planting Date:	16 January 1989
Substrate:	Rockwool
Varieties:	Bendigo, Delphin, Madara
Training:	2 leaders per plant
Spacing:	45 cm in the row
Environment:	A fixed screen of anti-condensate polythene lined the house until 7 March.

Temperatures (^{o}C):

	Day	Night	Vent
From Planting:	23	21	27
6 weeks after planting:	23	Gradually reduced to 19	27
From first harvest:	Gradually reduced to 21	19	Gradually reduced to 24

Nutrition:	Slab Conductivities from planting	
	Low:	2,000-2,500 us
	Medium:	3,000-3,500 us
	High:	4,000-4,500 us

First harvest: 30 March 1990

Design: 3 x 3 x ; Youden square design

Records: Fruit harvested weekly - weighed
- % Class I/II graded
- % Waste
- >75 mm

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