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|---|---|
| Project title: | Crop management systems for chilli pepper production |
| Reports: | First Annual Report (1998)<br>Final Report (1999) |
| Project number: | PC 138 |
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| Date Project commenced: | February 1997 |
| Key words: | Chilli pepper, Scoville index, capsaicinoid, capsaicin, pungency, yield and labour requirement. |

The results and conclusions in this report are based on a single experiment. The conditions under which the experiment was carried out and the results have been reported with detail and accuracy. However, because of the biological nature of the work it must be borne in mind that different circumstances and conditions could produce different results. Therefore, care must be taken with interpretation of the results especially if they are used as the basis for commercial product recommendations.

**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.

Signature .....A. Lee.....

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## CONTENTS

## PRACTICAL SECTION FOR GROWERS

### Objectives and background

In year 1 of the project (PC 138 Annual Report), trials were conducted to provide agronomic information relating to the production of chilli peppers to growers of rockwool crops and those using lower input soil systems. The main objective of the trials was to identify suitable cultivars for UK markets and to provide information on crop management systems in order to maximise productivity with efficient use of labour. Results from these trials indicated that the Jalapeno and Cayenne varieties were most suited to UK production and that the plants should be grown on the V-system rather than in double rows. Plant yields were also increased by harvesting green fruit twice weekly with the increase in labour requirement being offset by an increase in returns.

Two potential problems were highlighted from the first year of this study namely that the labour requirement for the crop per kilo of harvested fruit increased dramatically once the crop reached the wire (2.25 m). Secondly that the "heat" or "pungency" of the fruit varied throughout the season. In some instances this resulted in the chillies being described as having "no pungent taste" by a major marketing company. However fruit pungency was increased in the hydroponic crop by raising the slab Ec. Chillies are eaten because they are pungent. It is therefore a major quality requirement that growers maintain adequate pungency levels throughout the season if the crop is to compete with that coming from abroad.

From mid season onwards trolleys were required for harvesting and because of the bush habit of the plants fruit was also developing lower down the plant. Therefore pickers were required to search a greater proportion of the plant for ripe fruit. In order to maintain profit margins potential growers will need to adopt growing methods that will reduce the need for trolleys.

The work reported in this study is split into 3 sections. The main focus of the work was designed to evaluate a range of crop management systems for long season hydroponic crops. Secondly we investigated the effects of different feed regimes on the pungency of the fruit. As in the first year of the study a short season summer crop was also grown using a low input soil system. This section maybe of particular interest to those growers seeking alternatives to protected summer lettuce as the growing season for this crop was scheduled to run from 1st May to the 25th September.

Varietal choice

The trials in 1997 indicated that the Jalapeno and Cayenne types were most suited to UK production. During 1997 some of these varieties suffered from Pepper Mild Mottle Virus (PMMV), a type member of the TMV family of viruses. Significant yield loss and poor fruit quality followed. Initial infections were probably seed transmitted. Therefore in 1998 TMV resistant varieties were chosen and prior to sowing the seed was surface sterilised in a 10% solution of tri-sodium phosphate ($Na_3P0_4$) (Appendix I) as an added precaution.

Fruit cracking, which resulted in fruit being downgraded, was also a problem in 1997 although it was specific to the Jalapeno varieties. However the "problem" is seen as a favourable trait in the U.S. and Mexican markets. Breeding programmes in these countries actively select Jalapeno varieties that exhibit the presence of cuticular skin cracks. For trials in 1998 a hybrid Jalapeno cv Hercules was selected that exhibited resistance to skin cracking making it more suitable for the UK fresh market.

**Summary of results**

Average Class I yield recorded in the hydroponic crops were 16.5 kg $m^{-2}$ and 14.2 kg $m^{-2}$ for Jalapeno cv Hercules and Cayenne cv Wonder Hot respectively. These were increased compared to those obtained in 1997 due partly to a longer growing season and also a better choice of variety. Labour required for harvesting was positively correlated to plant yields and was highest for cv Wonder Hot when grown on a high wire system (3.6 m). Layering cv Hercules reduced plant yields compared

to stopping the crop at a low wire (2.1 m). This was attributed to the different growth rates of the selected leaders which resulted in the heads of adjacent plants becoming tangled.

In the low input soil system cv Hercules produced 6.6 kg $m^{-2}$ Class I fruit compared to 3.3 kg $m^{-2}$ for cv Wonder Hot. Yields from these crops could have been substantially increased if they had been allowed to grow on for longer towards the end of the season. However they were purposely pulled out at the end of September to allow a winter crop of lettuce to be planted.

Fruit quality from both varieties was excellent with Class I fruit representing approximately 90% of total yield. No fruit cracking was observed in the Jalapeno crop cv Hercules and no symptoms of Pepper Mild Mottle virus were seen.

The Scoville Index (pungency) of the fruit fluctuated throughout the season in both the rockwool and soil grown crops. However pungency was always higher in fruit harvested 35 days after pollination compared to those harvested after 25 days. This was attributed to the mature fruit accumulating more or the chemicals responsible for pungency (capsaicinoids). At no stage in the season did fruit pungency levels drop so as to be described as having "no taste".

**Action points for growers**

- Grow only TMV resistant cultivars.

- Prior to sowing treat all seed in a 10% solution of tri-sodium phosphate ($Na_3P0_4$) as an added precaution against virus spread (Appendix I).

- Grow varieties suitable for the UK market, namely Jalapeno varieties for green fruit that express resistance to cuticular skin cracking. Hercules used in this trial was an excellent variety.

- Fruit pungency fluctuates naturally throughout the season. Choose varieties with genetically high pungency ratings (medium / hot). Your seed supplier should be able to give you an indication of the Scoville index rating of a particular variety. Mild varieties may give fluctuations in pungency levels which in some instances may lead to "no taste" sensation.

- Position the crop wires so that the tops of plants can be reached from ground level this will help reduce harvesting costs from mid season.

- Yields from the soil grown crops could be increased dramatically by extending the season into November.

- Use calcium nitrate fertiliser to prevent problems of blossom end rot in soil grown crops.

**Practical and financial anticipated benefits**

Currently the area of chilli peppers grown in the UK is small, estimated at around 2 to 3 ha. The retail market is also relatively small, estimated to be in the region of 1100 tonnes per year, but expanding in volume terms at a rate of 15% per year, and marketing organisations are keen to replace imported produce with home-grown fruit. Small bird-eye chilies represent one third of the total market (366 tonnes) and are valued at £9.80/kilo. Unfortunately these types are unsuitable for long-season cropping in the UK. The remaining 734 tonnes consists of Jalapeno, Fresno, Cayenne and Scotch Bonnet chillies valued at £4.40/kilo.

With supermarkets also placing increasing emphasis on product quality in terms of freshness, traceability and reduced pesticide usage through bio-control and IPM systems there is tremendous opportunity for the UK protected salads industry, which is world class in this area, to develop chilli pepper production. Initially there is scope for production to increase without adversely affecting prices through import substitution. It has been suggested that 30% of the UK chilli market could be satisfied by UK production.

The processing market is also showing rapid growth. Retail sales of prepared ethnic foods (Indian, Mexican and Chinese) were valued at $429 million in 1997. These foods and other popular cuisines (Caribbean, Thai and Indonesian) rely heavily on chillies as a raw ingredient.

For further information on the market potential of chilli peppers read the report by Miles (1994) *Market development potential for hot chilli peppers*. This details the Australian market but as both Australia and the UK follow American trends it is particularly relevant.

## SCIENCE SECTION

### Introduction

The initial experiments conducted in 1997 (PC138 Annual Report) suggested that the pungency of the chilli fruit was reduced in mid summer when grown in hydroponics. Chillies are eaten because they are pungent it is therefore a major quality requirement for the crop. Supermarkets and processors require mild chillies to remain mild and hot chillies to remain hot. Varietal choice, crop nutrition, environmental factors (Harvell and Bosland 1997) and fruit maturity at harvest (Balbaa *et al.*, 1968; Estrada *et al.*, 1997) have all been shown to contribute to the pungency of field grown chilli peppers. Trials at Stockbridge House in 1997 indicated that growing the crop at elevated slab Ec's increased the pungency, although sampling was limited to three dates. In 1998 two experiments were designed to measure the effects of feed composition, electrical conductivity, watering regime and fruit maturity at harvest on the pungency of fruit harvested throughout the entire season from hydroponic and soil-grown glasshouse crops.

Fruit pungency is caused by a group of chemicals called capsaicinoids of which capsaicin is the major analogue. The methods used to measure fruit pungency in chillies range from the unrefined to the scientific. A common style of evaluating pungency is to simply take a fruit and taste it. However, whilst being quick and cost effective, this may leave much to the palate of the taster. The Scoville index (Anon, 1989) is a more refined approach. In this method human subjects taste a chilli sample and record the heat level. There is a British Standard test for this method, BS 45 85. The samples are diluted in a sugar solution until the palate no longer detects the pungency. This dilution is called the Scoville index. This methodology was used in experiments at Stockbridge House during 1997. However this test is still subjective and there are serious limitations on how many samples a taster can handle within a reasonable time.

The most accurate method for measuring pungency is to use High Performance Liquid Chromatography (HPLC). In this procedure chilli fruit are dried, ground to a fine powder and the capsaicinoids extracted (Collins *et al.,* 1995). The Scoville index of the sample can then be determined using a simple calculation. HPLC was used for the purposes of this study.

Another finding from the work conducted in 1997 was that from mid season onwards the labour required to harvest the crop rose dramatically. Trolleys were required for harvesting and because of the bush habit of the plants fruits were also developing lower down the plant. Therefore pickers were required to search a greater proportion of the plant for ripe fruit. During 1998 a number of crop management systems were evaluated for hydroponic crops aimed at minimising the labour requirement.

As in the first year of the study a short season summer crop was also grown using a low input soil system. This section maybe of particular interest to those growers seeking alternatives to protected summer lettuce as the growing season in the glass was scheduled to run from 1st May to the 25th September.

## 1. Effect of training systems and variety on the labour requirement and productivity of a long-season chilli pepper crop.

### MATERIALS AND METHODS

#### Crop diary

| | |
|---|---|
| Varieties: | Hercules (Jalapeno) |
| | Wonder Hot (Cayenne) |
| Sowing date: | 17 November 1997 |
| Blocked on: | 3 December 1997 |
| Spaced: | 22 December 1997 |
| Planting date: | 16 January 1998 |
| Date of first pick: | 23 February 1998 |
| Final harvest: | 3 November |

#### Cropping details

The plants were grown on the V-system in a modern 200m$^2$ Venlo glasshouse. Each plot contained 20 plants spaced at 22.5 cm within the row and 1.6 m between rows. Planting density was 2.8 plants m$^{-2}$. The final head density was increased to 8.3 heads m$^{-2}$ by taking 3 leaders from each plant. The lateral branches of cv Hercules were trimmed back to 3 nodes. Those of cv Wonder Hot were trimmed to 2 nodes. The crop was harvested twice weekly until September when one weekly harvest was taken.

#### Pest and disease control

Biological control agents were used where possible and introduced at standard tomato rates.

*Aphidius colemani*
*Aphidius ervi*
*Aphidoletes aphidimyza*
*Phytoseiulus persimilis*
*Amblyseius cucumeris*
*Amblyseius degenerans*

Prior to the establishment of *Phytoseiulus persimilis* a spot spray of Torq was applied on 20 March to control emerging spider mites. An application of Pirimor was made on the 27 March to control aphids. *Bacillus thuringiensis* was applied on 24 July. No fungicides were applied to the crop.

Climate control

After transplanting the temperature set points for day and night were 22°C venting at 25°C and 20°C venting at 22°C respectively. To enable fruit set from the 3rd lateral break onwards the day / night set points were reduced to 20°C and 19°C respectively. $CO_2$ was enriched to 800 vpm throughout the season until 9 September.

Experimental design

The design had eight treatments comprising all combinations of two varieties (Wonder Hot and Hercules). Two layering treatments and two string-angle treatments:

1. Crop grown straight to the wire
2. Crop angled to the wire.
3. Crop grown straight to the wire and layered.
4. Crop angled to the wire and layered.

The design was arranged in eight rows of plants with the four combinations of layering and string angle treatments applied randomly to the eight rows to give two replicates of each treatment combination. The rows were orientated north-south and each was divided between the two varieties. For each layering by string angle

combination each variety was allocated to a north plot in one replicate and a south plot in the other so that north-south trend effects on variety comparisons and variety by treatment interaction comparisons could be eliminated.

The strong vigour of the Cayenne variety cv Wonder Hot prevented it from being layered. Therefore the treatments were modified during use by changing the treatments for this variety to a high-wire treatment (3.6 m). These were compared to those plants grown to a low wire (2.1 m).

## RESULTS

### Yield

Fruit was harvested from the last week in February to the first week in November. Class I yield peaked in May at 2.5 kg $m^{-2}$ and in June at 3.4 kg $m^{-2}$ for cv Hercules and cv Wonder Hot respectively (Figures 1 and 2). Class I yield was significantly higher for cv Hercules when this crop was grown to the low wire (2.1 m) and stopped (15.5 kg $m^{-2}$) compared to layering the crop (10.3 kg $m^{-2}$) (Figure 1). Class I yield was significantly higher for cv Wonder Hot when this crop was grown to the high wire (17.8 kg $m^{-2}$) compared to the low wire (10.7 kg $m^{-2}$) (Figure 2). Angling the string to the wire had no significant effect on Class I yields. A full breakdown of monthly Class I yield figures is provided in Appendix II.

Fruit quality was excellent with Class I fruit representing 92% and 89% of total yield for cv Hercules and cv Wonder Hot respectively. No fruit cracking was seen in cv Hercules (Plate 1) and cv Wonder Hot produced good quality straight fruit (Plate 2). No virus symptoms were seen.

### Plant growth rate

Sloping the strings to the wire significantly reduced plant growth rates in cv Hercules from approximately 4 weeks after planting (Figure 3). Sloping the strings did not reduce the growth of cv Wonder Hot (Figure 4).

Plate 1. Jalapeno chilli peppers cv. Hercules

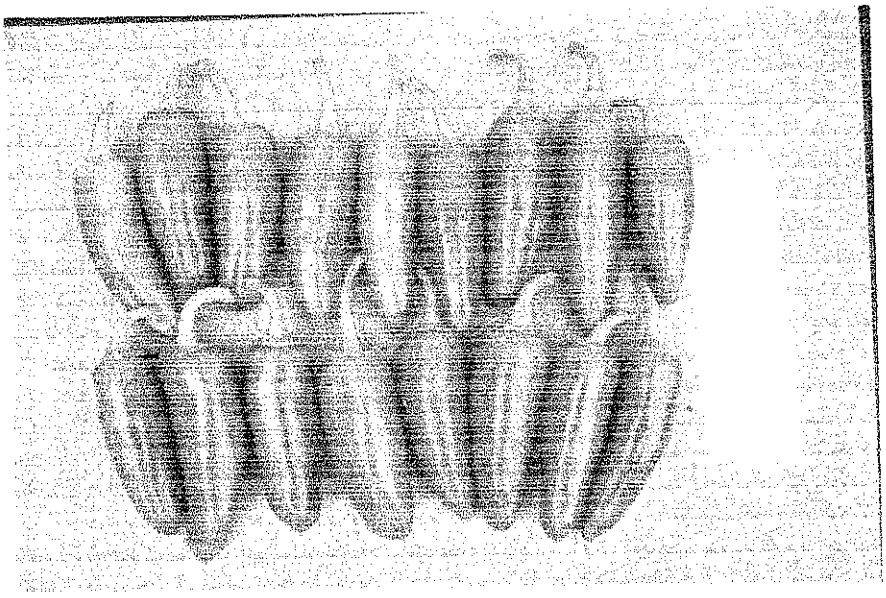


Plate 2. Cayenne chilli peppers cv. Wonder Hot

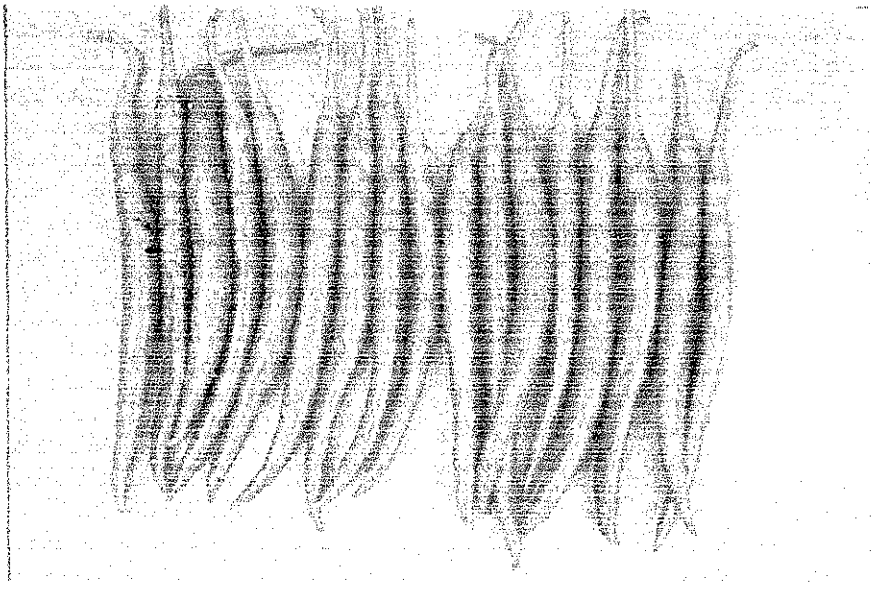


**Figure 1. Monthly Class I yield for chilli peppers cv Hercules grown to a low (2.1 m) wire and layered or stopped.**

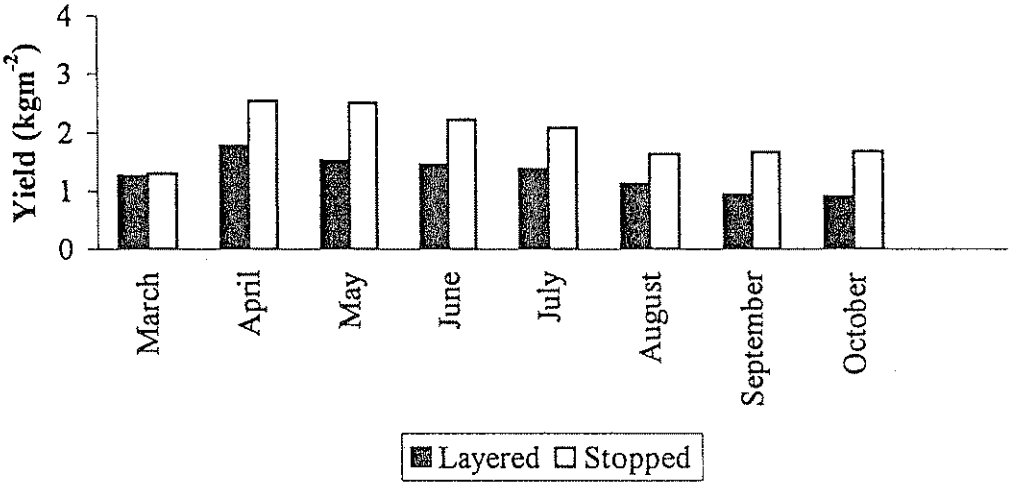
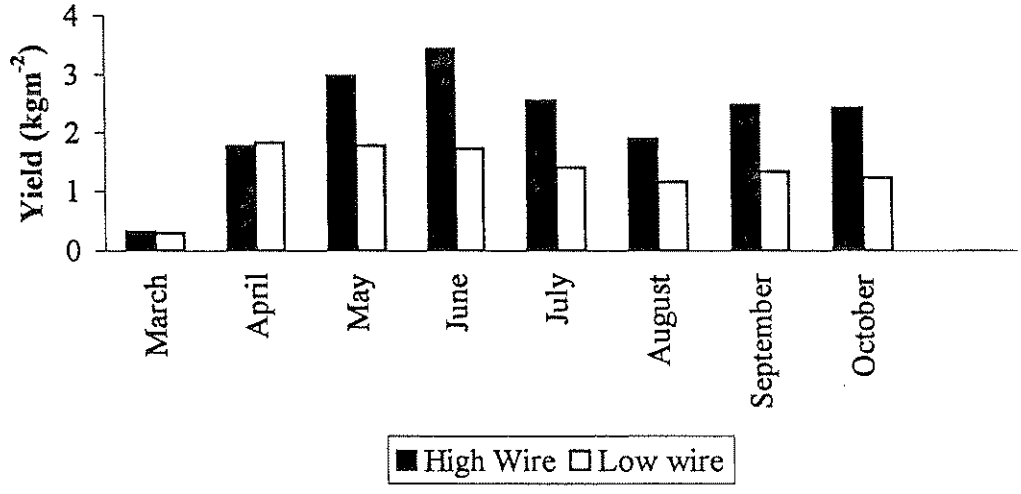



**Figure 2. Monthly Class I yield for chilli peppers cv Wonder Hot grown on a high (3.6 m) and low wire (2.1 m) system.**



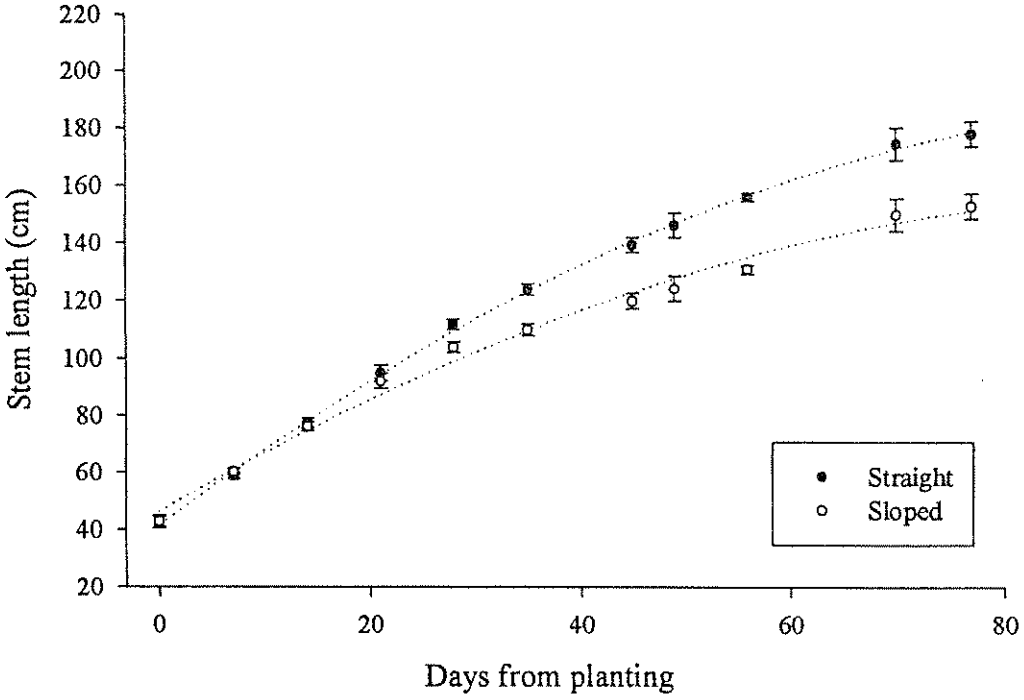



**Figure 3. Effect of wire angle on plant height of Jalapeno chilli peppers cv Hercules**
**Bars represent $SED_{(df=13)}$**

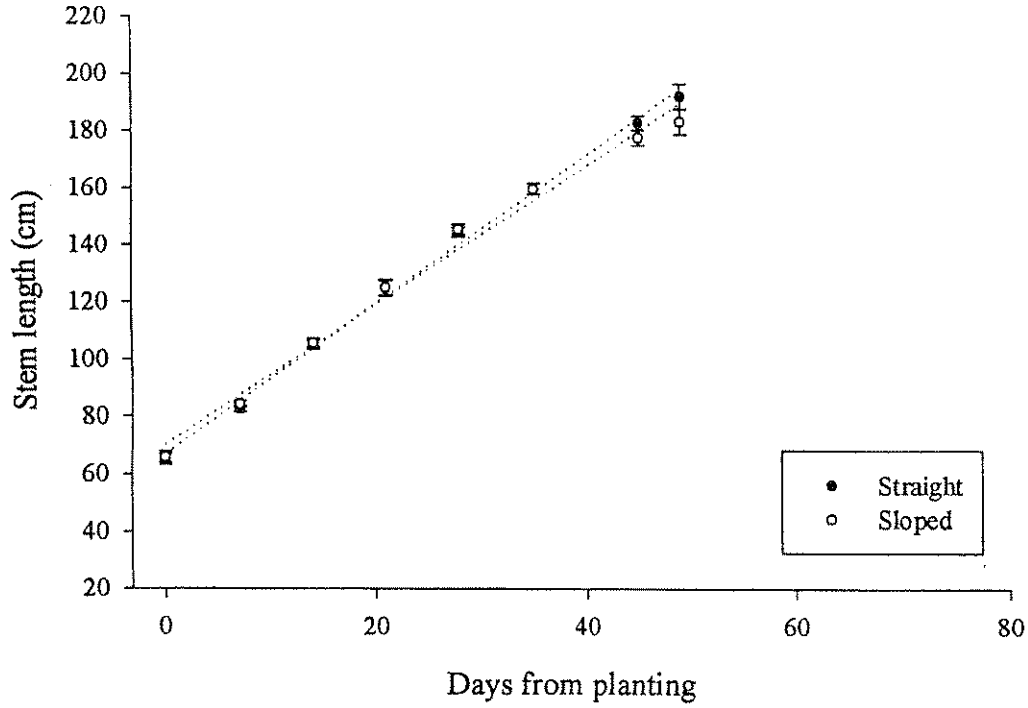



**Figure 4. Effect of wire angle on plant height of Cayenne chilli peppers cv Wonder Hot**
**Bars represent $SED_{(df=13)}$**

Labour requirement

The Jalapeno crop cv Hercules required considerably less labour compared to the Cayenne cv Wonder Hot. Total labour required for cv Hercules was 11118 hrs $ha^{-1}$ when grown on a low wire system and layered compared to 11223 hrs $ha^{-1}$ when stopped (Figure 5a-5c). Total labour required for cv Wonder Hot was 26706 hrs $ha^{-1}$ and 18557 hrs $ha^{-1}$ when grown on a high wire (3.6 m) and low wire (2.1 m) system respectively (Figure 6a-6c).

Harvesting represented the majority of labour required by both crops (Figure 7a-7d). However in contrast to 1997 the differences in harvesting times for both varieties on each of the growing systems was positively related to Class I yield, the increase in time relating to an increase in yield.

Figure 5a. Total labour (hrs $ha^{-1}$) required per month for twisting trimming and harvesting Jalapeno chilli peppers cv Hercules grown to a low wire (2.1m) and layered.

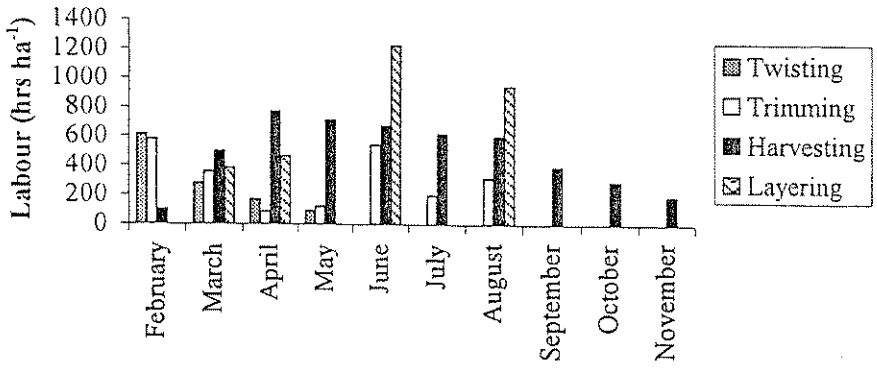



Figure 5b. Total labour (hrs $ha^{-1}$) required per month for twisting, trimming and harvesting Jalapeno chilli peppers cv Hercules grown to a low wire (2.1m) and stopped.

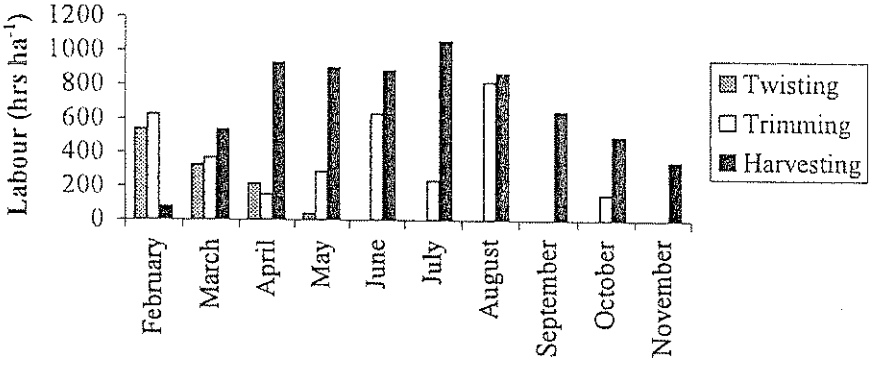



Figure 5c. Total labour (hrs $ha^{-1}$) required for twisting, trimming and harvesting Jalapeno chilli peppers cv Hercules grown on a Low wire (2.1m) system and layered or stopped.

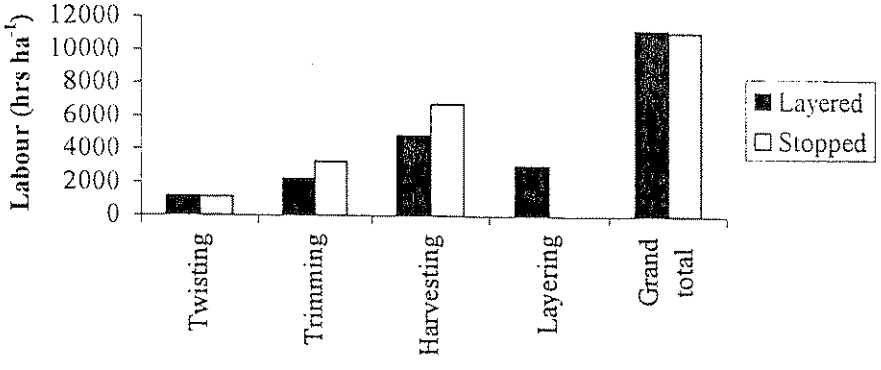


**Figure 6a. Total labour (hrs ha$^{-1}$) required per month for twisting trimming and harvesting Cayenne chilli peppers cv Wonder Hot grown on a high wire (3.6m) system.**

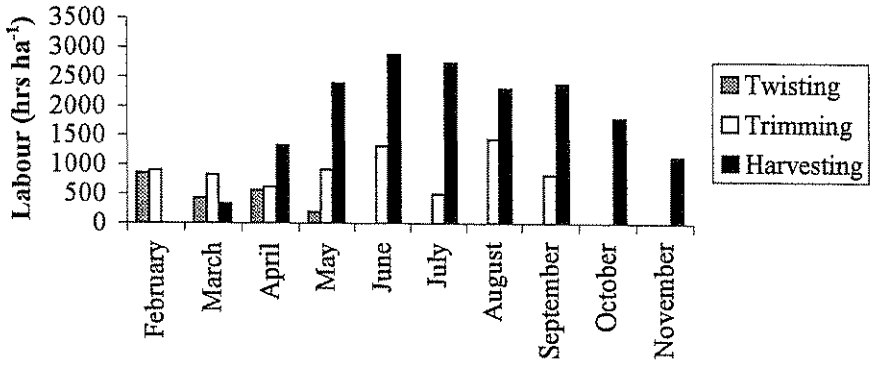



**Figure 6b. Total labour (hrs ha$^{-1}$) required per month for twisting trimming and harvesting Cayenne chilli peppers cv Wonder Hot grown on a low wire (2.1m) system.**

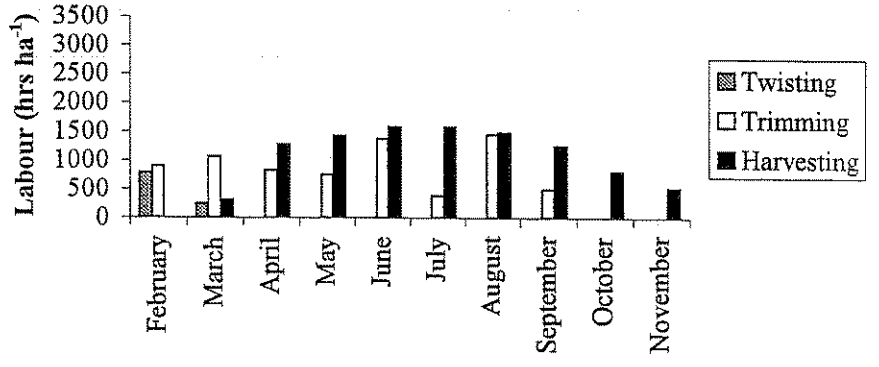



**Figure 6c. Total labour (hrs ha$^{-1}$) required for twisting trimming and harvesting Cayenne chilli peppers cv Wonder Hot grown on a low wire (2.1 m) and a high wire system (3.6 m).**

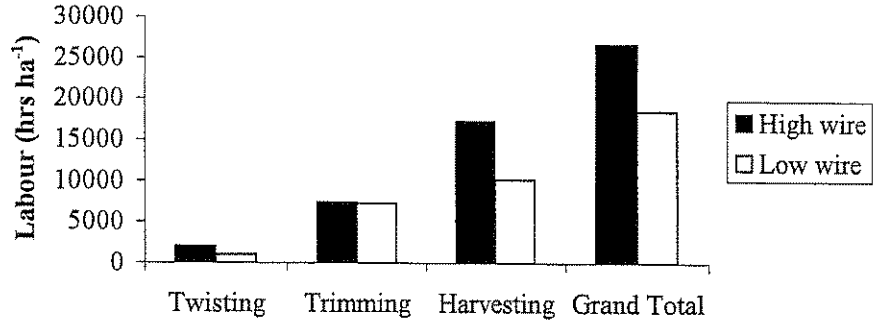


**Figure 7a. Percentage time spent on twisting, trimming and harvesting Jalapeno chilli peppers cv Hercules grown to a low wire (2.1m) and layered.**

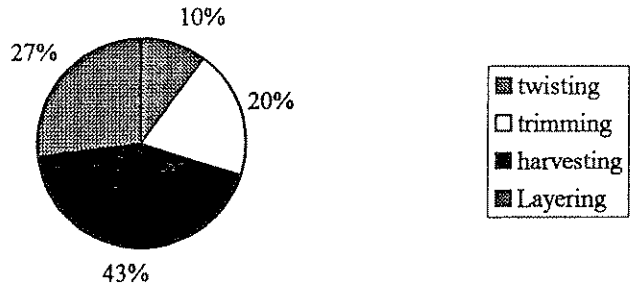



**Figure 7b. Percentage time spent on twisting, trimming and harvesting Jalapeno chilli peppers cv Hercules grown to a low wire (2.1m) and stopped.**

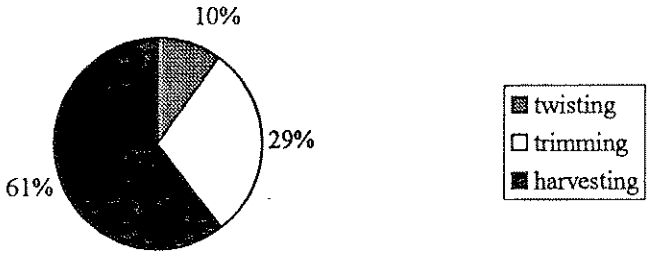



**Figure 7c. Percentage time spent on twisting, trimming and harvesting Cayenene chilli peppers cv Wonder hot grown on a high wire (3.6m) system.**

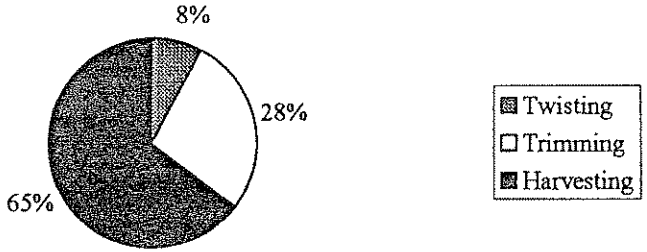
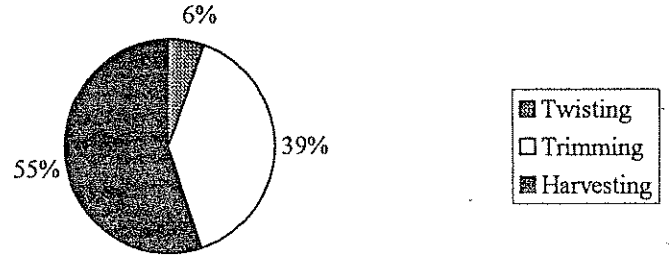



**Figure 7d. Percentage time spent on twisting, trimming and harvesting cayenne chilli peppers cv Wonder Hot grown on a low (2.1m) wire system.**



**2. Effect of nitrogen and electrical conductivity on the yield and pungency of a long-season chilli pepper crop.**

## MATERIALS AND METHODS

### Crop diary

| | |
|---|---|
| Variety: | Hercules (Jalapeno) |
| Sowing date: | 17 November 1997 |
| Blocked on: | 3 December 1997 |
| Spaced: | 22 December 1997 |
| Planting date: | 16 January 1998 |
| Date of first pick: | 23 February 1998 |
| Final harvest: | 3 November |

### Cropping details

The plants were grown on the V-system in a modern 200 $m^2$ Venlo glasshouse. Each plot contained 16 plants spaced at 22.5 cm within the row and 1.6 m between rows. Planting density was 2.8 plants $m^{-2}$. The final head density was increased to 8.3 heads $m^{-2}$ by taking 3 leaders from each plant. The lateral branches were trimmed back to three nodes. The crop was harvested twice weekly until September when one weekly harvest was taken.

### Pest and disease control

Biological control agents and spray applications were the same as those described in Section 1.

Climate control

After transplanting the temperature set points for day and night were 22°C venting at 25°C and 20°C venting at 22°C respectively. To enable fruit from the 3rd lateral break onwards the day / night set points were reduced to 20°C and 19°C respectively. $CO_2$ was enriched to 800 vpm throughout the season until 9 September.

Experimental design

There were six treatments comprising of all combinations of three nitrogen regimes (N100, N200 and N300) and two drip electrical conductivity's (2.3 mS and 4.0 mS). The experiment was arranged as a (3x4)/2 augmented Trojan square design comprising a 3 x 2 factorial design. Each treatment was replicated four times.

Measuring chilli pungency

Flowers were tagged at anthesis on 11 dates throughout the season on 8 plants within each plot. This was recorded as the date of pollination. The effects of season and fruit maturity at harvest on pungency were recorded by removing fruit 25 days and 35 days after pollination or until they had accumulated approximately 470 and 680 day degrees respectively. The day degrees were calculated as the average 24-hour temperature from pollination to harvest (Table 1).

Fruit pungency was analysed using High Performance Liquid Chromatography (HPLC) as described by Collins *et al* (1995). The tagged fruit was harvested and their calyces were removed before being oven dried. Samples were then sent to Bretby Analytical Consultants for HPLC analysis where the levels of capsaicin, dihydrocapsaicin and nordihydrocapsaicin were determined.

The Scoville index of the crop was calculated by multiplying the capsaicinoid (capsaicin + dihydrocapsaicin) content (ppmH) of the fruit by a factor of 15 (Collins *et al.*, 1995). For the purposes of recording yield the fresh weight of the fruit removed was added to yield data for each plot.

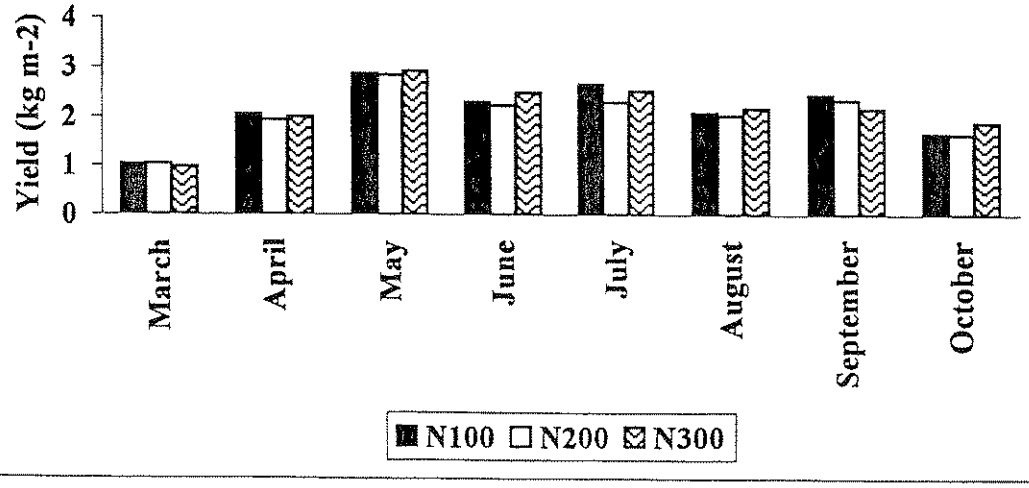
## RESULTS

### Yield

Fruit was harvested from the last week of February to the first week in November. Class I yields peaked at 3 kg $m^{-2}$ in May (Figure 8) and remained between 2.0 kg $m^{-2}$ and 2.5 kg $m^{-2}$ each month until September. In October the yield dropped below 2 kg $m^{-2}$ for all treatments (Figure 8). Although the plants were still producing flowers and showed no signs of damage from pest or disease the trial was terminated during the first week of November.

There were no significant treatment effects on Class I yield recorded at the end of the season. Mean Class I yield for plants grown at 2.3 mS compared with 4.0 mS was 16.8 kg $m^{-2}$ and 16.9 kg $m^{-2}$ respectively. Nitrogen concentration of the applied hydroponic feed also had no effect on yield. Mean Class I yield for plants grown on N100 ppm, N200 ppm and N300 ppm was 17.0 kg $m^{-2}$, 16.4 kg $m^{-2}$ and 17.2 kg $m^{-2}$ respectively. A full breakdown of monthly Class I yield figures is provided in Appendix III.

**Figure 8. Effect of nitrogen content of applied hydroponic feed on the Class I yield of a long-season chilli pepper crop cv Hercules.**



Fruit quality was excellent (Plate 1) with Class I fruit representing 93% of total yield. No fruit cracking was observed and no virus symptoms were seen.

Fruit pungency

Table 1 illustrates the date of pollination, days to harvest and accumulated day degrees for chilli fruit used to determine the pungency of the crop throughout the season. Capsaicin is primarily responsible for fruit pungency and was the major analogue present representing 65% - 76% of total capsaicinoids followed by dihydrocapsaicin (21% - 30%) and nordihydrocapsaicin (1% - 4%). The total capsaicinoid content was higher in fruit harvested 35 days after pollination compared to fruit harvested 25 days after pollination (Table 1).

**Table 1. Date of pollination, days to harvest, accumulated day degrees (calculated as average 24-hour temperature), total capsaicinoid content (ppmH) and percentage different capsaicinoids present for chilli fruit cv Hercules grown in hydroponics.**

| Date of pollination | Days to harvest | Accumulated day degrees | Total capsaicinoid (ppmH) | % CAP | % DHC | % NDC | Scoville Index |
|---|---|---|---|---|---|---|---|
| 5 Feb | 25 | 472 | 1023 | 73 | 23 | 2 | 14731 |
| | 35 | 659 | 2187 | 65 | 30 | 4 | 31062 |
| 19 Feb | 25 | 469 | 547 | 69 | 26 | 3 | 7843 |
| | 35 | 657 | 1115 | 65 | 29 | 4 | 15798 |
| 5 March | 25 | 479 | 915 | 71 | 24 | 2 | 13140 |
| | 35 | 678 | 1717 | 65 | 30 | 4 | 24473 |
| 19 March | 26 | 513 | 904 | 71 | 25 | 2 | 13078 |
| | 34 | 676 | 1702 | 68 | 28 | 3 | 24588 |
| 2 April | 25 | 508 | 713 | 74 | 23 | 2 | 10350 |
| | 33 | 674 | 1247 | 70 | 26 | 3 | 18028 |
| 16 April | 23 | 454 | 1379 | 74 | 23 | 2 | 19980 |
| | 32 | 667 | 2162 | 73 | 24 | 2 | 31385 |
| 28 May | 25 | 533 | 944 | 75 | 21 | 2 | 13725 |
| | 32 | 684 | 2455 | 72 | 26 | 2 | 36003 |
| 11 June | 22 | 473 | 1570 | 74 | 24 | 2 | 22960 |
| | 32 | 661 | 2719 | 76 | 21 | 1 | 39743 |
| 25 June | 24 | 486 | 1589 | 74 | 23 | 2 | 23195 |
| | 32 | 659 | 1897 | 73 | 25 | 2 | 27663 |
| 9 July | 24 | 508 | 2488 | 73 | 23 | 2 | 36030 |
| | 31 | 659 | 2122 | 73 | 24 | 2 | 30960 |
| 23 July | 25 | 513 | 1507 | 72 | 25 | 2 | 22000 |
| | 33 | 670 | 1572 | 71 | 25 | 3 | 22690 |

CAP = capsaicin

DHC = dihydrocapsaicin

NDC = nordihydrocapsaicin

Fruit pungency tended to follow a cyclical pattern throughout the season with the Scoville index fluctuating between 7843 – 36030 for fruit harvested 25 days after pollination (Figure 9a) and 18028 – 39743 for fruit harvested 35 days after pollination (Figure 9b).

The nitrogen concentration and electrical conductivity of the applied hydroponic feed had little effect on the mean capsaicin and dihydrocapsaicin content of the fruit over the entire season (Figures 10 and 11).

**Figure 9a. The capsaicin and dihydrocapsaicin content and associated Scoville index of hydroponically grown chilli peppers cv Hercules recorded throughout the season on fruit harvested 25 days after pollination.**

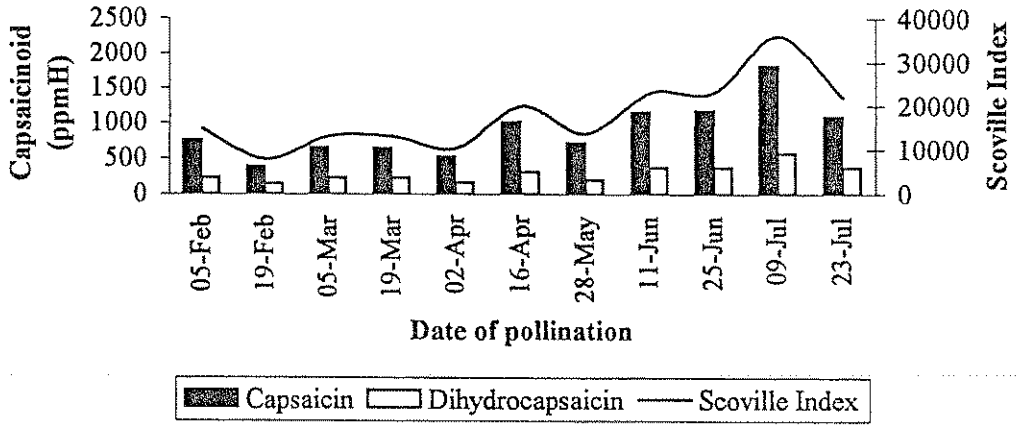



**Figure 9b. The capsaicin and dihydrocapsaicin content and associated Scoville index of hydroponically grown chilli peppers cv Hercules recorded throughout the season on fruit harvested 35 days after pollination.**

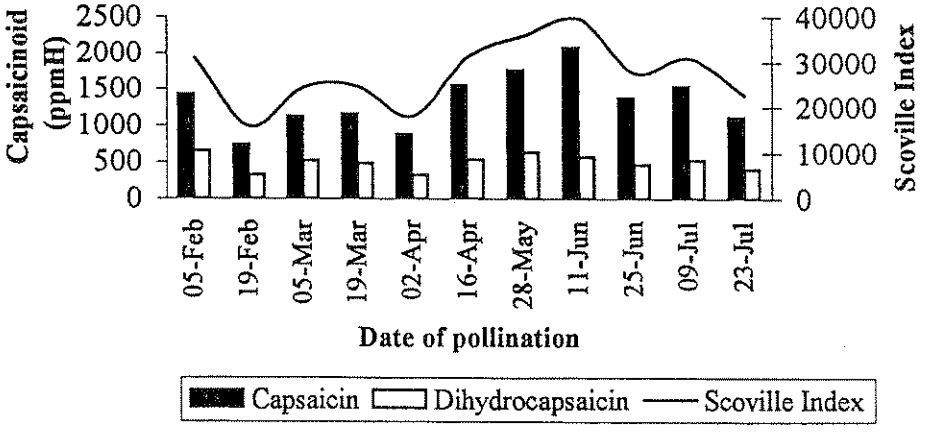


**Figure 10. Effect of nitrogen concentration of applied feed on the mean capsaicin and dihydropcapsaicin content of chilli peppers cv Hercules.**

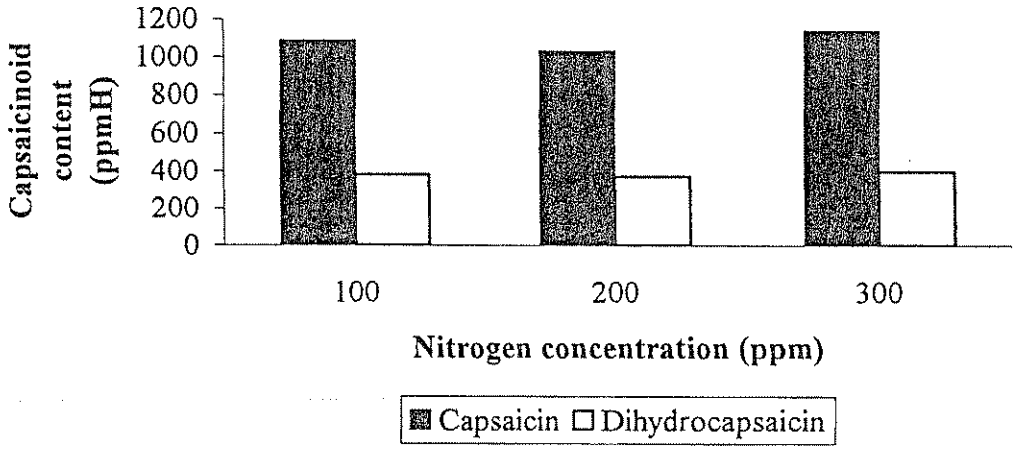
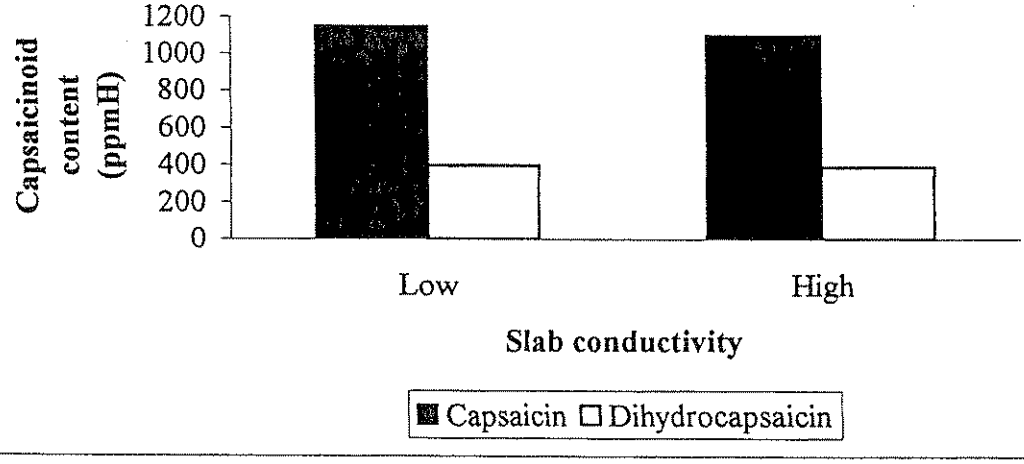



**Figure 11. Effect of electrical conductivity of applied hydroponic feed on the mean capsaicin and dihydrocapsaicin content of chilli peppers cv Hercules.**



Fruit weight and dry matter content

The fresh weight of fruit fluctuated between pollination dates ranging from 15.2 g to 20.1 g for fruit harvested 25 days after pollination and 16.9 g to 27.2 g for fruit harvested 35 days after pollination. However the differences were greatest during the early part of the season (Figure 12). The more mature fruit also had a higher percent dry matter content fluctuating from 8.1 % to 9.4 % compared to 7.7 % to 8.7 % for fruit harvested 25 days after pollination (Figure 13).

Increasing the electrical conductivity of the applied hydroponic feed significantly reduced the fresh weight of the fruit and increased the percent dry mater content (Figures 14 and 15).

Plant growth

The applied nitrogen levels in the hydroponic feed had no significant effect on plant growth (data not shown). However increasing the electrical conductivity of the feed did reduce the rate of growth approximately 60 days after planting (mid March) as the plants were approaching the wire (Figure 16).

**Figure 12. Effect of pollination date and fruit maturity at harvest on fresh weight (g) of chilli peppers cv Hercules.**

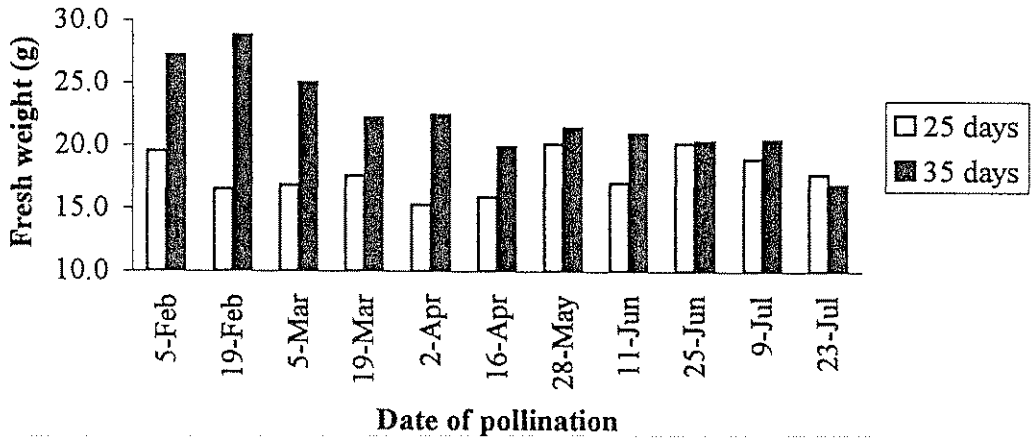



**Figure 13. Effect of pollination date and fruit maturity at harvest on % dry matter of chilli peppers cv Hercules.**

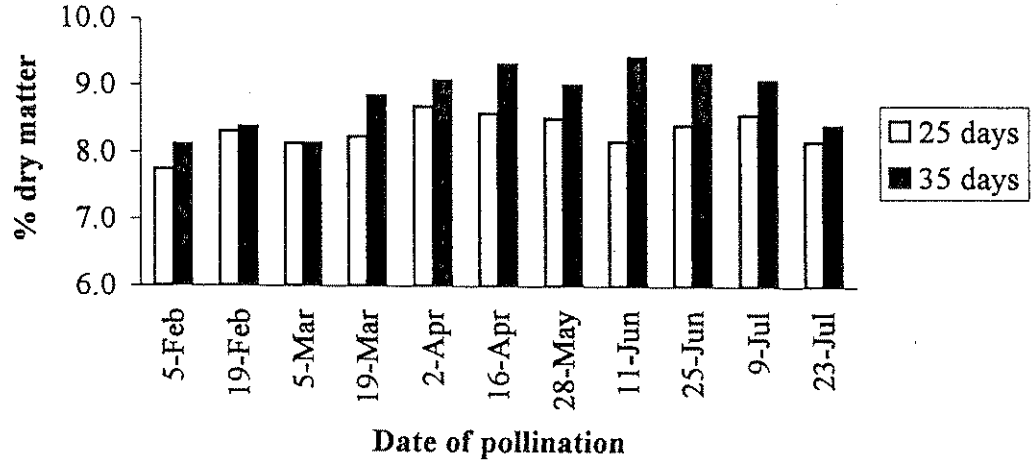


**Figure 14. Effect of pollination date and electrical conductivity of the applied hydroponic feed on fruit fresh weight (g) of chilli peppers cv Hercules.**

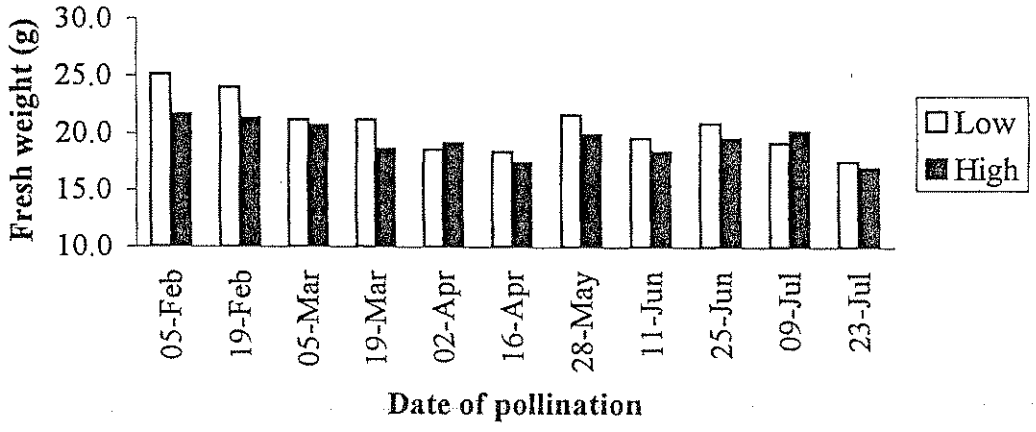
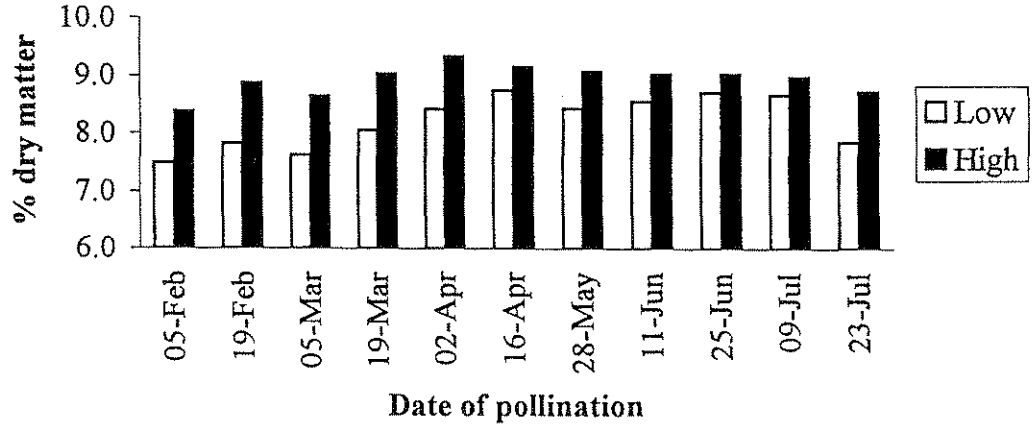



**Figure 15. Effect of pollination date and electrical conductivity of the applied hydroponic feed on % dry matter of chilli peppers cv Hercules.**



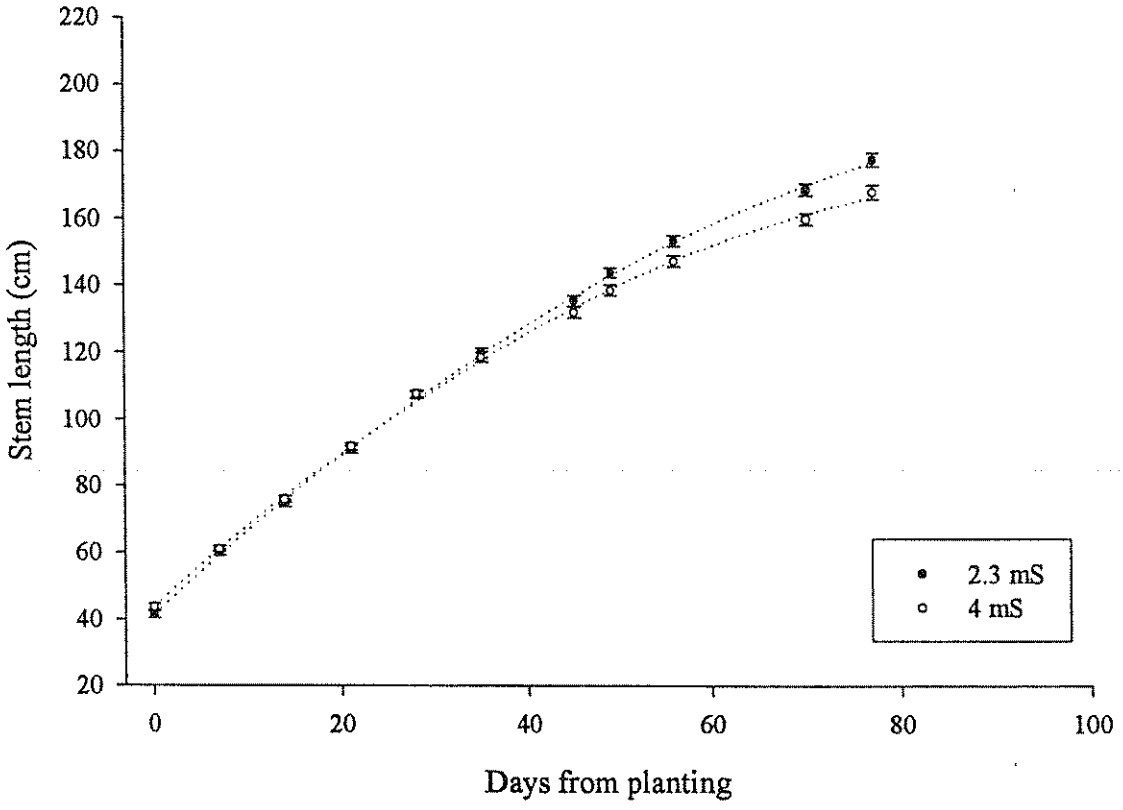



**Figure 16. Effect of slab conducitvity on plant height of Jalapeno chilli peppers cv Hercules**

**Bars represent $SED_{(df=13)}$**

**3. Effect of nitrogen and irrigation regime on the yield and pungency of a short-season soil grown crop.**

## MATERIALS AND METHODS

### Crop diary

| | |
|---|---|
| Varieties | Hercules (Jalapeno) |
| | Wonder Hot (Cayenne) |
| Sowing date: | 24 March 1998 |
| Pricked out: | 3 April 1998 |
| Planting date: | 1 May 1998 |
| Date of first pick: | 18 June cv Hercules |
| | 29 June cv Wonder Hot |
| Final harvest: | 24 September 1998 |

### Cropping details

The plants were grown on the V-system in 150 $m^2$ Venlo glasshouse. Each plot contained 14 plants spaced at 18 cm within the row and 1.6 m between rows. Planting density was 3.5 plants $m^{-2}$. The final head density was increased to 7.0 heads $m^{-2}$ by taking 2 leaders from each plant. The lateral branches of cv Hercules were trimmed back to 3 nodes. Those of cv Wonder Hot were trimmed to 2 nodes. The crop was harvested twice weekly until September when one weekly harvest was taken.

### Pest and disease control

Biological control agents were used where possible and introduced at standard tomato rates.

*Aphidius colemani*
*Aphidius ervi*
*Aphidoletes aphidimyza*
*Phytoseiulus persimilis*
*Amblyseius cucumeris*
*Amblyseius degenerans*

The Jalapeno cv Hercules received no chemical applications. Pirimor was applied to the Cayenne crop on 10 June and *Bacillus thuringiensis* was applied to both crops on 24 July.

Climate control

Temperature set points were pre-determined, based on those which could be achieved in a standard low input soil-system (lettuce). Temperature set points were therefore low at 5°C day and night. The temperature in the glasshouse was raised using solar heat and high day / night vent temperatures of 24°C and 20°C respectively. In line with a low input system no additional $CO_2$ was put into the house.

To stop fruit set during the early stages of growth flowers that set fruit below the 3rd lateral break were removed by hand.

Experimental design

There were eight treatment combinations comprising two levels of nitrogen applied as a base dressing (8 g $m^{-2}$ and 16 g $m^{-2}$) two levels of irrigation (wet and dry) and two nitrogen fertigation regimes (50 ppm and 100 ppm). Nitrogen was supplied as calcium nitrate in the base dressing and fertigation treatments to avoid problems of blossom end rot. The experiment was arranged as a split-plot design with base dressing treatments assigned to main plots. Each treatment was replicated 3 times. The two varieties were assigned to a separate 150 $m^{-2}$ Venlo glasshouse with exactly the same layout used for each glasshouse. Irrigation was scheduled using two soil

moisture probes (Irrometer Company Inc. USA) placed at 6" and 12" in both the wet and dry plots of each house. Total water (l $m^{-2}$) and total N supplied (g $m^{-2}$) for the various fertigation treatments are shown in Table 2.

**Table 2. Total amount of irrigation supplied to the crop (l $m^{-2}$) under the "wet" and "dry" regimes and the corresponding amount of nitrogen supplied in the fertigation treatments (g $m^{-2}$) for soil grown chilli peppers cv Hercules and Wonder Hot.**

| | | Fertigation regime | |
|---|---|---|---|
| Irrigation regime | Water supplied | 50 ppm N | 100 ppm N |
| Wet | 263 l $m^{-2}$ | 13.3 g $m^{-2}$ | 26.6 g $m^{-2}$ |
| Dry | 156 l $m^{-2}$ | 7.7 g $m^{-2}$ | 15.6 g $m^{-2}$ |

Measuring chilli pungency

The pungency of the crop was recorded in exactly the same way as that for the hydroponic crop (Section 2). HPLC analysis was performed only for cv Hercules.

## RESULTS

Yield

Fruit was harvested from 18 June to 24 September for the Jalapeno crop cv Hercules and from 29 June to 24 September for the Cayenne crop cv Wonder Hot. Hercules produced a total yield of 6.6 kg $m^{-2}$ Class I fruit compared to the Cayenne cv Wonder Hot which produced 3.3 kg $m^{-2}$ Class I fruit (Figures 17 and 18). Applying 16 g $m^{-2}$ calcium nitrate compared to 8 g $m^{-2}$ significantly increased the yield of Class I fruit for both varieties during the early stages of harvesting. However by the end of the trial the effect was only apparent for cv Hercules (Figure 17). The fertigation treatments had no significant effect on yield. A full breakdown of the Class I monthly yields for each variety is provided in Appendix IV.

Fruit pungency cv Hercules

Table 3 illustrates the date of pollination days to harvest and accumulated day degrees (calculated as average 24-hour temperature) for chilli fruit used to determine the pungency of the crop throughout the season. As with the hydroponic trial, capsaicin was the major analogue present representing 66% - 73% of total capsaicinoids followed by dihydrocapsaicin (23% - 29%) and nordihydrocapsaicin (2% - 3%). The total capsaicinoid content was also higher in fruit harvested 35 days after pollination compared to fruit harvested 25 days after pollination (Table 3).

**Figure 17. Effect of base N application on the Class I yield of soil grown Jalapeno chilli peppers cv Hercules.**

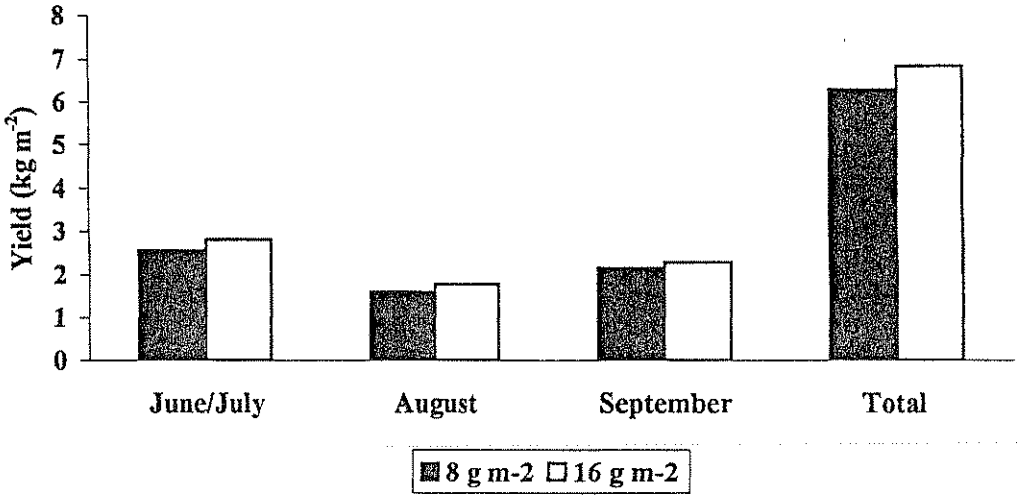



**Figure 18. Effect of base N application on the Class I yield of soil grown Cayenne chilli peppers cv Wonder Hot.**

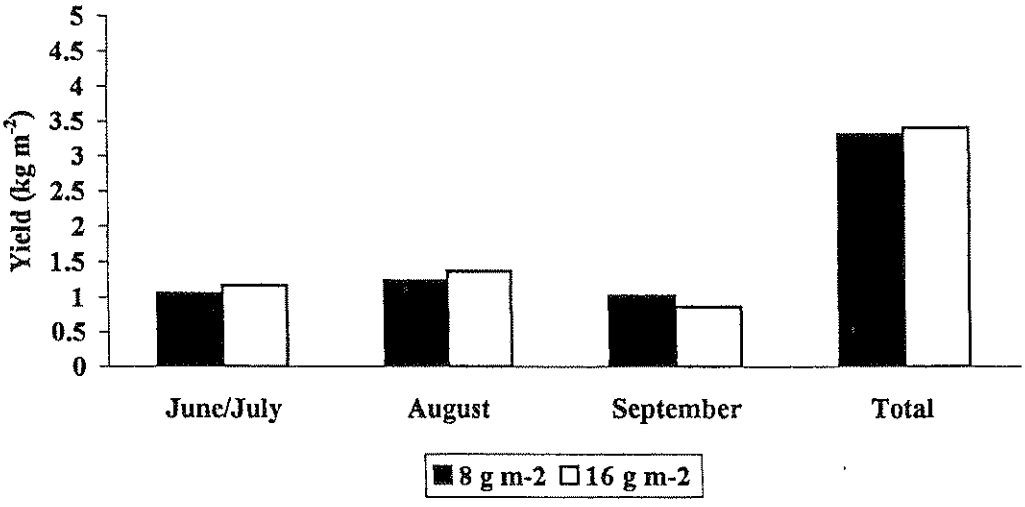


**Table 3. Date of pollination, days to harvest, accumulated day degrees (calculated as average 24-hour temperature), total capsaicinoid content (ppmH) and percentage different capsaicinoids present for chilli fruit cv Hercules grown in hydroponics.**

| Date of pollination | Days to harvest | Accumulated day degrees | Total capsaicinoid (ppmH) | % CAP | % DHC | % NDC | Scoville Index |
|---|---|---|---|---|---|---|---|
| 11 June | 25 | 490 | 1391 | 71 | 25 | 2 | 20083 |
| | 33 | 657 | 1719 | 66 | 29 | 3 | 24664 |
| 25 June | 24 | 477 | 900 | 72 | 23 | 2 | 13046 |
| | 34 | 622 | 770 | 67 | 28 | 3 | 11083 |
| 9 July | 25 | 484 | 1230 | 71 | 25 | 2 | 17730 |
| | 34 | 668 | 1280 | 70 | 27 | 2 | 18651 |
| 23 July | 25 | 478 | 860 | 73 | 27 | 2 | 12621 |
| | 24 | 662 | 1157 | 70 | 26 | 2 | 16738 |
| 6 August | 25 | 495 | 1692 | 71 | 25 | 2 | 24414 |
| | 35 | 675 | 2661 | 70 | 26 | 3 | 38423 |

CAP = capsaicin

DHC = dihydrocapsaicin

NDC = nordihydrocapsaicin

Fruit pungency followed a similar cyclical pattern to that of the hydroponic crop with the Scoville index fluctuating between 12621 – 24414 for fruit harvested 25 days after pollination (Figure 19a) and 11083 – 38423 for fruit harvested 35 days after pollination (Figure 19b). Base dressing application of calcium nitrate fertiliser (Figure 20) and the fertigation treatments (Figures 21 and 22) had little effect on the capsaicin and dihydrocapsaicin content of the fruit and therefore did not influence fruit pungency.

**Figure 19a. Capsaicin and dihydrocapsaicin content and associated Scoville Index of soil grown chilli peppers cv Hercules recorded throughout the season on fruit harvested 25 days after pollination.**

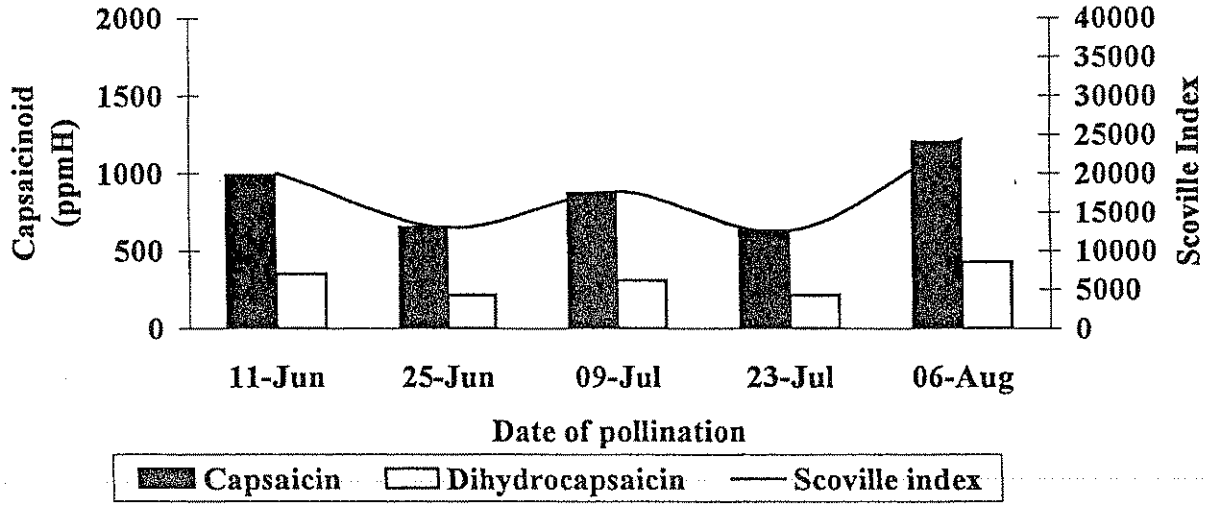



**Figure 19b. Capsaicin and dihydrocapsaicin content (ppmH) and associated Scoville Index of soil grown chilli peppers cv Hercules recorded throughout the season on fruit harvested 35 days after pollination.**

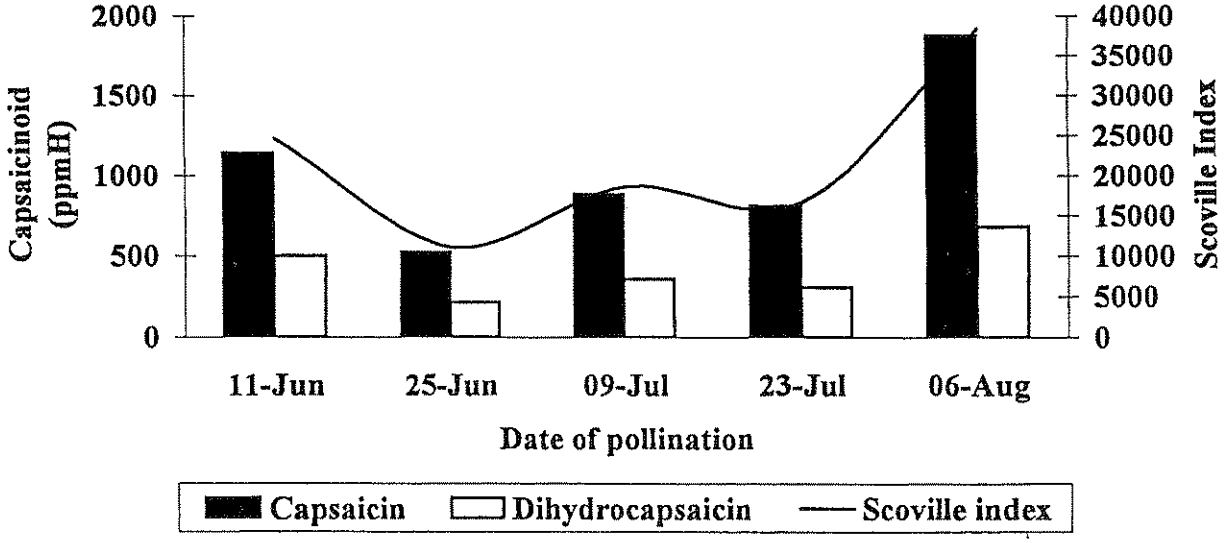


Figure 20. Effect of base N application on the mean capsaicin and dihydrocapsaicin content (ppmH) of soil grown chilli peppers cv Hercules harvested throughout the season.

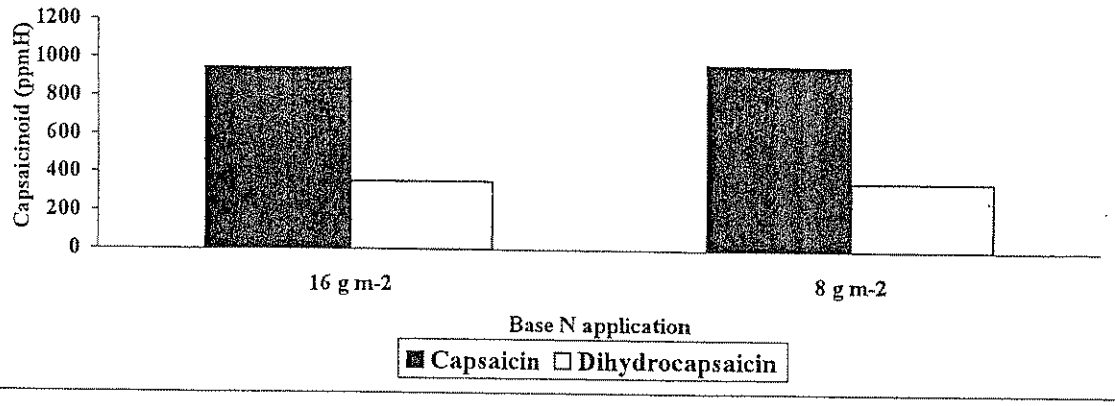



Figure 21. Effect of irrigation on the mean capsaicin and dihydrocapsaicin content (ppmH) of soil grown chilli peppers cv Hercules harvested throughout the season.

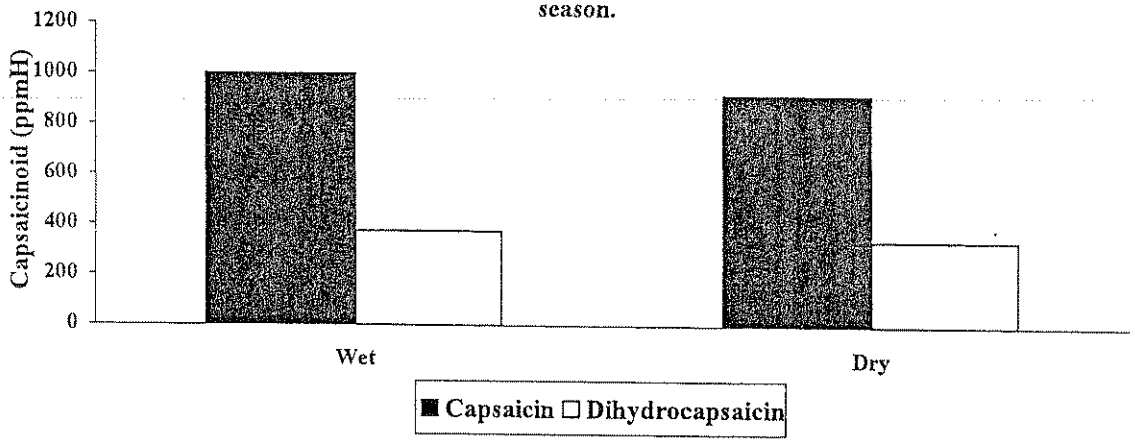
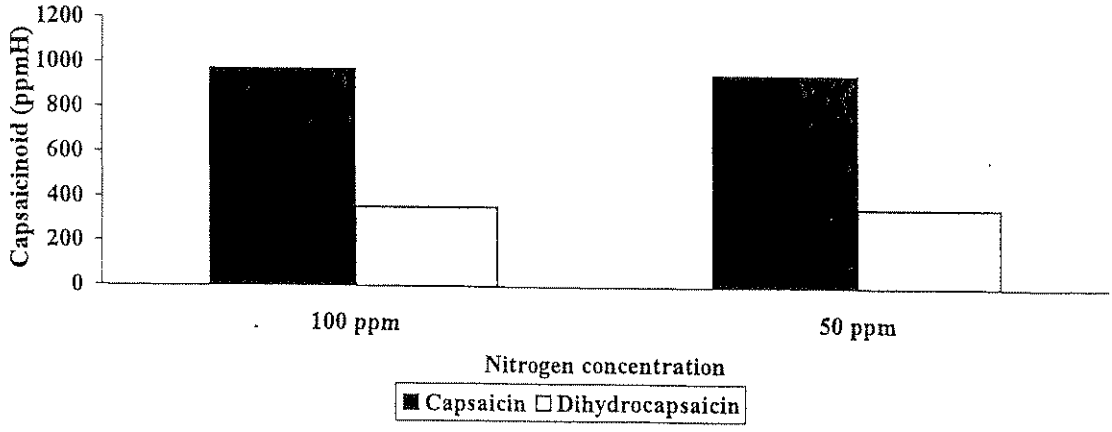



Figure 22. Effect of Nitrogen concentration of applied feed on the mean capsaicin and dihydrocapsaicin content (ppmH) of soil grown chilli peppers cv Hercules harvested throughout the season.



Fruit weight and dry matter content

Fruit fresh weight fluctuated between pollination dates ranging from 18.6 g to 25.2 g for fruit harvested 25 days after pollination and 20.6 g to 30.5 g for fruit harvested 35 days after pollination for cv Hercules (Figure 23). Although still visually mature (green stage) the fresh weight of cv Wonder Hot was lower, fluctuating between 7.8 g to 9.4 g for fruit harvested 25 days after pollination and 11.9 g to 13.0 g for fruit harvested 35 days after pollination (Figure 25).

The more mature fruit also had a higher percent dry matter content fluctuating in cv Hercules from 6.7 % to 7.7 % compared to 7.5 % to 8.5 % for fruit harvested 25 and 35 days after pollination respectively (Figure 24). Percent dry matter was higher in cv Wonder Hot fluctuating from 8.1 % to 9.0 % compared to 8.5 % to 9.6 % for fruit harvested 25 and 35 days after pollination respectively (Figure 26).

Base dressing application of calcium nitrate and fertigation regimes had no effect on fruit fresh weight or percent dry matter.

Plant height

Due to the lower initial growing temperatures plant growth rates were reduced in the soil grown crops compared to the hydroponic crops (Figures 27 and 28). Applying 16g $m^{-2}$ calcium nitrate as a base dressing increased plant growth rate compared to 8 g $m^{-2}$. There were no fertigation effects on plant growth rates. As observed in the hydroponic crop the Cayenne variety cv Wonder Hot grew at a faster rate (Figure 28). As with the hydroponic crop this variety required more trimming and hence labour input (data not presented).

**Figure 23. Effect of pollination date and fruit maturity at harvest on fresh weight (g) of soil grown chilli peppers cv Hercules.**

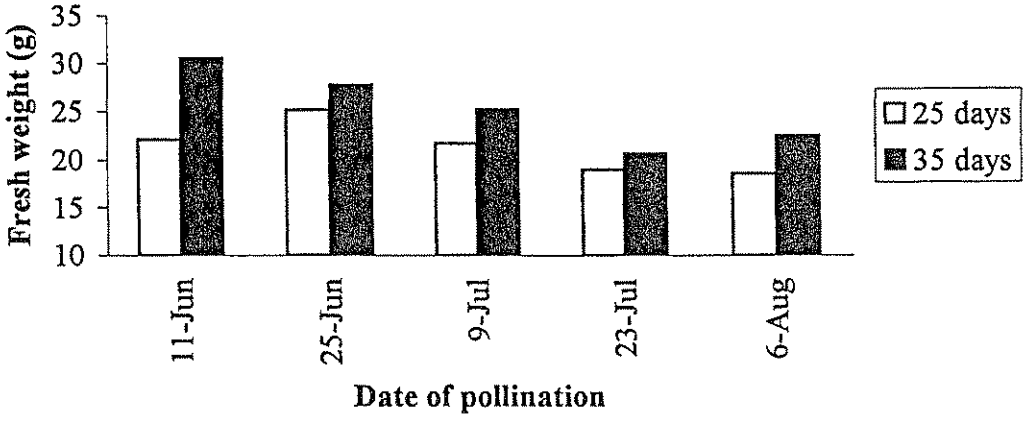



**Figure 24. Effect of pollination date and fruit maturity at harvest on % dry matter of soil grown chilli peppers cv Hercules.**

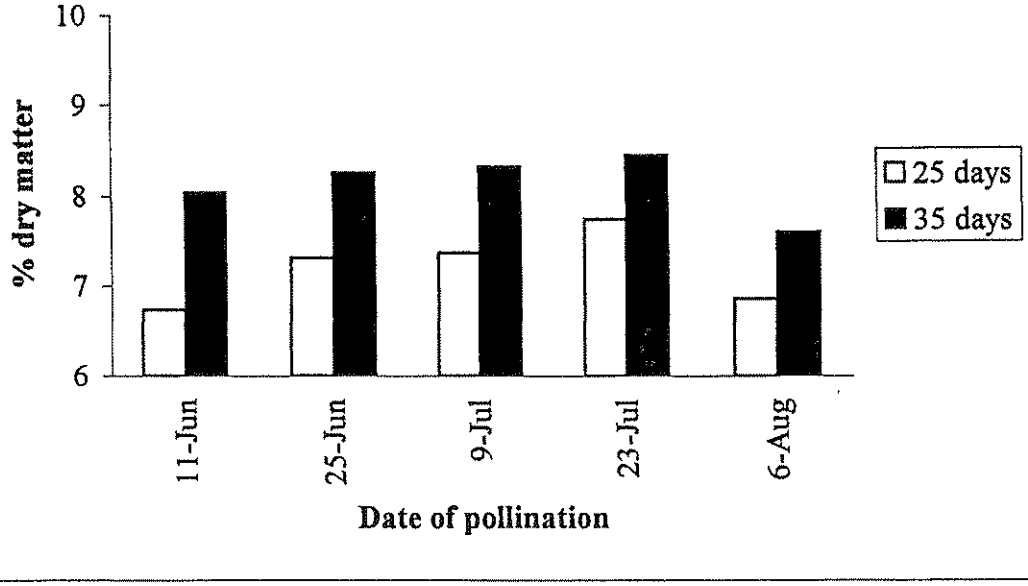


**Figure 25. Effect of pollination date and fruit maturity at harvest on fresh weight (g) of soil grown chilli peppers cv Wonder Hot.**

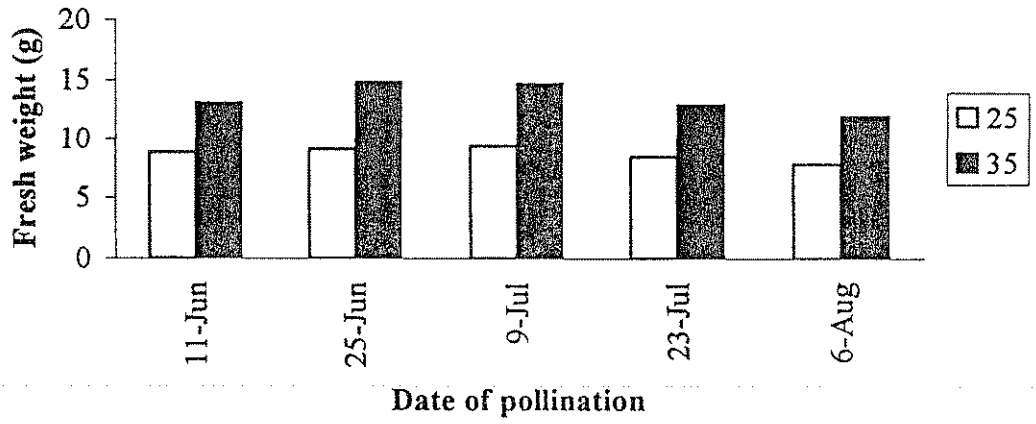
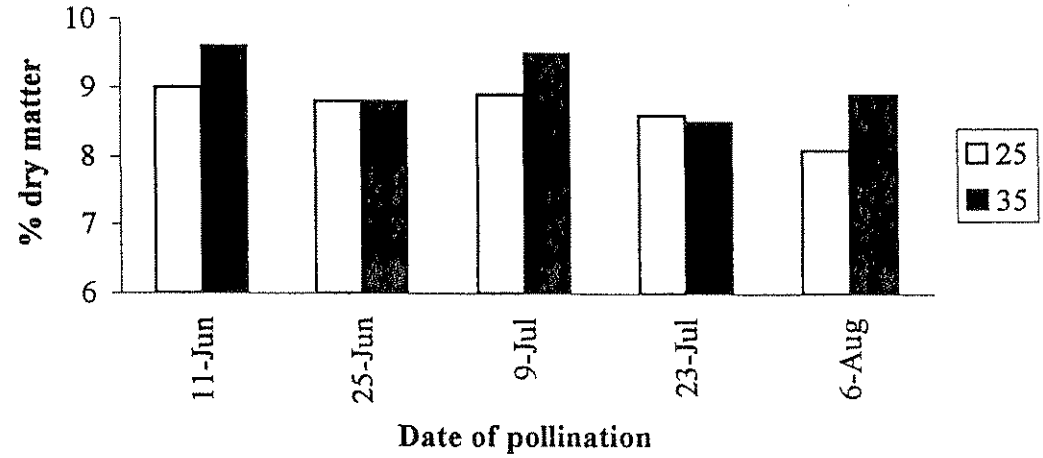



**Figure 26. Effect of pollination date and fruit maturity at harvest on % dry matter of soil grown chilli peppers cv Wonder Hot.**



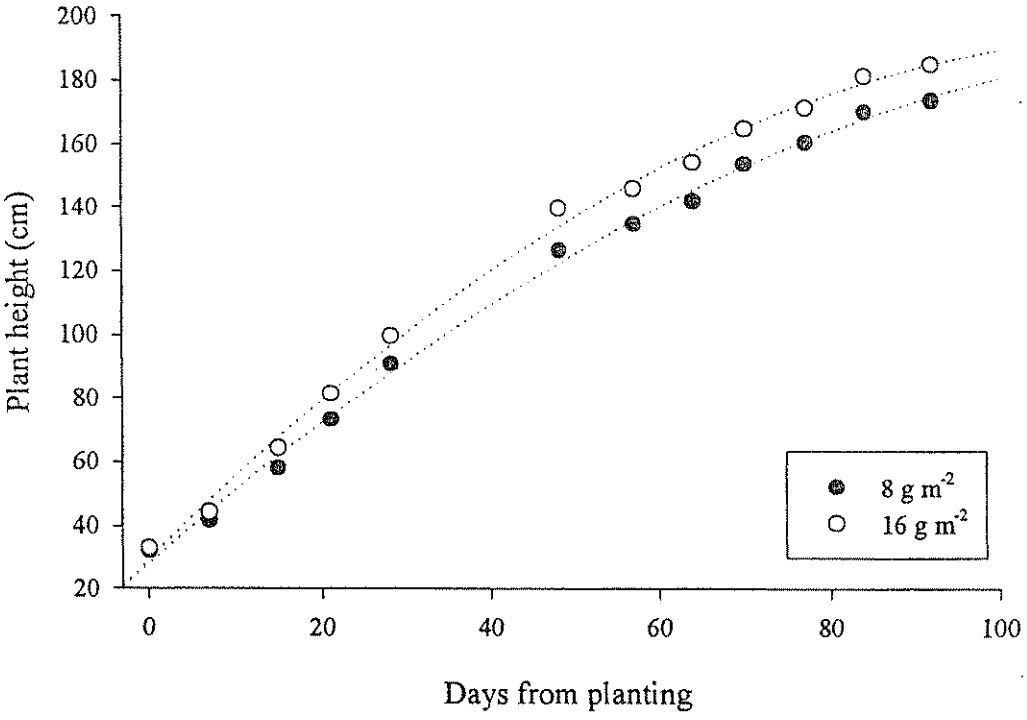



**Figure 27. Effect of base N application on plant height of Jalapeno chilli peppers cv Hercules**

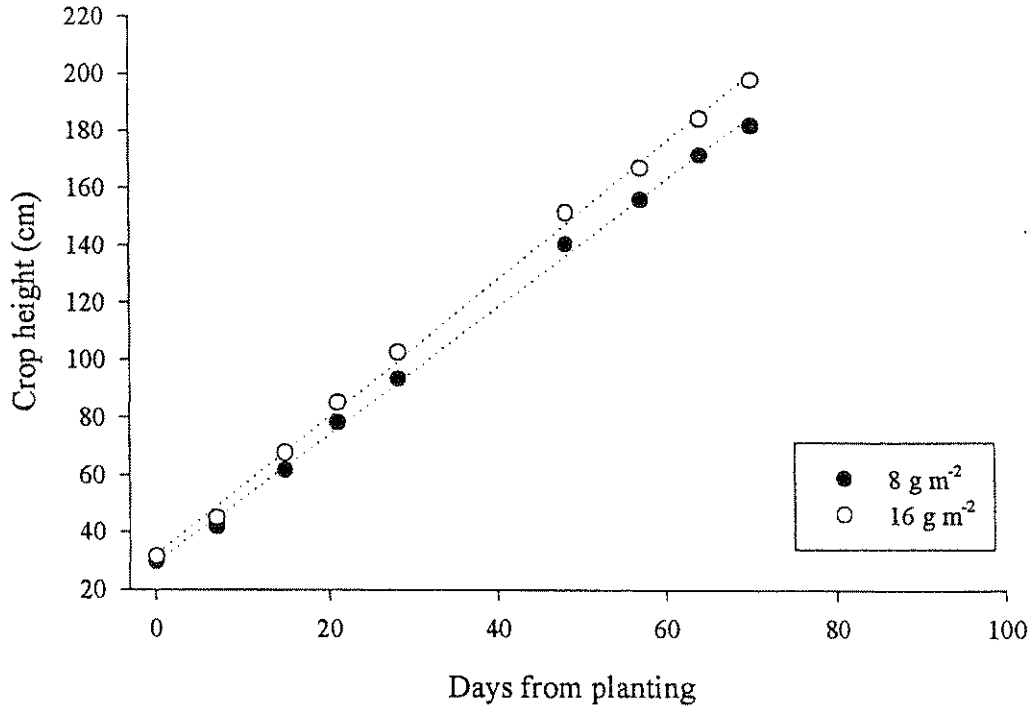



**Figure 28. The effect of base N application on the plant height of Cayenne chilli peppers cv Wonder Hot**

## DISCUSSION

### Yield and crop growth

Class I yield for the long season hydroponic crops were higher than those achieved in 1997 (Table 4). This can be attributed to the longer growing season, harvesting commenced in February compared to May in the 1997 trial and to a better choice of variety which resulted in no skin cracking in the Jalapeno fruit or virus transmission. Consequently approximately 90% of all fruit harvested was Class I (Plates 1 and 2).

**Table 4. Comparison of Class I yield for hydroponic crops grown in 1997 and 1998.**

| | Class I yield kg $m^{-2}$ | |
|---|---|---|
| Variety | 1997 | 1998[2] |
| Jalapeno[1] | 7.8 | 16.5 |
| Cayenne cv Wonder Hot | 10.0 | 14.2 |

[1] cv Tam Vera Cruz 1997, cv Hercules 1998

[2] Mean of all treatments (Experiments 1 and 2).

The Class I yield from the soil-grown crop was 6.6 kg $m^{-2}$ and 3.3 kg $m^{-2}$ for Hercules and Wonder Hot respectively (Figures 17 and 18). These could have been significantly increased if they had been allowed to grow on for longer at the end of the season. However the crop was purposely pulled out at the end of September to allow a winter crop of lettuce to be planted.

## Labour requirement

The increase in labour requirement for cv Wonder Hot was attributed to the increased vigour exhibited by this variety making higher demands for trimming. The variety also had a dense bushy habit that made green-ripe fruit harder to see and increased harvesting times compared to cv Hercules which had a much more open structure. In contrast to 1997 harvesting times were positively correlated to Class I yield. The Jalapeno cv Hercules had a total labour requirement similar to that of many tomato crops grown in the UK of approximately 11000 hrs $ha^{-1}$. Layering the Jalapeno crop reduced plant yields compared to stopping the crop at a low wire (2.1 m). This was attributed to the different growth rates of the selected leaders which resulted in the heads of adjacent plants becoming tangled.

The total labour requirement of the Cayenne variety cv Wonder Hot were in comparison 18557 hrs $ha^{-1}$ when grown on a low wire system (2.1 m). Although yields were increased by approximately 7 kg $m^{-2}$ by growing on a high wire system (3.6 m) the labour required to harvest the crop rose from 10248 hrs $ha^{-1}$ to 17277 hrs $ha^{-1}$.

## Fruit pungency

The pungency of the hydroponic crop was sampled from 11 pollination dates throughout the season. The Scoville index fluctuated between samples ranging from 7843 to 36030 and 18028 to 39743 for fruit harvested 25 and 35 days after pollination respectively. The pungency of the soil crop was sampled from 5 pollination dates and the Scoville index was found to fluctuate between 12621 to 24414 and 11083 to 38423 for fruit harvested 25 and 35 days after pollination respectively. Fruit was visually mature (green harvest) 25 days after pollination in both crops. Capsaicinoids, which are the chemicals responsible for fruit pungency are normally formed 14 – 21 days after pollination and have been shown to increase as the fruit matures (Balbaa *et al.*, 1968). Therefore the more mature fruit would have had a chance to synthesise and accumulate more capsaicinoids.

Fruits from different plants of one variety grown side-by-side have been shown to fluctuate between 4300 to 13300 on the Scoville index (Hibbard *et al.*, cited Berke, pers. comm). Node position has also been shown to affect pungency with fruit developing at lower node positions having greatest pungency (Zewdie and Bosland, 1994). These authors sampled chillies on nodes 2 to 6 and it was suggested that the higher pungency rating at lower node positions might be related to less competition for substrate between fruits at the time of development. At later stages in growth there are potentially more fruits per plant hence competition between fruit for substrate is higher and this results in a low amount of capsaicinoid synthesised per fruit.

Although fruit was not allowed to set until the third node the total amount of capsaicinoids was higher from the first pollination date in the hydroponic trial (5 February compared to pollination dates up to and including 2 April especially for fruit harvested after 35 days (Figure 9b). From April capsaicinoid levels and hence fruit pungency levels rose generally over the season reaching a peak for fruits pollinated in June by which time fruit was being tagged at random positions on the plant. Similar results were recorded for the soil-grown crop (Figure 19b). However fruit pungency levels rose in association with plant yields suggesting that fruit competition for substrates required for capsaicinoid synthesis is not the only factor involved in determining the pungency of the crop.

The phenotypic expression of chilli pungency is usually the result of a genotype x environment interaction. For example it has been observed that the pungency of a given cultivar grown outdoors in the soil varies from year to year, field to field and in different growing regions of the world (Lindsey *et al.*, 1994). As a general rule the more stress the plant is under the higher the pungency rating of the fruit (Berke, pers. comm). It is therefore possible for a mild chilli cultivar, bred for low levels of pungency to become more pungent when exposed to any type of stress. Alternatively a relatively hot chilli cultivar given optimal environmental conditions will become only moderately pungent. Despite the increase in percent dry matter of the fruit grown at high Ec's the feed / watering regimes imposed on the crop had little effect on the pungency of the fruit in 1998. No significant yield differences were recorded

between the nitrogen, Ec and watering regimes in the hydroponic or soil grown crops and this would suggest that the plants were not under sufficient stress to influence fruit pungency.

Soil moisture stress has been shown to increase the capsaicinoid content of chilli fruit (Levy *et al.*, 1989). However to achieve the increase in pungency there was a 4-fold decrease in irrigation supplied to the crop in the wet and dry regimes (Levy *et al.*, 1989). We achieved a 1.7-fold decrease between wet and dry regime (Table 2). Johnson and Decoteau (1996) have shown that nitrogen concentration of the applied feed can influence pungency. They suggest that for optimum yields chillies should be grown at 210 ppm N and between 105 ppm – 315 ppm for optimum fruit pungency. Increasing temperatures has also been shown to increase fruit pungency (Levy *et al.*, 1989). However to limit changes in temperature influencing the stage of fruit development the chillies were picked 25 or 35 days after pollination or when they had accumulated a set number of day degrees, based on the average 24 hour temperature in the glasshouse. Therefore any temperature effects as a result of season would have been minimised.

When growing under glass we strive to provide ideal growing conditions to maximise potential yields. Putting plants under sufficient stress to influence the pungency rating of the crop would probably reduce potential yields and would not be advisable under commercial situations. However supplying water freely in highlight situations for chilli crops grown under protection may cause rapid fruit swelling resulting in marketable fruits which have just started or have yet to start synthesising capsaicinoids. Therefore if mild varieties are planted they may produce chillies with very low Scoville indices. In 1997 the pungency of mild Jalapeno chilli fruit was assessed on 3 dates during the summer. The Scoville index was found to fluctuate between 600 and 2300. The much lower pungency rating for this crop is probably why the fruit was described as having "no taste" at certain times of the year by a major food marketing company. Planting Jalapeno cultivars that have the genetic potential to be hotter, as we did in 1998 may help in providing the correct pungency rating for protected crops. However the fluctuations in chilli pungency at different times of the year were large and probably related to a number of environmental

conditions during the time the fruit was developing on the plant. In order to reduce these fluctuations cultivars expressing a low genotype x environment interaction for pungency may be needed by the industry (Harvell and Bosland, 1997).

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## APPENDICES

### Appendix I Seed treatment against pepper strains of TMV.

A complex of viral pathogens are responsible for the decline of chilli pepper productivity particularly TMV and PMMV.

To avoid the introduction of virus, and to prevent a massive build up of viral contamination in the glasshouse, we recommend that all chilli pepper seeds be soaked in a tri-sodium phosphate solution before sowing.

1. Wrap dry seeds into a muslin cloth and place in a 10% solution of $Na_3P0_4$ in tap water for 2 hours.

2. Rinse in running water for 45 minutes, stirring continuously.

3. Spread the seeds in thin layers on a screen with upward air movement in order to dry the seeds as quickly as possible.

*Source: Asian Vegetable Research Development Council, Taiwan*

## Appendix II

**Effect of crop training system on the Class I yield (kg $m^{-2}$) of a long-season Jalapeno chilli pepper crop cv Hercules.**

| Growing system | String angle | March | April | May | June | July | August | September | October / November | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Layered | Straight | 1.42 | 2.03 | 1.77 | 1.48 | 1.54 | 1.16 | 1.00 | 0.96 | 11.35 |
| | Sloped | 1.08 | 1.49 | 1.25 | 1.40 | 1.20 | 1.08 | 0.86 | 0.81 | 9.16 |
| Stopped | Straight | 1.26 | 2.88 | 2.71 | 2.41 | 2.22 | 1.31 | 1.58 | 1.70 | 16.06 |
| | Sloped | 1.33 | 2.19 | 2.29 | 2.01 | 1.91 | 1.94 | 1.73 | 1.64 | 15.04 |
| SED(8df) | | 0.056 | 0.228 | 0.237 | 0.341 | 0.203 | 0.304 | 0.431 | 0.192 | 0.969 |
| LSD(5%) | | 0.13 | 0.53 | 0.55 | 0.79 | 0.47 | 0.70 | 0.99 | 0.44 | 2.23 |
| Significance | | *** | NS | NS | NS | NS | NS | NS | NS | NS |

**Effect of crop training system on the Class I yield (kg $m^{-2}$) of a long-season Cayenne chilli pepper crop cv Wonder Hot.**

| Growing system | March | April | May | June | July | August | September | October / November | Total |
|---|---|---|---|---|---|---|---|---|---|
| High wire (3.6m) | 0.31 | 1.76 | 2.96 | 3.43 | 2.55 | 1.89 | 2.46 | 2.4 | 17.78 |
| Low wire (2.1m) | 0.29 | 1.82 | 1.77 | 1.71 | 1.40 | 1.15 | 1.33 | 1.2 | 10.70 |
| SED(8df) | 0.039 | 0.161 | 0.168 | 0.241 | 0.144 | 0.215 | 0.305 | 0.136 | 0.685 |
| LSD(5%) | 0.09 | 0.37 | 0.39 | 0.56 | 0.33 | 0.49 | 0.70 | 0.31 | 1.58 |
| Significance | NS | NS | *** | *** | *** | ** | ** | *** | *** |

## Appendix III

**Effect of nitrogen content (ppm) and Ec (mS) of the applied hydroponic solution on the Class I yield (kg $m^{-2}$) of long-season chilli peppers cv Hercules.**

| | N ppm | March | April | May | June | July | August | September | October / November | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Low Ec | 100 | 1.12 | 2.21 | 3.04 | 2.25 | 2.67 | 1.97 | 2.43 | 1.54 | 17.22 |
| | 200 | 1.05 | 1.99 | 2.88 | 2.19 | 2.24 | 1.91 | 2.43 | 1.55 | 16.22 |
| | 300 | 0.96 | 2.12 | 2.98 | 2.55 | 2.50 | 2.02 | 2.07 | 1.78 | 16.98 |
| High Ec | 100 | 0.92 | 1.88 | 2.72 | 2.33 | 2.66 | 2.21 | 2.45 | 1.78 | 16.94 |
| | 200 | 1.05 | 1.87 | 2.81 | 2.29 | 2.37 | 2.16 | 2.23 | 1.76 | 16.54 |
| | 300 | 1.00 | 1.88 | 2.85 | 2.43 | 2.58 | 2.33 | 2.28 | 1.99 | 17.34 |
| SED(13df) | | 0.076 | 0.121 | 0.185 | 0.148 | 0.211 | 0.167 | 0.156 | 0.162 | 0.920 |
| LSD(5%) | | 0.16 | 0.26 | 0.40 | 0.32 | 0.46 | 0.36 | 0.34 | 0.35 | 1.98 |
| Significance | | NS | NS | NS | NS | NS | NS | NS | NS | NS |

## Appendix IV

**Effect of base dressing application (g $m^{-2}$) and fertigation rate (ppm) of calcium nitrate and the watering regime (wet / dry) on the Class I yield (kg $m^{-2}$) of a short-term summer crop of chilli peppers cv Hercules.**

| | June/July | | | | August | | | | September | | | | Total | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fertigation | 50ppm | | 100 ppm | | 50ppm | | 100ppm | | 50ppm | | 100ppm | | | | | |
| Base | Wet | Dry | Wet | Dry | Wet | Dry | Wet | Dry | Wet | Dry | Wet | Dry | Wet | Dry | Wet | Dry |
| 8 g $m^{-2}$ | 2.43 | 2.67 | 2.65 | 2.49 | 1.63 | 1.60 | 1.60 | 1.51 | 2.10 | 2.26 | 2.27 | 1.94 | 6.16 | 6.53 | 6.52 | 5.95 |
| 16 g $m^{-2}$ | 2.58 | 2.82 | 2.94 | 2.85 | 1.68 | 1.74 | 1.76 | 1.84 | 2.22 | 2.26 | 2.35 | 2.28 | 6.47 | 6.81 | 7.05 | 6.97 |
| SED(16df) | 0.163 | | | | 0.117 | | | | 0.233 | | | | 0.435 | | | |
| LSD(5%) | 0.35 | | | | 0.25 | | | | 0.49 | | | | 0.92 | | | |
| Significance | NS | | | | NS | | | | NS | | | | NS | | | |

**Effect of base dressing application (g $m^{-2}$) and fertigation rate (ppm) of calcium nitrate and the watering regime (wet / dry) on the Class I yield of a short-term summer crop of chilli peppers cv Wonder Hot.**

| | June/July | | | | August | | | | September | | | | Total | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fertigation | 50ppm | | 100 ppm | | 50ppm | | 100ppm | | | | | | | | | |
| Base | Wet | Dry | Wet | Dry | Wet | Dry | Wet | Dry | Wet | Dry | Wet | Dry | Wet | Dry | Wet | Dry |
| 8 g $m^{-2}$ | 1.00 | 1.11 | 1.01 | 1.06 | 1.23 | 1.28 | 1.24 | 1.18 | 1.03 | 1.14 | 0.95 | 0.95 | 3.25 | 3.53 | 3.20 | 3.20 |
| 16 g $m^{-2}$ | 1.10 | 1.18 | 1.28 | 1.11 | 1.26 | 1.47 | 1.36 | 1.40 | 0.79 | 0.98 | 0.85 | 0.81 | 3.15 | 3.63 | 3.49 | 3.32 |
| SED(16df) | 0.060 | | | | 0.090 | | | | 0.088 | | | | 0.166 | | | |
| LSD(5%) | 0.13 | | | | 0.19 | | | | 0.19 | | | | 0.35 | | | |
| Significance | NS | | | | NS | | | | NS | | | | NS | | | |