The Effect of Nutrition on the Flavour of Strawberries Grown under Protection

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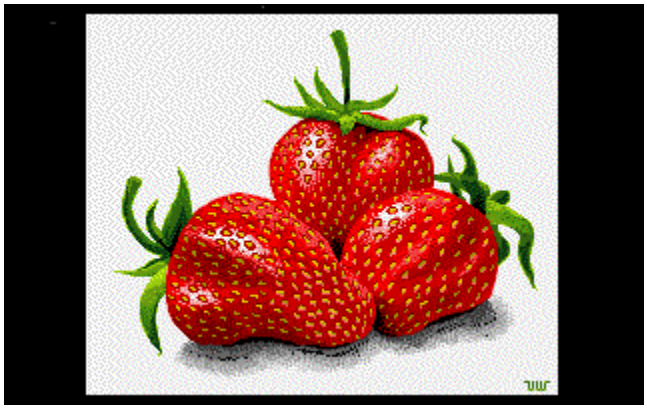


Conclusions

(1) Altering the nutrient balance within the standard Kinsealy liquid feed affects the fruit flavour and the concentration of sugar and acid within the fruit.

(2) Altering the overall concentrations of nutrients upwards or downwards in the growing medium or in the liquid feed also affects the fruit flavour.

(3) The sugar acid ratio which gives the best fruit flavour is in the range of 8 to 11. However, the results suggest that flavour may be affected by the overall concentrations of sugar and acid. For example flavour is less intense when the sugar and acid concentrations are low although the ratio may fall within the above range.

(4) Good fruit flavour as assessed by sensory analysis using taste panels was associated with moderate to high concentrations of K in the liquid feed. Such concentrations were present in the

standard Kinsealy liquid feed and in the Kinsealy feed with increased K concentrations.

(5) A high EC brought about by high nutrient concentrations in the growing medium or in the liquid feed also improved fruit flavour, particularly when this high concentration was associated with high K concentrations.

(6) Low K concentrations and low K high Ca concentrations were normally associated with poor fruit flavour.

(7) A growing medium made up of coarse textured peat (>25mm) gave the largest fruit yield but had no affect on fruit flavour or sugar acid ratio.

(8) High K and high overall nutrient concentration in the growing media increased fruit yield and the shelf life of the fruit.

Introduction

For the past 50 years research in strawberries has been directed at increasing the yield to improve the cash returns, increasing the fruit size to promote more rapid harvesting, increasing the skin strength to avoid damage during handling and increasing the shelf life so that the product can be retained for a longer period on the shelves of retail outlets. Resistance to pests and diseases has also been an aspect which has received attention in research on strawberry production. All of these factors have been used as parameters in strawberry breeding programmes. Due to these breeding programmes fruit size in strawberries has increased by up to three fold in the past two decades. However, the increase in size has been accompanied by the dilution of many important characteristics including the flavour of the fruit. This has resulted in well justified consumer complaints about lack of flavour in modern strawberry varieties. Some attention has been given to fruit flavour in research programmes carried out at European Research Institutes in the past decade but none of the research programmes undertaken have included fruit flavour as a major research objective. The restoration of flavour by classical breeding methods is problematic because it involves cumbersome testing and multigenic manipulation.

In recent years there has been a greater emphasis on quality aspects in fruit production. The significance of flavour has been recognised and attempts are being made by researchers to concentrate on this aspect as well as the other desirable characteristics mentioned above. Among these has been the aspect of flavour.

Flavour in fruit and vegetables is a combination of an impression on the tongue (taste), mainly determined by the sugar acid ratio, and an

impression on the nose (aroma), due to the volatile organic compounds (Dininck et al, 1977). Taste consists of 5 main components, i.e. sweet, sour, bitter, salt and quinine. Sweetness (sugar content) is estimated by refractometric index, sourness (acidity) is measured by titration or pH, and both factors have a considerable affect on the taste quality of the strawberry. Aroma on the other hand is a more complex quality, having numerous dimensions. However it can be calculated by gas liquid chromatography and mass spectrometry. Studies on flavour have shown that the taste panel is one of the most effective methods of measuring this characteristic (Gormley, 1974), and is an essential component of any research in this area.

The most important flavour compounds in the strawberry are 2, 5 - dimethye -4- hydroxy - 3 (2H) furanone (furaneol) (Re et al, 1973) and its derivatives (Mayeri et al, 1989, Roscher et al, 1996).

Field strawberries have traditionally been grown in Ireland on the brown earth soils of the southeast. These soils are derived from Ordovician shales (Gardiner and Radford 1980). The brown earth soils have a low pH, are low in calcium and are high in potassium (Blagden 1989). The major strawberry production area in the United Kingdom is located in Kent. The soils in this region are derived mainly from chalk and so have a high pH, a high calcium content and are low in potassium. The superior flavour of strawberries grown in the brown earth soils in Ireland compared with those grown on podsolics derived from calcium rich chalk has been recognised by UK wholesalers for some time. The strawberry variety Elsanta is the most common variety grown in both regions and it is reasonable to conclude that environmental factors especially soil type are mainly responsible for the superior flavour of strawberries grown on brown earth soils. The differences in soil pH, calcium and potassium concentrations were used as the main basis in drafting a research project investigating the effect of nutrition on the flavour of strawberries. A research project on the effect of nutrition on the flavour of strawberries under protection was undertaken at Clonroche in 1997.

The normal season of production for field strawberries occurs from late June to late July. In the past 10 years a programme which enables production to start in late April and finish in mid-November has been developed at Clonroche. The early and late production programmes are based on the growth of plants under polythene using peat as a growing medium. The peat contains extremely low concentrations of plant nutrients and has a low pH. In order to produce satisfactory fruit

crops all of the plant nutrients must be premixed with the growing medium or applied through the irrigation system. This provides the grower with the opportunity to control the quantity and ratio of nutrients, which are supplied to the crop. The research project on the effect of nutrition on flavour was carried out in protected crops in peat based growing media for the following reasons.

(1) In the late April to mid-November period with the exception of a relatively brief time in late June to late July all fruit is produced in growing media based on peat.
(2) Crop production in peat based media provides the opportunity to apply maximum control of the amount of nutrients which are applied in the strawberry crop.
(3) It is possible to control the pH and the calcium (Ca), nitrogen (N) and potassium (K) supply to the plant in peat based growing media. This provides an opportunity to investigate the effect of different Ca, N and K ratios on fruit flavour and to influence fruit flavour by manipulation of these ratios where such an effect exists.

Some preliminary investigations have been carried out on the effects of high K and low N on strawberry yields at Clonroche in 1995 and 1996. These investigations showed that low N rates and high K rates resulted in better fruit shape and larger fruit yields. Lieten et al, 1993 carried out similar investigations with N, K, Ca and Zinc (Zn) on Elsanta plants. He showed that these four nutrients accounted for by far the greatest percentage of all minerals in the strawberry fruit. The values in order of magnitude were as follows: K (70%), N (50%), Zn (30%) and Ca (7%). The Ca content of the fruit is remarkably low in consideration of the fact that the plant uptake of Ca is only slightly lower than that of N and K. Zn content of the fruit is remarkably high in consideration of the fact that Zn uptake by the plant is normally less than 100 mg/kg. In the Clonroche investigations Zn was also included as a treatment because its influence on flavour might also be important. Care must be taken to preserve a reasonable balance between K, Ca, N and Zn when improving fruit flavour through the manipulation of mineral ratios. Lieten (2001) has reported that increasing the Ca ratio can improve fruit firmness and shelf life. This factor was also taken into consideration in the Clonroche investigation.

Investigations on substrate types were carried out in the course of this project Various combinations of peat, sand and grit mixtures of different ratios were assessed. Different rates of slow release fertilisers were applied as a base dressing to the substrate to assess

the effect on growth and fruit yield. The use of grit and sand enhances the wettability and the moisture retaining characteristics of growing media used in container production (Bunt, 1998).

Methods of Investigation

The experiments were carried out in an unheated polythene tunnel 9m wide and 30m long at Clonroche and in an unheated glasshouse 12m wide and 50m long at Kinsealy. At Clonroche the containers used for the strawberries were 5.0 l pots which were suspended from the super structure of the tunnel by polythene ties. At Kinsealy the investigations were carried out in peat modules placed on suspended shelves in the glasshouse.

In January 1997 cold stored Elsanta runners with a crown diameter of 15mm+ were planted in 5 l pots containing the growing media at Clonroche. Four runners were planted in each pot. These were suspended from the superstructure in rows spaced at 1.5m. The pots were placed in the row at 25cm centres to give a density of 10.5 plants per m^2. The pots were irrigated by a single drip unit placed in each pot. Irrigation was controlled automatically by a trip switch which was operated electronically when the moisture content was reduced to 70 per cent and which ceased operation when the pots were irrigated to full container capacity.

Growing media:

Six types of growing media were investigated. These were:

(1) Coarse peat
(2) Coarse peat and standard acidic grit at a ratio of 2:1 peat/grit
(3) Coarse peat and local alkaline grit at a ratio of 2:1 peat/grit.
(4) Medium grade peat.
(5) Medium peat and standard acidic grit at a ratio of 2:1 peat/grit.
(6) Medium peat and local alkaline grit at a ratio of 2:1 peat/grit.

The local grit was used in the experiment because it was less costly to purchase and to transport. The medium and coarse grade peat are the standard peat grades commercially available from Bord na Mona. The medium and coarse grade peat used in the experiment was treated with 1 kg/m^3 of 8-9 month osmocote and 8.0 kg/m^3 of ground mineral limestone. The strawberry runners were grown on in these growing media without liquid feed until the first flowering stage of the crop.

Nutrient application:

The 1991 Kinsealy liquid feed for strawberries was selected as the control treatment. The stock solutions used in this liquid feed are shown in Table 1. The feed was applied through the irrigation system at a ratio of 1 in 200.

Table 1. Kinsealy Liquid Feed Mix for Strawberries, 1991.

Compound	Tank A (kg/10l)	Tank B (kg/10l)
Potassium nitrate	0.36	0.36
Calcium nitrate	1.2	-
Magnesium sulphate	-	0.72
Mono-Potassium sulphate	-	0.4
Ammonium sulphate	-	0.06
Iron chelate	32 (grams)	
Trace Element Solution	-	0.1 (litres)

Trace Element Mix:

Trace Element	g/10l
Solubor 20%	500
Manganese sulphate	480
Copper sulphate	160
Zinc sulphate	695
Sodium Molybdate	18.4

The other five treatments used in the experiment were based on variations which were made in the levels of K, Ca, N and Zn in this stock solution. In the case where a high level of a particular nutrient was applied the concentration of that particular nutrient was increased by 100 per cent. In the case where a low level of the nutrient was applied the concentration of that particular nutrient in the stock solution was decreased by 50 per cent. The effect of the Zn on fruit flavour was evaluated by excluding the Zn from the treatment. The following treatments were applied from the first flowering stage

onwards until the end of harvest at a rate of 1.52 l per pot once per week.

Treatment 1 - High potassium - low calcium
Treatment 2 - Low potassium - high calcium
Treatment 3 - Kinsealy liquid feed with no zinc
Treatment 4 - Standard Kinsealy liquid feed
Treatment 5 - High potassium, high calcium, high nitrogen
Treatment 6 - Low potassium, low calcium, low nitrogen.

The EC of the feed was measured once per week to ensure that the level of nutrients being applied was in accordance with predetermined rates.

Methods of Fruit Analysis

Four methods of fruit analysis were carried out to assess the effects of the various treatments on fruit quality and flavour. These were:

(1) Sensory analysis
(2) Chemical analysis for sugars and acids
(3) Fruit firmness
(4) Shelf life.

(1) Sensory analysis:

Sensory analysis was conducted by four taste panels set up at three different locations and used to assess fruit taste during each harvesting period. The taste panels were located at U.C.D., Kinsealy and Clonroche. Each taste panel consisted of a minimum of 12 persons. A total of 52 persons were used to assess fruit taste during the course of the investigation. A fruit sample from each treatment was ranked from best (ranked 1) to least good (ranked 6). The ranked scores were then referred to a range table to determine whether the sample in question was significantly better or worse than the control sample. Sensory analysis was carried out on spring and autumn fruit in each of the three years.

(2) Chemical analysis of sugars and acids:

(a) Sugar concentration was determined using refractometric index (RI). RI and sugar concentration are closely correlated in ripe fruit.
(b) Acidity was determined by titration of sodium hydroxide with strawberry juice (NaOH N/10 - pH 8.1 and 9.5).

(3) Physical analysis measurements:

Fruit firmness was assessed by using a shear press. A known quantity of fruit was subjected to a weighted press. The press was operated by hydraulics. A graph was produced to show the amount of pressure required to pulp the fruit.

(4) Shelf life

Samples from each treatment were stored at room temperature and at 4^{o}C. The samples were assessed at two stages, after a period of two days and after a period of four days.

(5) Yields

Yields were assessed by weighing the amount of ripe fruit produced by each plant. The fruit were graded and unmarketable fruit were also assessed.

Results

Sensory analysis, 1997, Clonroche.

In three of the taste panels the high potassium - low calcium feed (Treatment 1) was shown to have significantly better flavour than the other five treatments in the spring crop. All four taste panels placed treatments 2, 3, 4 and 5 within the range table, each sample having been adjudged to possess a good flavour. All of these treatments except treatment 2 were treated with medium or high potassium concentrations. Treatment 2 was treated with a low potassium - high calcium feed. Treatment 6 (low potassium - low nitrogen - low calcium) was placed just inside the range table, bordering on being significantly worse than the other treatments. In the autumn crop of Elsanta the high potassium - low calcium feed also gave the best fruit flavour while the fruit from the low potassium, - low nitrogen - low calcium treatment had the least fruit flavour. Flavour intensity was lower overall in the autumn crop compared with the spring crop. Sugar levels in the autumn crop were also lower compared with the spring crop. The reduction in fruit flavour was most likely due to the lower light intensity at the time of harvest. This resulted in a lower rate of sugar conversion in the fruit.

Yields 1997, Clonroche.

The plants treated with high potassium - low calcium feed gave a larger fruit yield than the other treatments but was not significantly greater than the control. The fruit yield for this treatment was 0.25 kg per plant. Treatments 2, 3 and 5 gave yield reductions of 4%, 12% and 13% respectively compared with the control. The plants treated with low potassium - low nitrogen - low calcium gave a yield reduction of 24% compared with the control.

External Fruit Quality, 1997, Clonroche

Fruit malformation, soft flesh and a high proportion of small fruits, was clearly evident in plants treated with the low potassium-low calcium-low nitrogen feed, (Treatment 6). Treatment 3 (Kinsealy mix, no zinc) also produced a large proportion of malformed and small fruits. Each of the remaining three treatments produced fruits of good external quality, equal to that of the control feed.

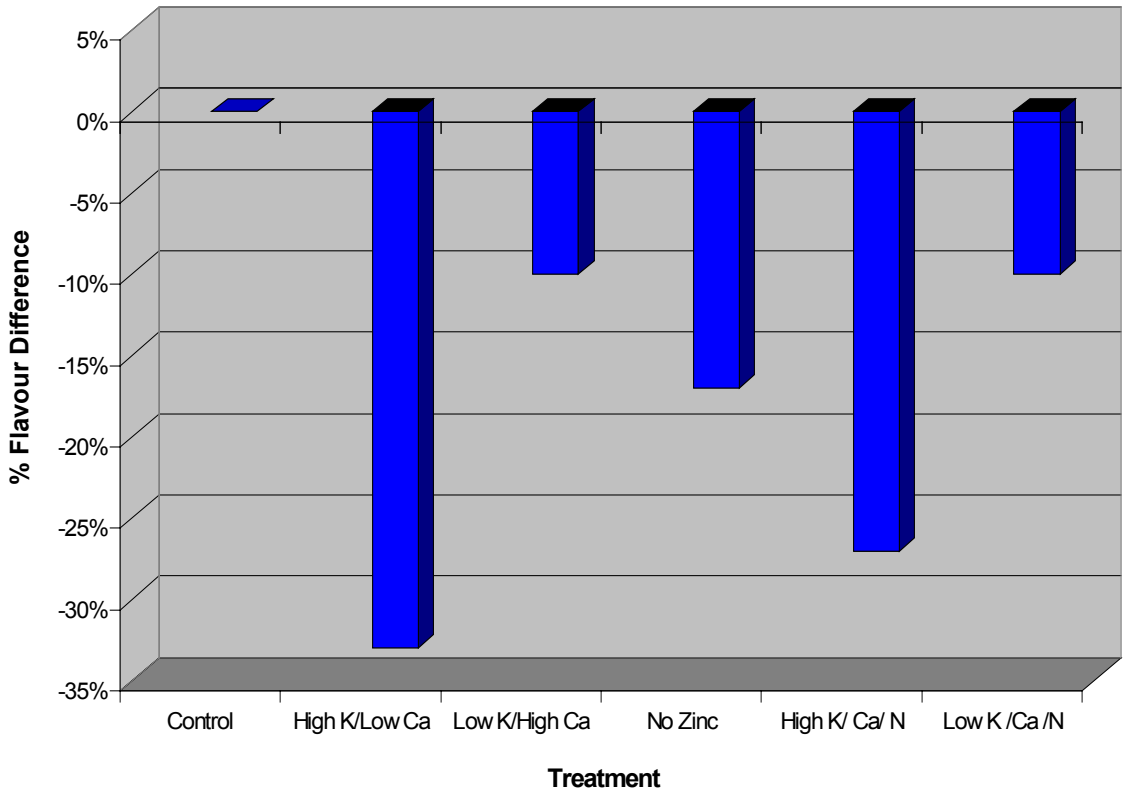
Growing media, 1997, Clonroche.

Overall yields were assessed in each of the growing media. The maximum yield was produced by coarse peat and no sand, at 0.25 kg per plant, while that of medium peat and no sand showed a yield reduction of 9%. Coarse peat and medium peat with acid grit incorporated into the mixture, produced reduced yields of 6% and 10% respectively. Poorest yields were obtained with the coarse peat/sand, and medium peat/sand mixtures. Yield reductions were 12% and 17% respectively.

Sensory Analysis, Spring, 1998, Clonroche.

Sensory analysis was conducted using 3 taste panels during the fruiting period in 1998. None of the treatments had any affect on fruit flavour. However when the results from all three panels were compared it was possible to give an overall assessment of differences in flavour compared to the control feed. The control feed produced the best flavour of all 6 treatments. A reduction in flavour of 10% occurred with the use of the low potassium, high calcium feed, and the low nutrient feed (low K, Ca, N). The absence of zinc from the control reduced flavour by 17%. The high nutrient feed (high K, Ca, N), and the high potassium, low calcium feed produced the largest reductions, i.e. 27% and 33% respectively, (Fig.1).

Figure 1. Taste Panel, Spring 1998, Clonroche



The levels of sugars and acids were measured at three intervals over the growing season.
The three sets of data were combined to give an overall indication of the sugar-acid ratio for each of the treatments. These levels were then compared to the control feed (Kinsealy mix) which produced a sugar-acid ratio of 12.5. The low potassium, high calcium feed produced a higher ratio of 13.9. 11% greater than the control (Fig. 2). The ratio obtained with low nutrient feed (low K, Ca, N) was slightly lower than the control at 11.9. The absence of zinc from the control resulted in a reduction of 15%. The high potassium, low calcium feed and the high nutrient feeds produced the lowest ratios compared to the control, with reductions of 18% and 24% respectively.

When observing sugar-acid ratios it is also important to take account of the individual levels of sugars and acids present in the sample. A high level of sugars combined with a very low level of acids will

produce a high sugar-acid ratio. This should normally produce a superior flavour. However due to the poor balance of sugars and acids the resulting flavour may be bland despite the high ratio.

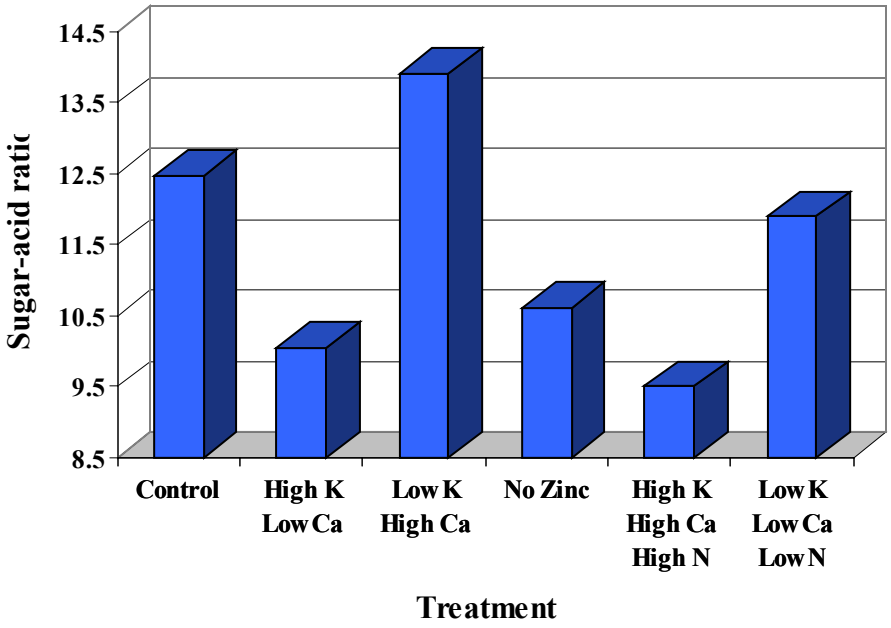
Measurements of the % sucrose present in the samples showed only one treatment producing higher levels than the control. This was the low K, high Ca treatment which contained an increase in sugar content of 2%. The greatest reduction in sugar content was observed in the high nutrient feed (high K, Ca, N). In this case a reduction of 16% was recorded. Each of the remaining treatments produced decreases in sucrose of between 4% and 8%.

Three of the treatments contained higher levels of acid than the control. The high K, low Ca treatment fruit contained 16% more citric acid. The absence of zinc produced an increase of 9%, while the high nutrient feed increased acidity by 6%. Lower citric acid levels were observed in both the low K, high Ca feed and the low nutrient feed. The reductions were 9% and 3% respectively.

Fruit Firmness, Spring 1998, Clonroche

Results showed that the control feed produced the least firm of all fruit. A pressure of 270N @ Span 20mv was required to press the fruit. The low nutrient feed produced the firmest fruit, requiring 36% more pressure than the control. The low potassium, high calcium feed produced fruit which was 29% more firm than the control. The high nutrient feed was closest to the control, requiring only 2% more pressure to compress the strawberries.

Fig. 2 Sugar-acid ratio



Yields, Spring 1998, Clonroche

Assessments of the yields showed that the highest yield was achieved with the high nutrient feed (high K, Ca, N). This treatment have a fruit yield which was 5% higher than the control. The high K, low Ca feed produced yields that were equal to that of the control. The low K, high Ca feed produced a 6% reduction in yield. Reductions of 10% were observed in the low nutrient feed (low K, Ca, N), and the feed without zinc. All these treatments contained the low rate of Osmocote.

3.5 Shelf -life, Spring 1998, Clonroche

Assessments of shelf life showed that all treatments deteriorated over time at an equal rate. There was a measurable deterioration in quality following two days on the shelf. Following four days at 4^{o}C all treatments showed good quality, good fruit sheen with no deterioration in colour but fruit quality deteriorated rapidly following removal from the cool shelves.

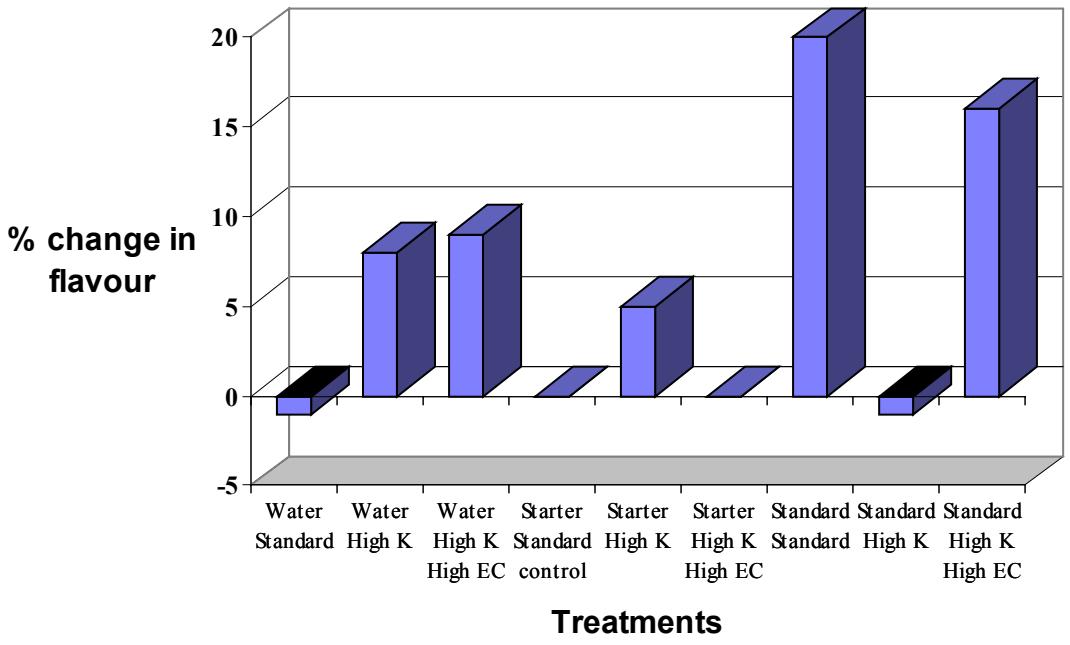
Sensory Analysis, Spring, 1998, Kinsealy:

Taste panels were carried out twice over the growing season. Due to the large number of treatments it was necessary to split each taste panel into 3 sub-panels, with the control present in each panel. The

control feed was that of number 4, the starter-standard feed regime, which is the normal feed used.

Five of the nine treatments were shown by sensory analysis to possess a superior flavour compared with the control (Fig. 3). Treatment 7 (standard-standard) had a significantly better flavour and gave an improvement of 20% compared to the control. Treatment 9 (standard-high K, high EC) was also significantly better, showing an improvement of 16%. Treatments 2, 3 and 5 also produced improvements of 8%, 9% and 5% respectively. Treatment 6 was equal to the flavour of the control. The remaining treatments, 1 and 8, both produced reductions in flavour of 1%.

Fig. 1 Kinsealy taste panel, Spring 1998



Sugar-Acid Ratio, Spring, 1998, Kinsealy

Sugars and acids were assessed at three intervals over the fruiting season. Average sugar-acid ratios were calculated from this data and the overall composition of the fruit samples was assessed. The control treatment produced the lowest sugar-acid ratio of all nine treatments, (Fig. 4). The highest sugar-acid ratio was found in treatment 5, (starter-high K). This value was 20% higher than the control. Treatments 6 (starter-high K, high EC), and 9 (standard-high K, high EC) both showed ratios 10% greater than the control. The remaining treatments gave improvements of between 1% and 6%.

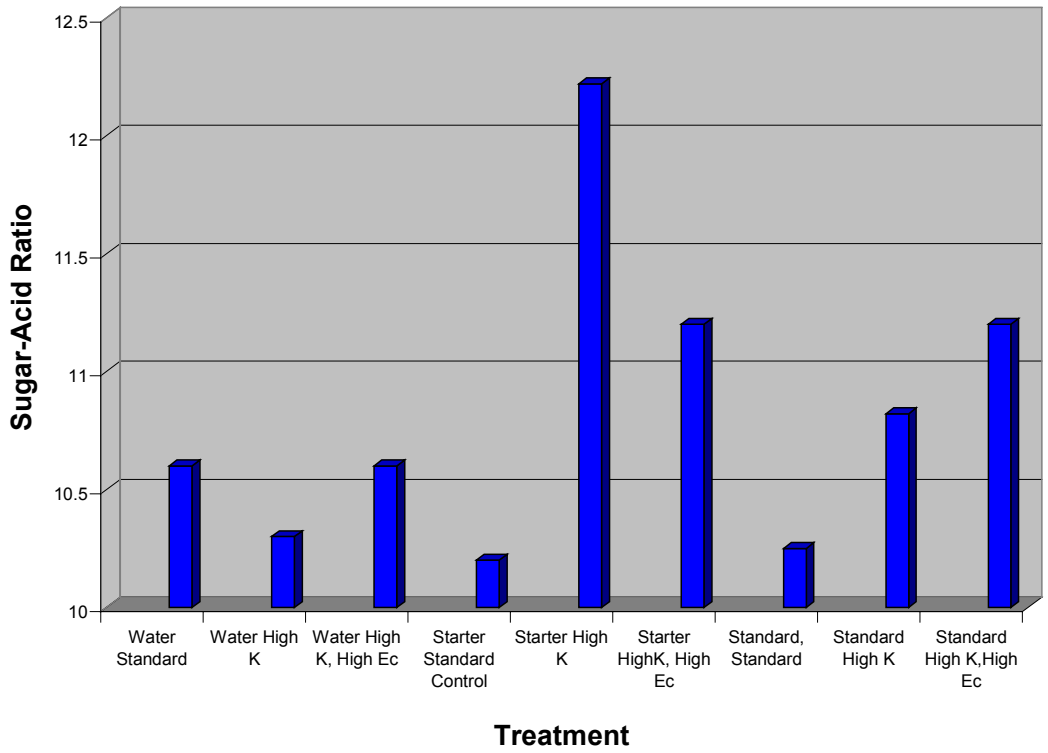
Fruit Firmness, Spring, 1998, Kinsealy

Fruit firmness was assessed by shear press. The firmness of the control sample was 257N @ Span 20. Only treatment 5 (starter-high K), produced firmer fruit, with a 5% increase over the control. Treatments 7 (standard-standard), and 9 (standard-high K, high EC), gave the softest fruit samples 16% lower than the control. Treatments 2 (water-high K), and 3 (water-high K, high EC) produced values which were equal to the control. Other treatments showed reduced firmness of between 5% and 7%.

Flower count, Spring, 1998, Kinsealy

A significant difference was not observed in the flower count. However in general the number of flowers was relatively high with an average count of 29 per plant. In treatment 9 (standard-high K, high EC) an average of 30.4 flowers per plant was observed. Treatment 3 (water-high K, high EC) produced the lowest count of 26.9 flowers.

Figure 4. Sugar- Acid Ratio Spring 1998, Kinsealy



Yields, Spring, 1998, Kinsealy

The highest yield obtained over the fruiting season was from treatment 7 (standard-standard) which yielded 374g/plant, of which 81% was marketable. This was 10.5% higher than the control treatment which yielded 339g/plant (76% marketable fruit). Treatment 1 (water-standard) have a fruit yield 4.5% higher than the control, 78% being marketable.

Treatments 2,3,5 and 6 produced yields similar to that of the control. However treatment 3 (water-high K, high EC) produced 82% marketable fruit. Reduced yields were observed in treatments 8 (standard-high K), and 9 (standard-high K, high EC), with reductions of 4% and 4.5% respectively.

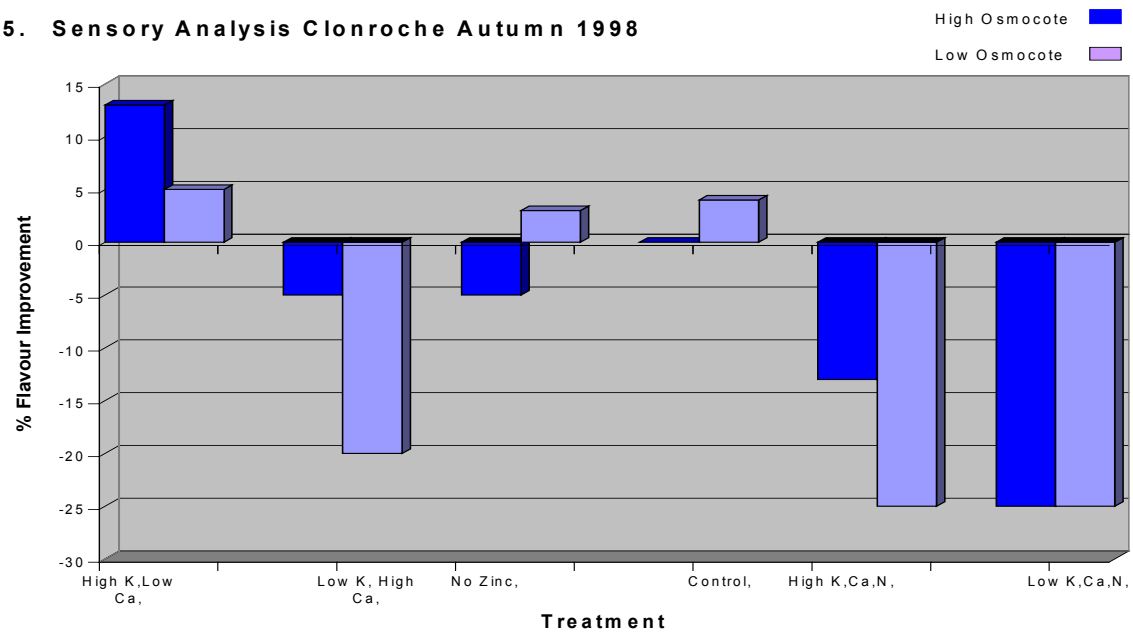
Shelf-life, Spring, 1998, Kinsealy

Samples of each of the 9 treatments were stored at two temperatures, room temperature and 4^{o}C. Observations were then made with regard to deterioration over 8 days at three periods. The shelf life of treatments 3`(water-high K, high EC), and 7 (standard-standard) was slightly longer than that of the other treatments. The remaining treatments had a shelf life equal to that of the control.

3. Sensory analysis, Autumn, 1998, Clonroche.

3.1 Sensory analysis was conducted by 2 taste panels over the fruiting period. Averages were taken from the two taste panels to give an overall assessment of flavour improvement. Comparisons were made against the control treatment with the high Osmocote rate. These comparisons involved converting the rank score values into percentage differences, taking the aforementioned control as having a value of zero. Fig. 1 represents the differences in flavour which were detected. Negative values indicate a reduction in flavour, while positive values show improvements in flavour. Improvement in flavour is consistently shown in the feed which was high in K, and low in Ca. Compared to the control, this treatment showed an improvement of 13% (significant) and 5% for the high and low Osmocote replications respectively. Three of the treatments produced a reduced flavour. These were the high and low nutrient feeds, and the low K, high Ca treatment, (Fig. 5). In general, the high Osmocote treatments tended to produce a better flavour than the low Osmocote treatments.

Figure 5. Sensory Analysis Clonroche Autumn 1998

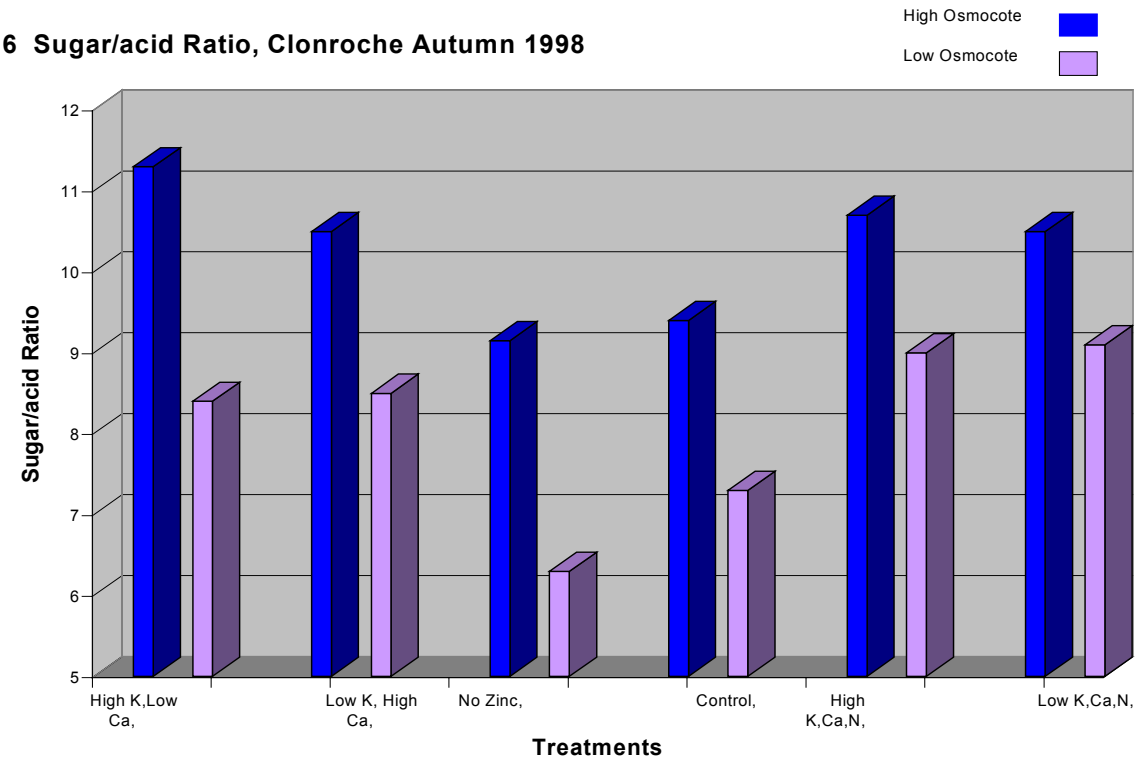


Sugar-Acid Ratio, Autumn, 1998, Clonroche.

The levels of sugars and acids were measured at three intervals over the growing season. The three sets of data were combined to give an overall assessment of the sugar-acid ratio for each of the treatments. These levels were then compared to the control feed (Kinsealy mix + high Osmocote). This treatment produced a sugar-acid ratio of 9.5, (Fig. 6). The highest ratio (11.3) was observed in the high K, low Ca, high Osmocote feed. The high nutrient and low nutrient feeds, along with the low K, high Ca feeds were also found to increase the sugar-acid ratio. The values were 10.7, 10.5 and 10.5 respectively. These high values may be due more to a poor balance of sugars and acids, rather than a sweeter flavour. The liquid feed, which was lacking in zinc gave reduced sugar-acid ratios for both the high and low rates of Osmocote.

The low rate of Osmocote when applied to all treatments gave lower sugar-acid ratios, ranging between 6.3 and 9.1. The high rate of Osmocote on the other hand produced a range of ratios for the six feeds of between 9.3 and 11.3. The higher ratio gives sweeter fruit.

Fig 6 Sugar/acid Ratio, Clonroche Autumn 1998



Yields, Autumn, 1998, Clonroche.

Assessment of yields shows that the low Osmocote treatments produced an overall reduction in yield of between 2% and 13%, when compared to the control treatment with the high Osmocote levels. The control produced an average yield of 239 g/plant. Each of the high Osmocote treatments gave higher yields than the control. The high K, low Ca feed yielding 9% higher (261 g/plant). The remaining treatments in combination with the high Osmocote level gave yield increases of between 3% and 6%.

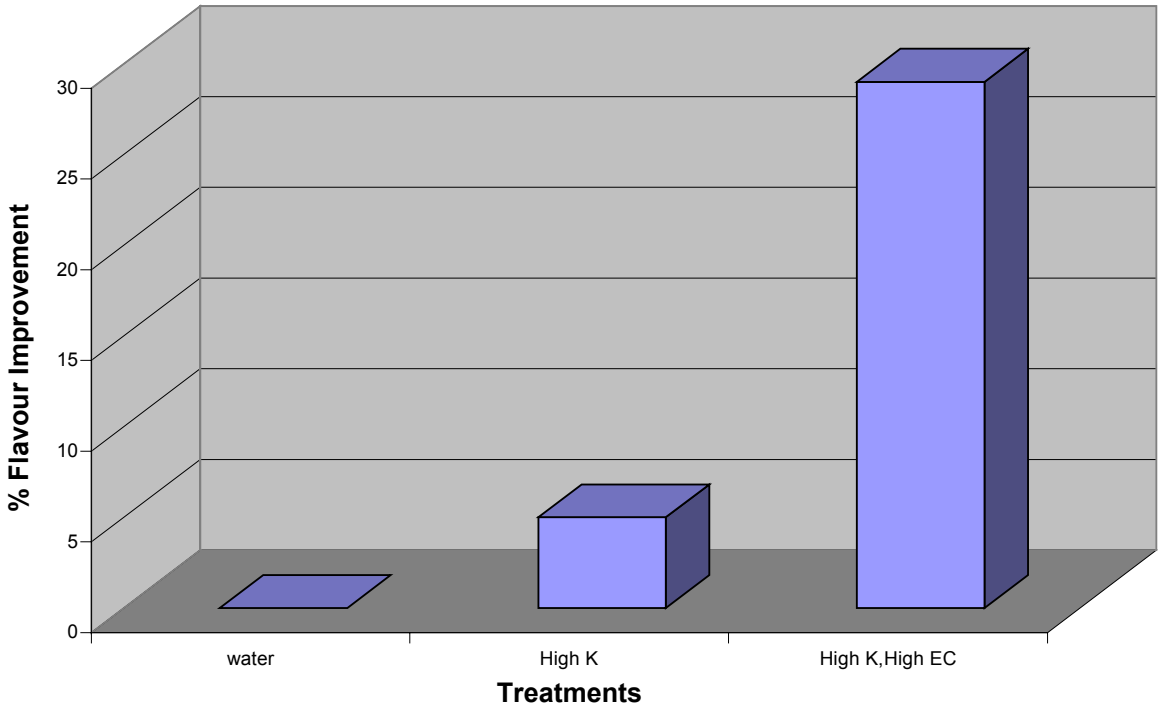
Shelf-life, Autumn, 1998, Clonroche.

Shelf life was assessed by storing samples of each of the 12 treatments at 4^{o}C. The samples were examined daily for any deterioration in quality. Four of the feed treatments gave a short shelf life. These were the high nutrient feed (high K, Ca, N) and the low nutrient feed (low K, Ca, N) at both levels of Osmocote. The remaining treatments had similar holding qualities.

Sensory Analysis, Autumn, 1998, Kinsealy.

Two taste panel assessments were carried out over the fruiting season. The water feed was taken as the control, and used for comparison against both the high K and the high K, high EC treatments. The high K, high EC feed had a significantly better flavour. This treatment provided an average flavour improvement of 29% when compared to the water feed, (Fig. 7). The high K treatment also gave an average improvement of 5%.

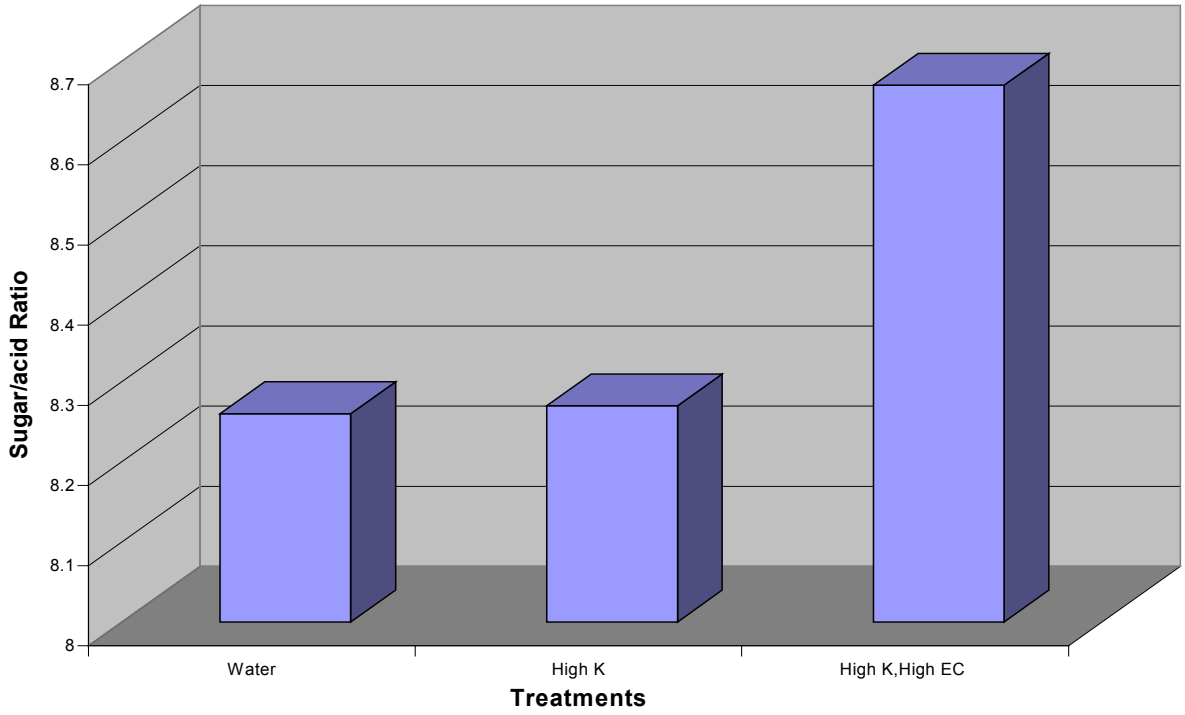
Fig.7 Kinsealy Taste Panel, Autumn 1998



Sugar-Acid Ratio, Autumn, 1998, Kinsealy.

Sugars and acids were assessed at two intervals during the growing season. The sugar-acid ratio was calculated from this data. The water treatment produced the lowest ratio at 8.26. The high K feed had an average ratio of 8.27. The highest ratio was produced by the high K, high EC feed at 8.67, i.e. a 5% improvement compared to the water treatment, (Fig. 8).

Figure 8. Sugar/acid Ratio. Kinsealy Autumn 1998



Fruit Firmness, Autumn, 1998, Kinsealy.

The water treatment provided the firmest fruit at 224N @ Span 20. Both the high K and the high K, high EC treatments produced fruit samples of equal firmness, at 196N @ Span 20. This constituted a 12.5% reduction in fruit firmness.

Yields, Autumn, 1998, Kinsealy.

The highest yield was obtained from the water treatment (134g/plant). The high K treatment gave a 1.5% reduction in yield. The high K, high EC treatment gave a 4% reduction in yield.

Shelf Life, Autumn, 1998, Kinsealy.

Observations were made on fruit quality at 3 intervals over an 8 day period. The water treatment and the high K treatment were both shown to have a similar ability to retain fruit quality. However, fruit samples from the high K, high EC treatment deteriorated at a slightly faster rate at both storage temperatures. However, when kept chilled at 4^{o}C the deterioration was delayed for 4 days.

Literature Review

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