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The results and conclusions in this report are based on an investigation conducted over a one-year period. The conditions under which the experiments were carried out and the results have been reported in detail and with 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.

Contents

GROWER SUMMARY

Headlines 2015

- The use of a low nitrogen regime in pot grown Duke blueberry not only reduced fertiliser costs but also reduced picking costs as a result of larger fruit.
- There were no adverse effects on plant growth or cropping for high nitrogen regimes and nitrogen was not a limiting factor at the lowest regimes.

Background and expected deliverables

This project aimed to ascertain the effects of different nitrogen application regimes on growth, yield, storage and frost sensitivity of two blueberry varieties – Duke and Aurora - to address gaps in knowledge about the timing of and optimum feed regimes.

The intended deliverable was to identify an adequate level of nitrogen feed for blueberry in pot grown systems. It was hoped that potential benefits of varying nitrogen through the season would be seen. Benefits from further work may include assessing adequate levels for other nutrients including potassium, phosphate and magnesium.

Optimum growth of canes is required to maximise the yield of blueberry bushes, with larger bushes having greater potential yields. Although nitrogen application is important for encouraging growth, it is not without potential problems. During fruiting, high nitrogen application has been shown to reduce fruit firmness in a number of crops and may reduce storage life. Commercial experience has shown that damage to developing flowers caused by frosts during autumn and winter can have adverse impacts on yield, with late nitrogen applications believed to increase sensitivity to frost. Excessive nitrogen applications at the time of autumn flower initiation also have the potential to reduce flower number. Anecdotal evidence from other blueberry growing areas suggests that nitrogen applications post-harvest can lead to late season bud break with the production of new shoots in the autumn, thereby reducing yield, since potential fruit buds are 'lost' to vegetative growth. Moreover, this late growth is said to be highly susceptible to damage by late autumn or early winter frosts. On the other hand, inadequate nutrition during flower initiation in the autumn has been shown to reduce crop potential in Southern Highbush blueberries. Each of these effects may have a considerable influence on yield.

The blueberry crop is relatively new to the UK with growers largely adopting pot grown production systems. Elsewhere in the world blueberries are predominantly soil grown. Consequently the majority of research into blueberry nutrition requirements has generally been conducted on field

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grown crops, so there is a need for trials to determine the optimum feeding regime in pot grown blueberries. It was hoped the work would lead to a number of commercial benefits:

- Pot grown plants are more sensitive to changes in the nutrients applied through the irrigation system and so this presents growers with an opportunity to manipulate nutrient balance to improve production.
- An understanding of the role of nitrogen at specific times of the year would allow the targeting of nitrogen applications where they would have most benefit.
- Determining how or whether nitrogen can be applied in the run up to fruiting without reducing storage potential could extend the market for UK blueberries.
- Yield losses due to frost damage are not sustainable and so a method of reducing the risk of frost damage is needed.

The two main objectives of the work are:

- **Objective 1:** Test the effect of three constant nitrogen levels on growth and yield (March 2012 - October 2012)
- **Objective 2:** Examine the effect of increasing and decreasing nitrogen feed levels during three key phases of growth: early spring growth, fruiting and autumn flower initiation (October 2012 - October 2015)

Summary of the project and main conclusions

The project was run at Brogdale Farm, Faversham, Kent. Three year old blueberry bushes of the varieties Duke and Aurora were sourced from Hall Hunter Partnership (HHP) in 25L pots on 6 March 2012. The variety Duke was sourced from Heathlands Farm, Wokingham and the Aurora was sourced from Tuesley Farm, Milford. The plants were selected for uniformity using a standard system. For Duke, the plants required three to five main structural branches and for Aurora, plants with two or three main structural branches were selected.

On arrival at Brogdale, the pots of the variety Duke were placed on a black Mypex floor covering, in a Spanish Tunnel. The tunnel was covered from bud break until the end of cropping at which point the plastic cladding was removed. The Aurora pots were placed outside on a black Mypex floor covering in line with commercial practice.

Objective 1: Test the effect of three constant nitrogen levels on growth and yield (March 2012 - October 2012)

Three feed solutions were supplied to plants with 60ppm N, 120ppm N or 180ppm N from March to October 2012. Ninety plants of each variety were arranged in a randomised block design with six plots per treatment. Irrigation was supplied to achieve a target of 60% substrate moisture content

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whilst maintaining EC within set limits. The nitrogen applied was in the form of 70% ammonium nitrogen and 30% nitrate nitrogen.

Shoot lengths of tagged and labelled shoots were recorded monthly from March to October 2012 to determine whether the nitrogen treatments stimulated different levels of growth. In addition, fruit were harvested weekly and the number and the weight of fruit were recorded for each plot. Fruit brix° was recorded from 20 fruit per plot twice during the cropping period of each variety along with shelf life.

The results of the work in Objective 1 have been summarised in previous annual reports.

Objective 2: Examine the effect of increasing and decreasing nitrogen feed levels during three key phases of growth: early spring growth, fruiting and autumn flower initiation (October 2012 - October 2015)

A separate batch of 252 plants of each variety is being used for the nitrogen timing treatments. These were sourced from HHP in March as above and were grown on at Brogdale for four months at 120ppm N from April 2012 to August 2012. At this point, on 15 August, the first treatment applications started with the application of the autumn treatments until 15 October 2012 (autumn high and autumn low below). Timings are based on specific growth stages although approximate timings are shown below for reference.

The plants were arranged in a randomized block design with six plots per treatment and seven plants per plot. Three separate lines of irrigation for the three nitrogen treatments allowed the plants to be plugged into the correct nitrogen treatment at the three points during the season outlined below (all dates vary according to the season).

'Autumn High'. A nitrogen level of 180mg/L was applied from the end of harvest until 90% leaf fall (15 August to 15 October 2012) and then 120mg/L was applied from bud break until the end of harvest (17 April to 12 September 2013).

'Autumn Low'. A nitrogen level of 60mg/L was applied from the end of harvest until 90% leaf fall (15 August to 15 October 2012) and then 120mg/L was applied from bud break until the end of harvest (17 April to 12 September 2013).

'Spring High'. A nitrogen level of 120mg/L was applied from 15 August to 15 October 2012. 180mg/L was then applied from bud break until first green fruit (17 April to 1 July 2013) and then decreased again to 120 mg/L until 12 September 2013.

'Spring Low'. A nitrogen level of 120mg/L was applied from 15 August to 15 October 2012. 60mg/L was then applied from bud break until first green fruit (17 April to 1 July 2013) and then increased again to 120mg/L until 12 September 2013.

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'Summer High'. A nitrogen level of 120mg/L was applied from 15 August to 15 October 2012 and from bud break until first green fruit (17 April to 1 July 2013). This was then increased to 180mg/L from first green fruit until the end of harvest (1 July to 12 September 2013).

'Summer Low'. A nitrogen level of 120mg/L was applied from 15 August to 15 October 2012 and from bud break until first green fruit (17 April to 1 July 2013). This was then reduced to 60mg/L from first green fruit to the end of harvest (1 July to 12 September 2013).

'Medium'. A standard nitrogen concentration of 120mg/L was applied from 15 August to 15 October 2012 and then from bud break until end of harvest (17 April to 12 September 2013).

'Low'. A nitrogen concentration of 60mg/L was applied from 15 August to 15 October 2012 and then from bud break until end of harvest (17 April to 12 September 2013).

'High'. A nitrogen concentration of 180mg/L was applied from 15 August to 15 October 2012 and then from bud break until end of harvest (17 April to 12 September 2013).

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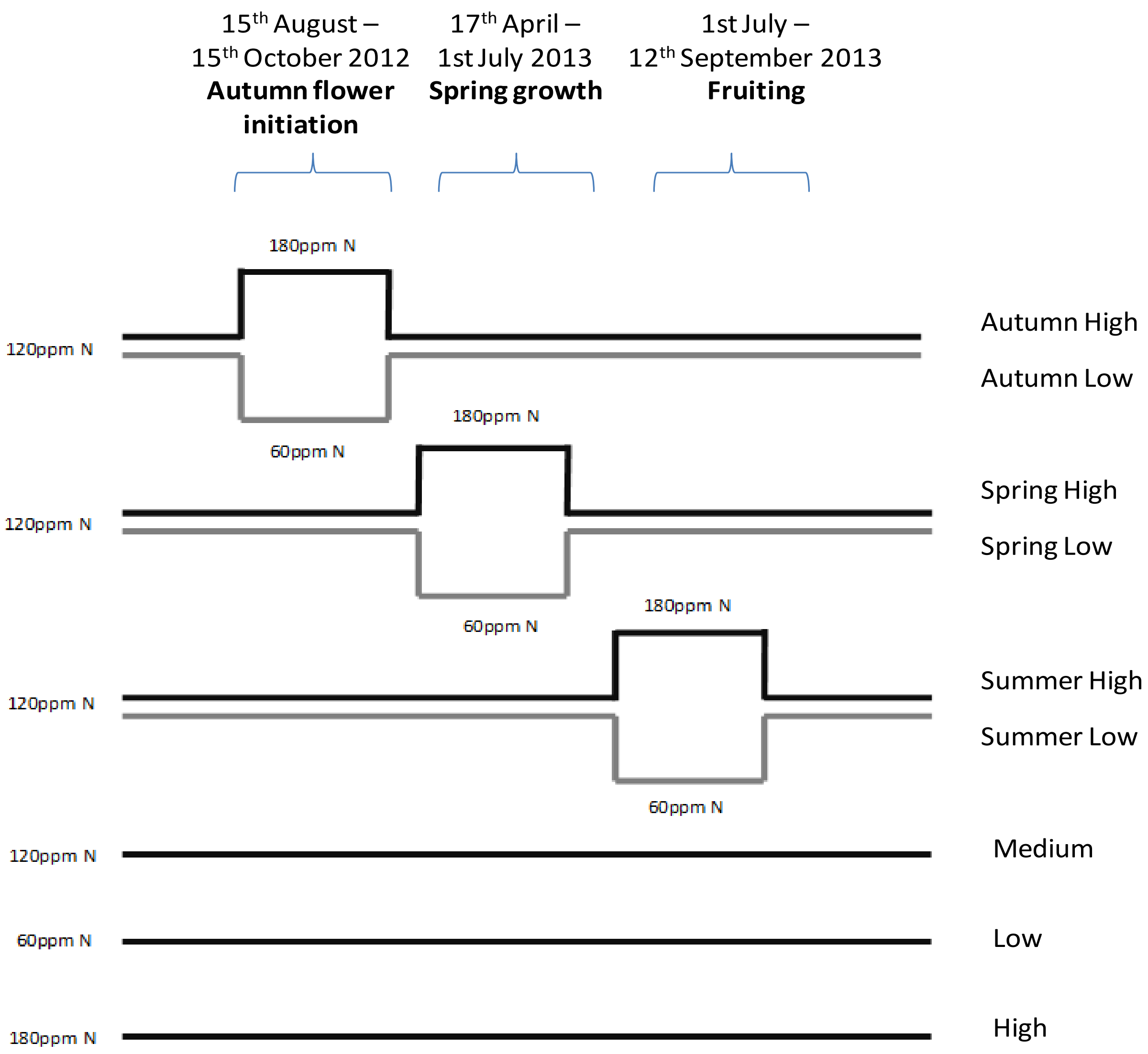

Figure 1. The treatments which were applied in Objective 2 of the project

From each treatment the growth, cropping and plant nutrition were assessed. These assessments began in 2013 apart from the growth measurements from the autumn high and autumn low treatments, which began in autumn 2012.

The assessments which were made included:

Growth Shoot growth measured from labelled branches at the end of each of the three nitrogen application timings at the following timings – green fruit, end of cropping and 90% leaf fall.

Cropping Fruit was harvested, counted and weighed, separated into Class I, Class II and Waste fruit to determine the effect of treatment on

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yield and overall fruit quality.

Storability Both the Aurora and the Duke were placed into an air store at 2ºC at Brogdale and assessed fortnightly until deemed non-marketable. The Duke was also placed into a CA store at Hall Hunter Partnership on 1 August and assessed after four and eight weeks. Assessments made fortnightly were as follows:

- Percentage fruit with shrivel
- Weight loss during storage
- Fruit collapse
- Flavour
- Overall marketability based on commercial specifications supplied by HHP

Flower initiation The percentage of floral buds was calculated and the average number of flowers per bud was recorded.

Percentage bud break The percentage of buds which broke from each treatment was assessed.

Plant nutrition Leaf samples were taken and analysed for nutrient content on 11 July and 4 September. In addition, irrigation input and runoff was analysed on 16 July.

The results from Objective 2 from 2012-2014 are summarised in previous reports.

Objective 2 results from 2015

Autumn 2014 was the third year during which nitrogen levels were increased and decreased depending on growth stage, namely: early spring growth, fruiting and autumn flower initiation. There were six different changing nitrogen regimes and three constant nitrogen reference regimes. The base nitrogen level applied was 120 mg/L and referred to as the 'Medium' feed and the treatments were either increased to 180 mg/L ('High') or decreased to 60 mg/L ('Low) at one of the three phases mentioned.

There were very few statistically significant results in 2015. However, in this trial overall, Aurora had higher percentage bud break than Duke – around 85% compared to 70%. Aurora also had approximately 55% floral buds compared to Duke at 40%. This is reflected in the total yields which in 2015 increased for Aurora (per pot average of 1.8kg compared to 1.6kg in 2014) but were static

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for Duke at an average of 2.3kg. The plants have not yet reached their maximum yield potential.

Percentage Class 1 (C1) fruit was higher for Duke than Aurora (92% compared to 88%). This was due to increased waste fruit for Aurora compared to Duke. Low nitrogen treatment for both varieties yielded the greatest C1 fruit per bush but results were not significant and differences between treatments were only 4%. Aurora Low had significantly lower Class 2 (C2) fruit than most other treatments but also the highest waste.

Low nitrogen treatment advanced ripening for both varieties during 2015 although marginally. However, in 2014, Low N retarded ripening.

Aurora had slightly heavier berries than Duke – 1.6g average compared to 1.5g, but Duke Low fruit were significantly heavier (1.7g) than any other treatment.

Berry size differences within varieties were minimal and not significant but Duke berries were slightly larger with an average of 14.6mm whereas Aurora were 13.7mm. The largest berries for Duke were from the Low treatment.

Low nitrogen treatment decreased Brix^0 in Duke but increased it in Aurora. Duke fruit had higher Brix^0 on average than Aurora– 12.8 compared to 10. Aurora Summer High had the lowest Brix^0 and, as in 2014, Autumn Low the highest (10.7). Values for Duke were highest for Medium nitrogen treatment and Low, Summer Low and Autumn Low had significantly lower Brix^0 than other treatments, which was similar to 2014, but all values were higher than for Aurora.

There were no significant impacts on cold storage for either variety. However, Aurora had a much greater percentage of marketable fruit remaining after the 8 week period concluded - >50% compared to <10% for Duke. Aurora Medium treatment performed best and losses were mainly due to dehydration and *Botrytis*. Greatest losses for Duke were from collapse and *Botrytis*. Duke Autumn Low performed best but marginally.

Shoot lengths appeared unaffected by treatment in 2015 for both varieties. Aurora shoot lengths for all treatments were very similar but High nitrogen reduced shoot growth compared to all other treatments, although not significantly. Applying Low nitrogen in Duke increased shoot length significantly however, but it is not known whether this is a seasonal effect, as seen in 2014.

Winter 2014/2015 and spring 2015 were again unusually mild in the south east of England. There were no harsh frost events, which prevented conclusions from being drawn on the impact of nitrogen nutrition on frost hardiness.

Main conclusions drawn from the first three years (2012-1014)

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Low rates of nitrogen reduced growth rates in Duke during the first two years of the trial but had no effect in 2014. This effect on growth did not have any apparent impact on yield.

Variety Aurora showed no response in terms of improved growth or yield to increasing levels of nitrogen.

Low N reduced storage losses in 2013 and 2014.

Increasing nitrogen levels to 180mg/L during the summer gave higher Brix (º) in Duke berries in years 2013 and 2014.

Main conclusions drawn from the final year (2015)

As stated previously, there would seem to be little benefit in using higher levels of nitrogen throughout the season, though increasing N in the summer could improve Brix (º) levels in Duke. Lower nitrogen rates would lead to reductions in fertiliser costs and have less environmental impact.

Benefits were seen from the Low N treatment in Duke (fruit weight) which is similar to results obtained in 2013 and 2014. Changes to feed regimes should be accompanied by careful monitoring of N levels in the run off.

There were no benefits for Aurora from increased levels of N.

Main conclusions from the life of the project (*2012-2015*)

In general there was little effect from varying N levels throughout the season or for periods within the season. There were no adverse effects on plant growth or yield at the highest N concentration of 180mg/L and it would appear that N levels of 60mg/L would be adequate for blueberries since N is not a limiting factor at this low regime. However, there were indications that there was also some consistency in maintenance of improved Brix^0, % marketable fruit out of store and Class 1 yields over the seasons for the following regimes:

- Aurora: Autumn Low / Spring High
- Duke: Autumn Low

Table 10 in the Science Section of the report summarises the treatment effects of all assessments.

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Financial benefits

The most likely sources of financial benefits to growers are:

- Potential saving of £270 per ha when using a low N regime (60mg/L) compared to a High N regime (when N = £1.50kg, approximately) (Duke and Aurora)
- Potential savings of 30p to 40p / kg on picking costs (when costs are around £1.50 to £2.00 per kg to pick) (Duke - assuming Low N results in 20% heavier fruit as seen in this trial)

Action points for growers

- Nitrogen feed concentrations of 60mg/L appear to be adequate for pot grown commercial blueberries.
- To achieve improved Brix°, marketable fruit out of store and class 1 yields, use the following nitrogen feeding regimes: Aurora – Autumn Low / Spring High, Duke: Autumn Low

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Science Section

Introduction

To maximise the yield of blueberry bushes, the optimum growth of canes is required, with larger bushes having the potential to produce greater yields. This requires the accurate application of nitrogen to encourage growth without developing other associated problems. For example, during fruiting, high nitrogen application has been shown to reduce fruit firmness (Kirimi et al 2011) in a number of crops and may reduce blueberry storage and shelf life. Throop and Hanson (1997) suggest that as nitrogen is retained in the plants, increasing nitrogen levels late in the season may benefit bushes in the following season. However, late nitrogen applications are believed to increase sensitivity to frost, and commercial experience has shown that frosts during autumn and winter can have significant effects on yield. Excessive nitrogen applications at the time of autumn flower initiation have the potential to reduce flower number, which could also have a considerable influence on yield (Sønsteby *et al*, 2009).

The UK is largely reliant on pot grown systems for blueberries primarily because of problems associated with soil type and pH. Bushes are usually fed using drip irrigation with a specific blueberry feed. Manipulating feed in pot grown blueberries generally has more effect than in soil grown bushes due to the buffering capacity of the soil. This gives the grower greater opportunity to alter the nutrient balance depending on growth stage.

Production of blueberries in the UK has expanded in recent years with the focus on early forced production of cultivars such as Duke and late production with cultivars such as Aurora. Controlled Atmosphere (CA) storage of blueberries has been used to extend the season of mid-season cultivars (but not cv. Aurora because of imports from South America) but this requires good quality, firm fruit to enable storage for sufficient duration. There are reports of a number of crops that, where excessive nitrogen has been applied, fruit quality has been adversely affected. In cranberries increased nitrogen resulted in an increase in fruit rots from 5 to 10% (Davenport, 1996). In apples excessive nitrogen applications can result in reductions in storage life, possibly through effects on fruit cell wall development or effects on fruit respiration rate (Fallahi *et al*., 1997). In strawberries fruit firmness during storage was reduced as a result of higher nitrogen applications, which also reduced fruit total soluble solids concentrations (Mukkun *et al*., 2001). Whilst being an important factor determining fruit quality, nitrogen is also required to encourage growth and so an application strategy is therefore required which optimises growth without adversely affecting fruit storage and shelf life.

In order to maximise blueberry yield potential early cane growth is required to produce larger bushes. This could be achieved by applying high levels of nitrogen to the bushes throughout the

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year. A number of studies have identified the beneficial effect of applying the ammonium form of nitrogen over nitrate nitrogen (Eck 1988 and Korcak 1988). However, there are reports where a balance of these forms of nitrogen is recommended (Hanson, 2006). Townsend (1967) compared a combination of ammonium N and nitrate N with nitrogen applied only in the form of nitrate or ammonium. Where nitrate N only was used, the root development was adversely affected and growth was reduced. However, there was no significant difference between the growth of canes with the combination of ammonium N and nitrate N compared with the application of ammonium N alone. Similarly, Rosen *et al*. (1990) found growth was most vigorous in blueberry shoots and roots when nitrogen was applied as a combination of both nitrate and ammonium forms, even though leaf nitrogen was greatest when only ammonium nitrogen was applied. It seems that there is a general consensus in the literature that applying nitrogen only in the nitrate form is detrimental to growth. There are a number of reports which suggest a combination of nitrate N and ammonium N has either similar effects to or is better than applying nitrogen only in the ammonium form. Commercial experience suggests using at least 50% of nitrogen in the form of ammonium. In the project described here, a combination of potassium nitrate, mono-ammonium phosphate and ammonium sulphate were used to achieve a ratio of 70% ammonium N and 30% nitrate N.

So it is clear that nitrogen does increase growth in blueberries when applied either as ammonium or as a combination of ammonium and nitrate nitrogen. It is less clear however what the effect is on yield. Whilst Kozinski (2006) found excess application of nitrogen did reduce yield in soil grown crops, it is not clear whether the decrease in yield was because flower initiation was adversely affected or whether growth was excessive, therefore creating competition for assimilates. Flower initiation occurs during the autumn under conditions of shortening photoperiods (Hall and Ludwig, 1961). At this time a greater application of nitrogen could influence flower bud formation and affect yield the following year. Plant dormancy is also induced during the autumn in preparation for the onset of winter and this is connected to cold hardiness. In a number of soft fruit crops, autumn nitrogen applications have been shown to reduce frost hardiness (Palonen and Buszard, 1997). For this reason, nitrogen fertilization is usually minimised after harvest.

In principle, a higher nitrogen level would favour growth and result in a larger bush size with a potentially higher yield. However, commercial experience of excessive growth causing detrimental effects on fruit quality, bud break and frost damage means that an optimum level has yet to be established and there are a number of feed programmes being recommended to growers. Clarification of the optimum level of nitrogen is required. If excessive nitrogen does have these negative effects, it would be useful to know whether there are particular periods during the year when nitrogen can be manipulated to increase growth without the plants suffering adversely in other ways.

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The overall aim of the project was to develop a strategy for applying nitrogen which achieves maximum yield without negative effects on fruit quality, storability, flower initiation and frost sensitivity. The effects of increasing or decreasing nitrogen levels during three critical phases of growth (early spring growth, fruiting and autumn flower initiation) have been tested. Throughout the duration of the project, the growth, yield and fruit development was recorded in a number of ways to monitor the effect of these treatments.

Materials and methods

The project began in April 2012 and concluded in October 2015. It aimed to address two objectives:

1. Testing the effect of three constant nitrogen levels on growth and yield.
   March 2012-October 2012
2. Examining the effect of timing the increase and decrease of nitrogen feed levels during three phases of growth: early spring growth, fruiting and autumn flower initiation.
   October 2012- October 2015

The project ran at FAST LLP, Brogdale Farm, Faversham, Kent. Three year old blueberry bushes (cvs. Duke and Aurora) were sourced from Hall Hunter Partnership (HHP) in 25L pots and established on site on 6 March 2012. The cv. Duke was sourced from Heathlands Farm, Wokingham and the cv. Aurora from Tuesley Farm, Milford. Plants were selected for uniformity: for cv. Duke the plants were required to have three-five main structural branches and for cv. Aurora plants with two-three main structural branches were selected.

The cv. Duke plants were placed on black Mypex floor covering in a Spanish Tunnel. The cv. Aurora plants were placed outside on black Mypex floor covering in line with commercial practice during 2102 to 2014. In 2015 cv. Aurora plants were protected after flowering.

Objective 1 - March 2012 - October 2012: The effect of constant nitrogen concentrations throughout the year

From March to October 2012 plants were supplied with different feed solution treatments: 60mg/L N, 120mg/L N and 180mg/L N (70% ammonium nitrogen and 30% nitrate nitrogen). Ninety plants of each variety were arranged in a randomised block design with six blocks per treatment. Irrigation was supplied to achieve a target of 60% soil moisture whilst maintaining EC within set limits.

Shoots were labelled and length recorded monthly from March to October 2012 to determine whether the nitrogen treatments stimulated different growth rates. Fruit were harvested weekly and the number and weight recorded for each plot. Fruit Brix° was recorded from 20 fruit per plot at two events during the cropping period. Shelf life was also assessed.

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Objective 2 - October 2012 - October 2015: The effect of nitrogen applications at three specific growth stages

A separate batch of 252 plants of each cultivar were used for the nitrogen timing treatments. These were sourced from HHP in March as stated above and were grown at Brogdale for four months (April to August 2012) at 120mg/L. On 15 August 2012, the first nitrogen regimes started with the application of the autumn treatments. The final nitrogen treatments were changed in summer 2015. Timings were based on specific growth stages.

The plants were arranged in a randomized block design with six plots per treatment and seven plants per plot (apart from Treatments 8 and 9 which had four plants). Each of the three nitrogen regimes had a separate irrigation line which enabled plants to be switched to the relevant nitrogen treatment at the correct stage within the season outlined below in Figure 2. Switching dates varied according to the season (see Table 1).

Nitrogen treatments

Autumn High - Nitrogen level of 180mg/L was applied from the end of harvest until 90% leaf fall and then 120mg/L was applied from bud break until the end of harvest.

Autumn Low - A nitrogen level of 60mg/L was applied from the end of harvest until 90% leaf fall and then 120mg/L was applied from bud break until the end of harvest.

Spring High - A nitrogen level of 120mg/L was applied from the end of harvest until 90% leaf fall. 180mg/L was then applied from bud break until first green fruit and then decreased again to 120 mg/L until the end of harvest.

Spring Low - A nitrogen level of 120mg/L was applied from the end of harvest until 90% leaf fall. 60mg/L was then applied from bud break until first green fruit and then increased again to 120mg/L until the end of harvest.

Summer High - A nitrogen level of 120mg/L was applied from the end of harvest until 90% leaf fall and from bud break until first green fruit. This was then increased to 180mg/L from first green fruit until the end of harvest.

Summer Low - A nitrogen level of 120mg/L was applied from the end of harvest until 90% leaf fall and from bud break until first green fruit. This was then reduced to 60mg/L from first green fruit to the end of harvest.

Medium - A standard nitrogen concentration of 120mg/L was applied from the end of harvest until 90% leaf fall and then from bud break until end of harvest.

Low – A nitrogen concentration of 60mg/L was applied from the end of harvest until 90% leaf fall and then from bud break until end of harvest.

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High - A nitrogen concentration of 180mg/L was applied from the end of harvest until 90% leaf fall and then from bud break until end of harvest.

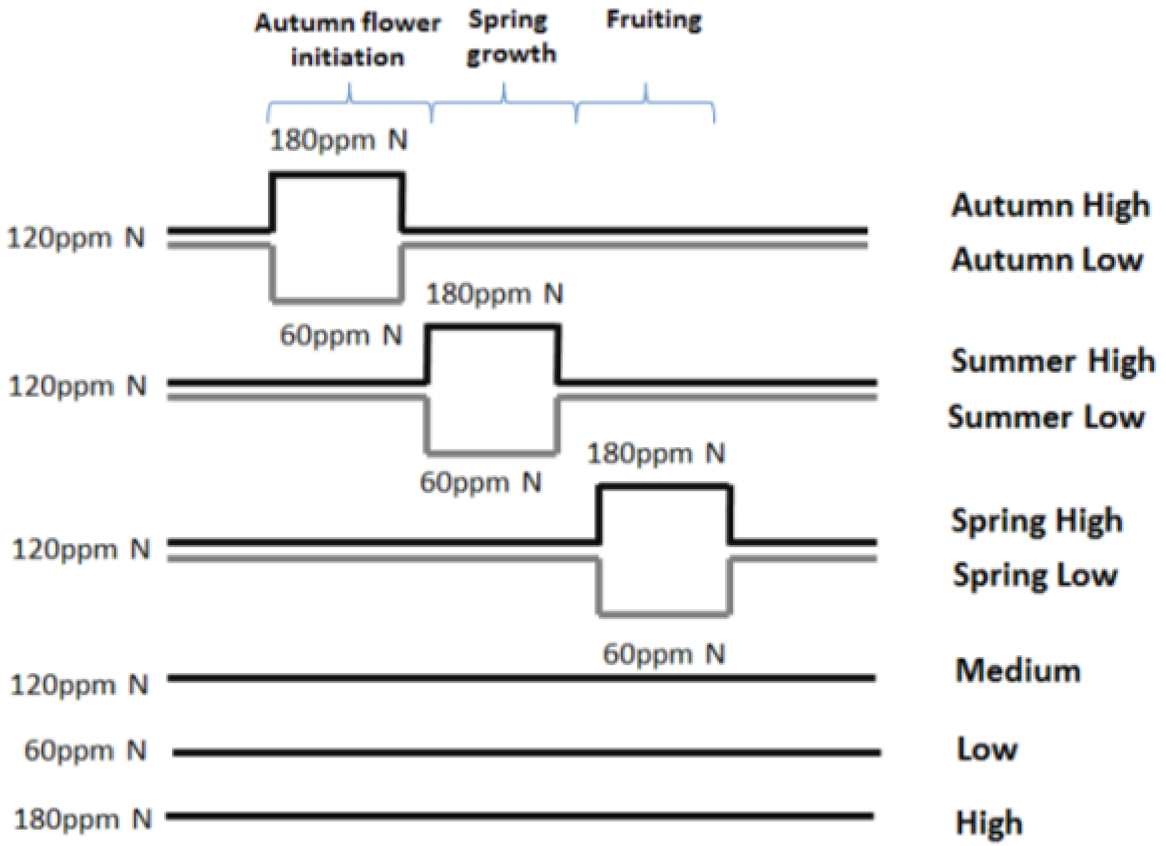

Figure 2. The nitrogen regimes which were applied in Objective 2 of the project.

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Table 1. The timing of changes in the nitrogen regime for 2013 to 2105.

Growth period and year	cv. Aurora	cv. Duke
Autumn flower initiation 2013	12 September- 28 November	12 September- 28 November
Spring growth 2014	28 March- 27 May	28 March- 19 May
Fruiting 2014	27 May- 29 September	19 May- 22 July
Autumn flower Initiation 2014	29 September 17 December	22 July to 5 December
Spring growth 2015	26 February to 22 June	26 February to 26 May
Fruiting 2015	22 June to 7 October	26 May to 6 August

For each treatment, growth, cropping and plant nutrition assessments were made. These assessments began in 2013 with the exception of the growth measurements from the Autumn High and Autumn Low treatments, which began in autumn 2012. The assessments made included:

Growth Shoot growth was measured from labelled branches at the end of each of the three nitrogen application timings – green fruit, post-harvest and 90% leaf fall.

Cropping Fruit from each treatment was harvested by block, a representative sample taken and graded into Class I, Class II and Waste fruit. Each category was then counted and weighed to determine the effect of treatment on yield and overall fruit quality.

Storage A sub sample of both cvs. Aurora and Duke were placed into an air store at 2ºC at Brogdale and assessed fortnightly until deemed non-marketable. Assessments were as follows:

- Percentage fruit dehydration
- Weight loss during storage
- Fruit collapse
- Incidence of *Botrytis*

- In addition, a sample of Duke was also placed into a CA store at Hall Hunter Partnership on the 25 July 2014 and assessed after four weeks for overall marketability.

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Flower initiation	The percentage of floral buds was calculated and the average number of flowers per bud recorded.
Percentage bud break	The percentage of buds breaking from each treatment was assessed.
Plant nutrition	Leaf samples were taken and analysed for nutrient content. Irrigation inputs and outputs were also monitored.

Pesticide applications and biological control 2015

An application of the insecticide thiacloprid (Calypso) was made in the middle of May in response to increasing levels of aphid and honeydew secretions in both varieties. Two weeks later the cv. Duke required an application of the insecticide lambda-cyhalothrin (Hallmark) for the same reasons. A further application of Calypso mixed with the insecticide pirimicarb (Aphox) was made in the middle of June to the cv. Duke where more aphid and sooty mould could be seen.

In early July an increase in the number of Light Brown Apple Moth (LBAM) larvae was observed in cv. Aurora and an application of the insecticide indoxacarb (Steward) was applied. At the end of July moth counts in the LBAM traps increased sharply so the ovicidal insecticide diflubenzuron (Dimilin) was applied together with Hallmark to target the larvae.

Hallmark was applied again in August on cv. Aurora for Spotted Wing Drosophila (SWD). A follow up spray of the insecticide spinosad (Tracer) was applied for SWD in September on the cv. Aurora.

Nematop (*Heterohabditis bacteriophora)* was applied through drip irrigation in August and October to control vine weevil larvae. These various applications are recoded in Table 2.

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Table 2. Pesticide applications and biological control used throughout the 2015 season. The variety which received treatment is indicated in the table.

Date	Product name	Active ingredient	Application rate	Approval status	cv. Aurora	cv. Duke
15/05/2015	Calypso	Thiacloprid	250ml/Ha	This product has an Extension of Authorisation for Minor Use (EAMU) for use on this crop: 2014/2133 and 2014/2141	✓	✓
29/05/2015	Hallmark	Lambda-cyhalothrin	17.5ml/100L	This product has an EAMU for use on this crop: 2014/0521		✓
12/06/2015	Calypso	Thiacloprid	250ml/Ha	This product has an EAMU for use on this crop: 2014/2141		✓
	Aphox	Pirimicarb	280g/Ha	This product has an EAMU for use on this crop: 2010/2319		✓
10/07/2015	Steward	Indoxocarb	170g/ha	This product has an EAMU for use on this crop: 2013/0988	✓	
31/07/2015	Dimilin Flo	Diflubenzuron	0.3L/2000L	This product has an EAMU for use on this crop: 2006/0573	✓	
	Hallmark	Lambda-cyhalothrin	17.5ml/100L	This product has an EAMU for use on this crop: 2014/0521	✓	
14/08/2015	Nematop	*Heterohabditis bacteriophora*	133,334 per plant	N/A	✓	✓
14/08/2015	Hallmark	Lambda-cyhalothrin	17.5ml/100L	This product has an EAMU for use on this crop: 2014/0521	✓	
11/09/2015	Tracer	Spinosad	200ml/ha	This product has an EAMU for use on this crop: 2015/0775	✓	
10/10/2015	Nematop	*Heterohabditis bacteriophora*	133,334 per plant	N/A	✓	✓

Data for cvs. Duke and Aurora have been analysed separately.

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Results 2015

Flower initiation and bud break

Frost damage

The 2014/2015 winter in Kent was very mild. The decline to sub-zero temperatures was very gradual. The first date the temperature fell below 0ºC was on 25 November 2014. The first date the temperature fell below -1ºC was on 14 December 2014. The lowest temperatures were in January (-3.8ºC). December 2014 and January 2015 had nine days of temperatures below zero. Buds of certain varieties, when fully dormant, can survive temperatures of -40ºC (Gough, 1994) and so the plants suffered very little frost damage.

Table 3. Minimum average and lowest temperatures.

Month	Average minimum ºC	Lowest minimum ºC	No of days min temp <0ºC
Oct-14	10.65	2.6	0
Nov-14	6.41	-0.7	1
Dec-14	3.02	-2.7	9
Jan-15	2.03	-3.8	9
Feb-15	1.76	-2.6	4
Mar-15	3.21	-2	5
Apr-15	4.96	-0.7	1

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Percentage bud break

The number of buds along the length of new shoots were counted and categorised. The percentage bud break along new shoots was calculated, together with the mean for each treatment. The assessments were carried out on 1 April 2015 for cv. Duke and on 1 May 2015 for cv. Aurora. Cv. Aurora exhibited higher percentage bud break than cv. Duke.

There were no significant differences between the percentage of bud break across treatments for cv. Aurora (P=0.56) which had between 85% and 89% bud break. Summer Low nitrogen treatment had the highest rate of bud break. Spring Low and Summer High had the lowest rate of bud break. See Figure 3 below.

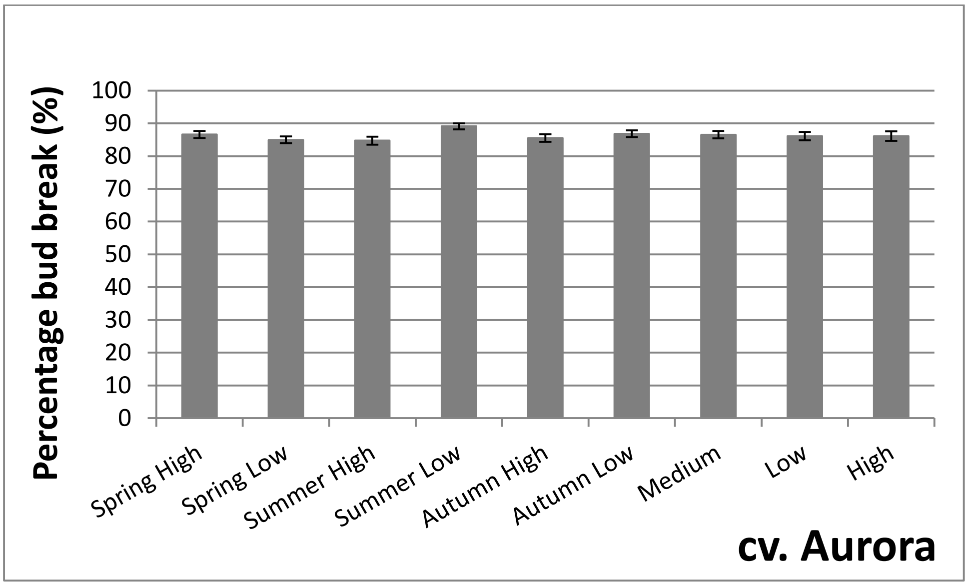

Figure 3. The effect of nitrogen treatment on the percentage bud break for cv. Aurora. Standard error bars are shown.

There were no significant differences between the percentage bud break across treatments for cv. Duke (P=0.603) which had between 65% and 72% bud break. Spring High and Autumn Low nitrogen treatments had the highest rate of bud break. Spring Low had the lowest rate of bud break. See Figure 4 below.

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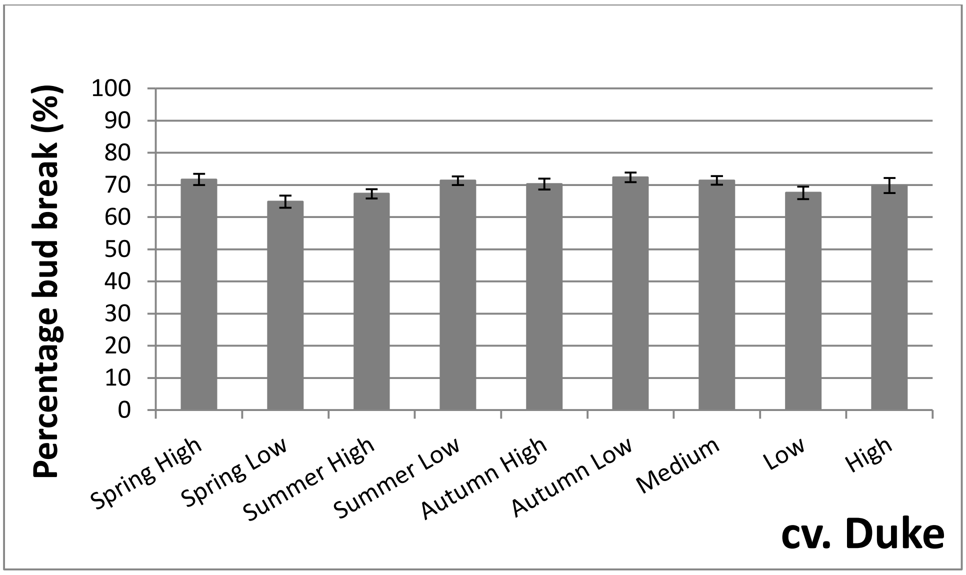

Figure 4. The effect of nitrogen treatment on the percentage bud break for cv. Duke. Standard error bars are shown.

Floral bud production

The proportion of floral buds in relation to the total bud number was recorded from three shoots per bush, the percentage and average per treatment calculated. This was assessed on 1 April 2015 for cv. Duke and on 1 May 2015 for cv. Aurora. Cv. Aurora exhibited higher percentage floral buds than cv. Duke. There were no statistically significant differences between treatments in cv. Aurora (P=0.368). Percentages ranged from 53% (Autumn High) and 58% (Summer Low, Autumn Low and Medium nitrogen).

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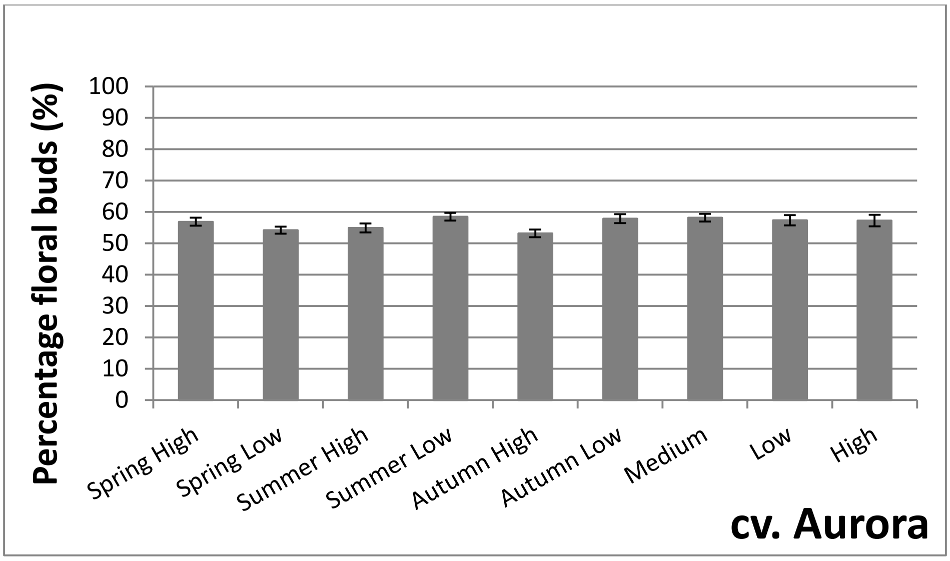

Figure 5. The effect of nitrogen treatment on the percentage of floral buds for cv. Aurora. Standard error bars are shown.

There were no statistically significant differences between treatments in cv. Duke (P=0.719). Percentages ranged from 40% (Spring Low and Summer High) to 46% (High nitrogen).

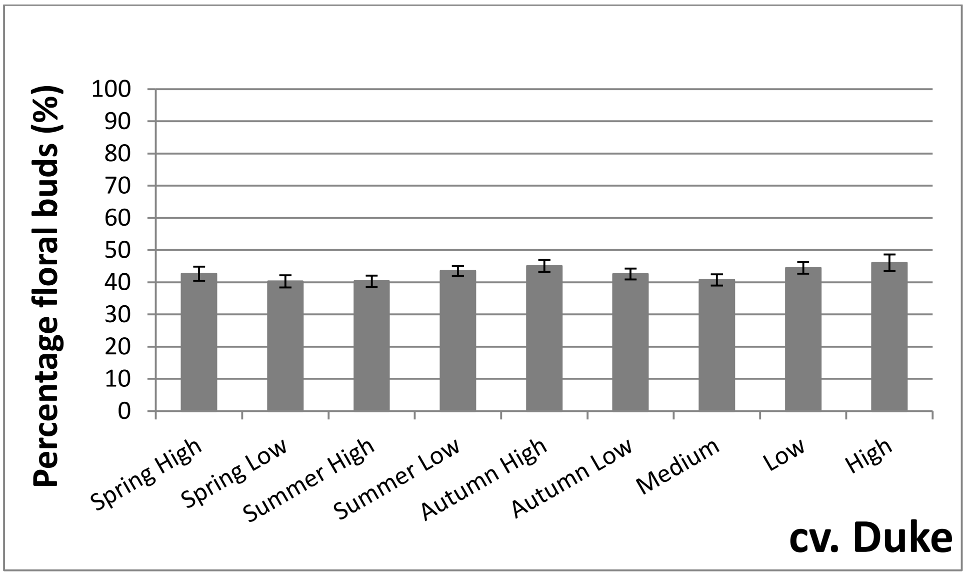

Figure 6. The effect of nitrogen treatment on the percentage of floral buds for cv. Duke. Standard error bars are shown.

Flower number

The number of flowers per bud of a representative sample for each treatment was assessed and the average calculated. This was assessed on 21 April and 21 May 2015 for cvs. Duke and Aurora respectively. Cv. Aurora exhibited slightly higher flower numbers per bud than cv. Duke.

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No significant differences were found between treatments for cv. Aurora (P=0.635). There was little variation in the average number per flower cluster. Lowest flower numbers per bud were for Medium N treatment (6.3). Highest flower numbers per bud were for Autumn High (6.9).

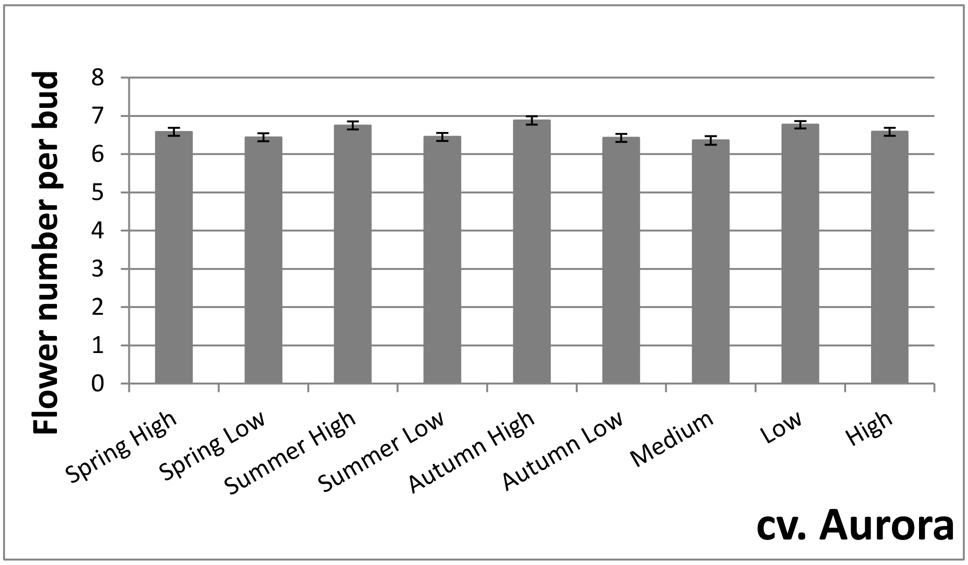

Figure 7. The effect of nitrogen treatment on the flower number per cluster for cv. Aurora. Standard error bars are shown.

There were no statistically significant differences between treatments for cv. Duke (P=0.056). There was little variation in the average number per flower cluster. Lowest flower numbers per bud were for High N treatment (5.7). Highest flower numbers per bud were for Low N treatment (6.4).

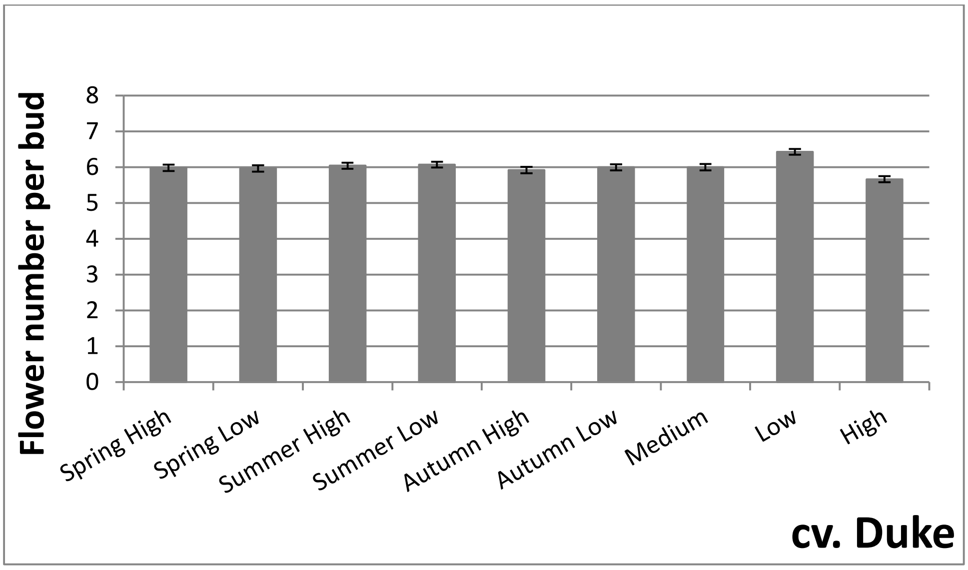

Figure 8. The effect of nitrogen treatment on the flower number per cluster for cv. Duke. Standard error bars are shown.

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Cropping

Yield

Fruit from all bushes within the plots were picked and the total yield recorded. A representative sample of fruit from each of the 54 plots was taken and the berries graded into Class I, Class II or waste fruit (weight and number).

Figure 9. Sampling and grading methods.

Cv. Aurora

Cv. Aurora was picked on two occasions – 3/4 September and 28/29 September.

There were no significant differences between treatments for total yield (Class 1, Class 2 and waste) (P=0.617). See Figure 10. Average total yield per bush was 1.8kg. Individual treatments ranged between 1.5kg (Low) and 2.1kg (Autumn Low).

There was no significant effect on total yields by treatment on the first harvest on 3 September (P=0.116). See Figure 11.

There was no significant effect on total yields by treatment on the second harvest on 28 September (P=0.205).

There were no statistical differences found between treatments for percentage Class1 fruit (see Table 4).

There were statistical differences found between treatments for Class 2 fruit namely:

- Low N was significantly different to all other treatments except Summer Low.
- Summer Low was significantly different to Summer High, Autumn Low, High and Medium.
- Spring Low was significantly different to Medium.
- Medium was significantly different to Spring Low, Summer Low and Low.

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There were no statistical differences found between treatments for waste fruit.

There were no statistical differences found between treatments for number of Class 1 fruit per bush.

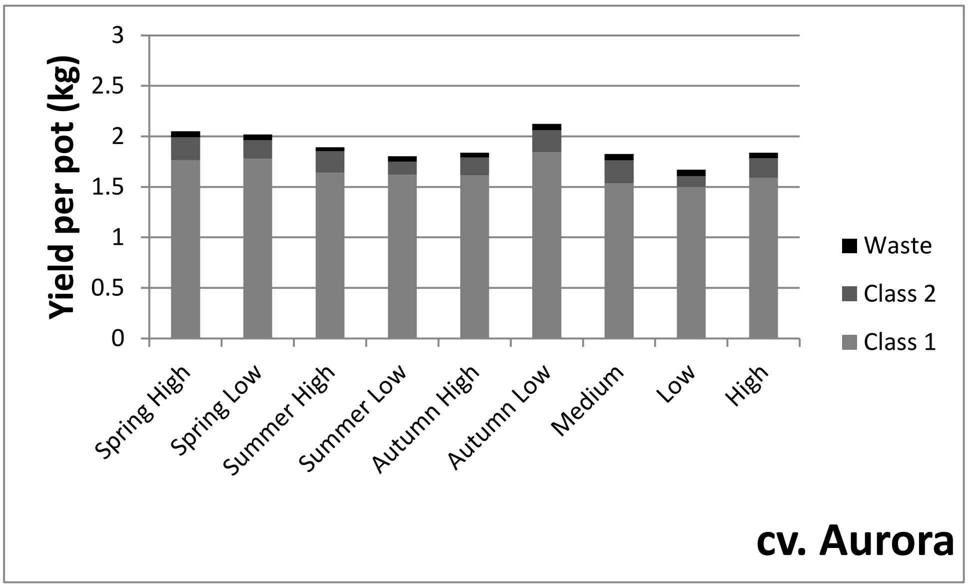

Figure 10. The effect of nitrogen treatment on the average yield per bush (kg) for cv. Aurora. The shading of bars represents the different quality classes.

Table 4. The effect of nitrogen treatment on the percentage fruit categorised in each quality class for cv. Aurora (average of both harvests). Letters show homogenous groups indicating statistically significant results.

Treatment	Class 1 yield per bush %	Class 2 yield per bush %	Waste yield per bush %
Spring High	88	9 **bcd**	3
Spring Low	89	8 **bc**	3
Summer High	89	10 **cd**	2
Summer Low	89	7 **ab**	3
Autumn High	89	9 **bcd**	2
Autumn Low	88	9 **cd**	3
Medium	86	11 **d**	3
Low	90	6 **a**	4
High	88	10 **cd**	3
P value	*0.104*	*0.0009*	*0.325*

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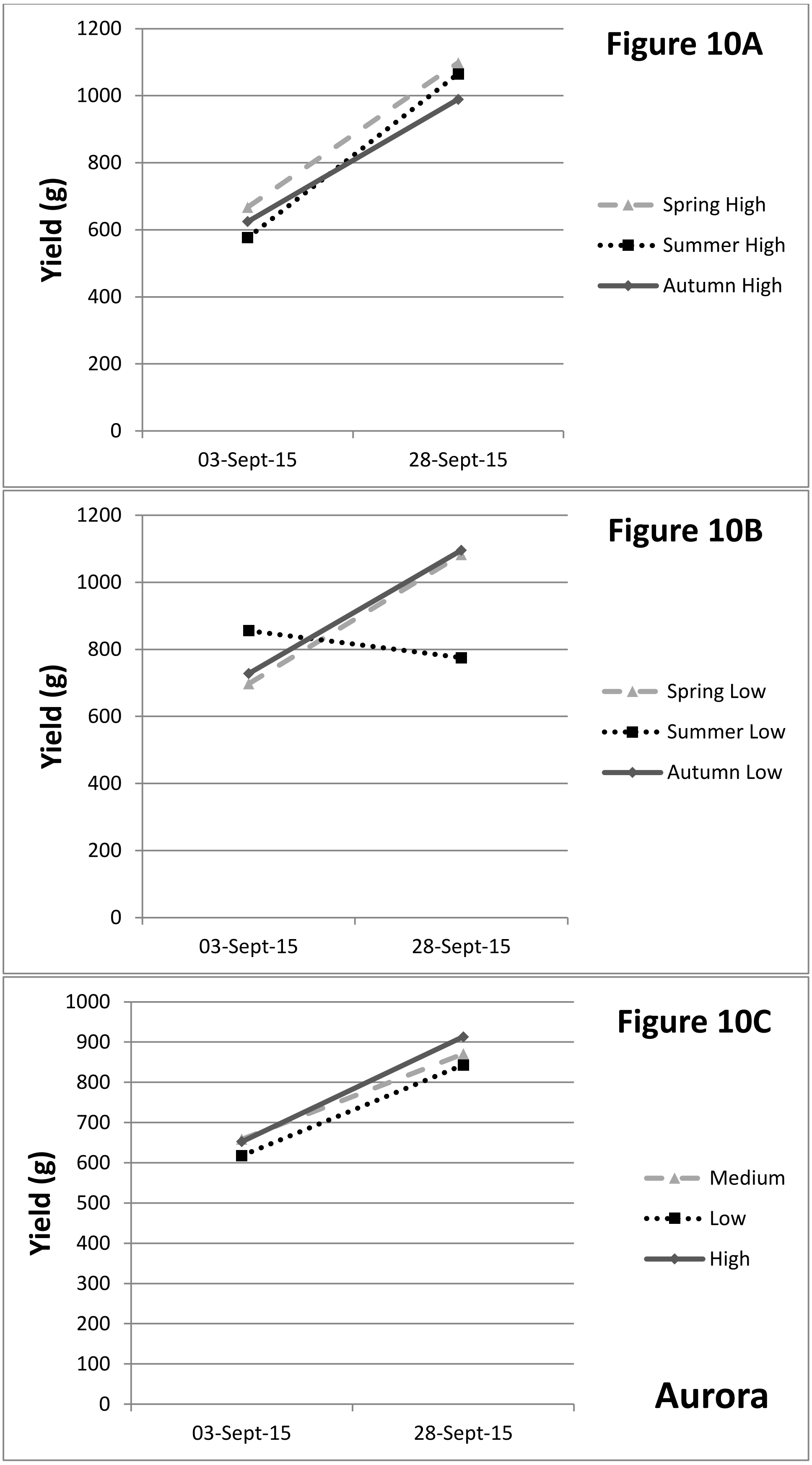

Figure 11. The effect of nitrogen treatment on the Class 1 yield profile per bush for cv. Aurora.

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Cv. Duke

Cv. Duke was picked on 6/7 and 21 July 2015.

There were no significant differences between treatments for total yield (Class 1, Class 2 and waste) (P=0.636). See Figure 12. Average total yield per bush was 2.3kg. Individual treatments ranged between 2.1kg (High N) and 2.7kg (Low N).

There was no significant effect on total yields by treatment on the first harvest on 6/7 July (P=0.792). See Figure 13.

There was no significant effect on total yields by treatment on the second harvest on 21 July (P=0.859).

There were no statistical differences found between treatments for Class 1 fruit (see Table 5).

There were no statistical differences found between treatments for Class 2 fruit.

There were no statistical differences found between treatments for waste fruit.

There were no statistical differences found between treatments for average number of Class 1 fruit per bush.

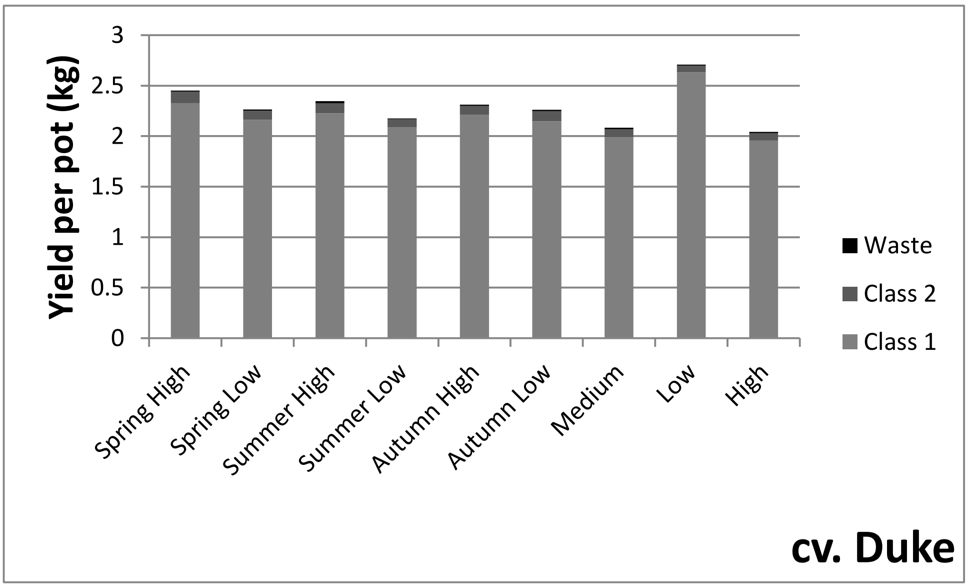

Figure 12. The effect of nitrogen treatment on the average yield per bush (kg) for cv. Duke. The shading of bars represents the different quality classes.

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Table 5. The effect of nitrogen treatment on the amount of fruit categorised in each quality class (%) for cv. Duke.

Treatment	**Class 1 yield per bush %**	**Class 2 yield per bush %**	**Waste yield per bush %**
Spring High	90	9	1
Spring Low	92	7	1
Summer High	90	9	1
Summer Low	91	8	1
Autumn High	91	8	1
Autumn Low	92	8	1
Medium	91	9	1
Low	94	5	1
High	92	7	1
P value	*0.313*	*0.335*	*0.840*

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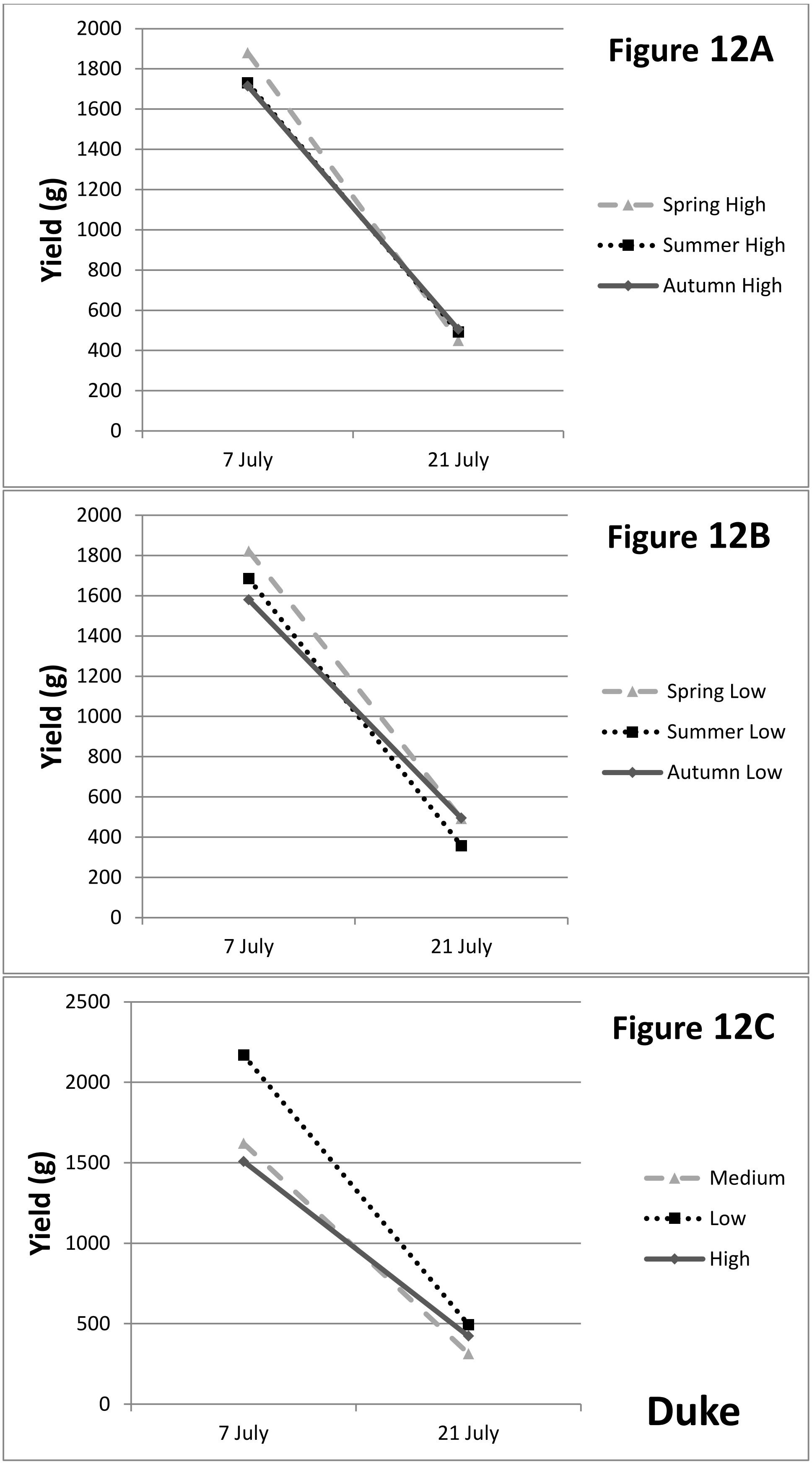

Figure 13. The effect of nitrogen treatment on the Class 1 yield profile per bush for cv. Duke.

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Berry weight

Average berry weight (g) of Class 1 fruit for each treatment was calculated using fruit from the representative samples collected at each harvest date.

There was no statistical significance between treatments for cv. Aurora average Class 1 berry weight (g) (see Figure 14) (P=0.237). There was very little variation in average Class 1 berry weight – Summer Low and Low had the greatest weight at 1.7g whilst all the other treatments were 1.6g.

There were statistically significant differences between treatments for cv. Duke average Class 1 berry weights (see Figure 15) (P=0.0001). Low N had an average berry weight of 1.8g, which was significantly higher than all the other treatments whose average weights were 1.5g.

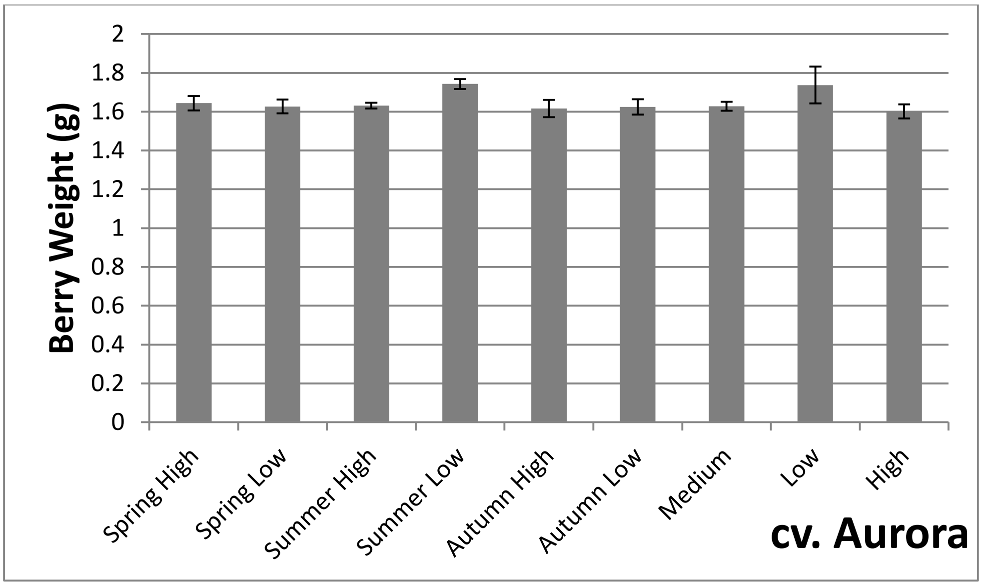

Figure 14. The effect of nitrogen treatment on the average Class1 berry weight for cv. Aurora. Standard error bars are shown.

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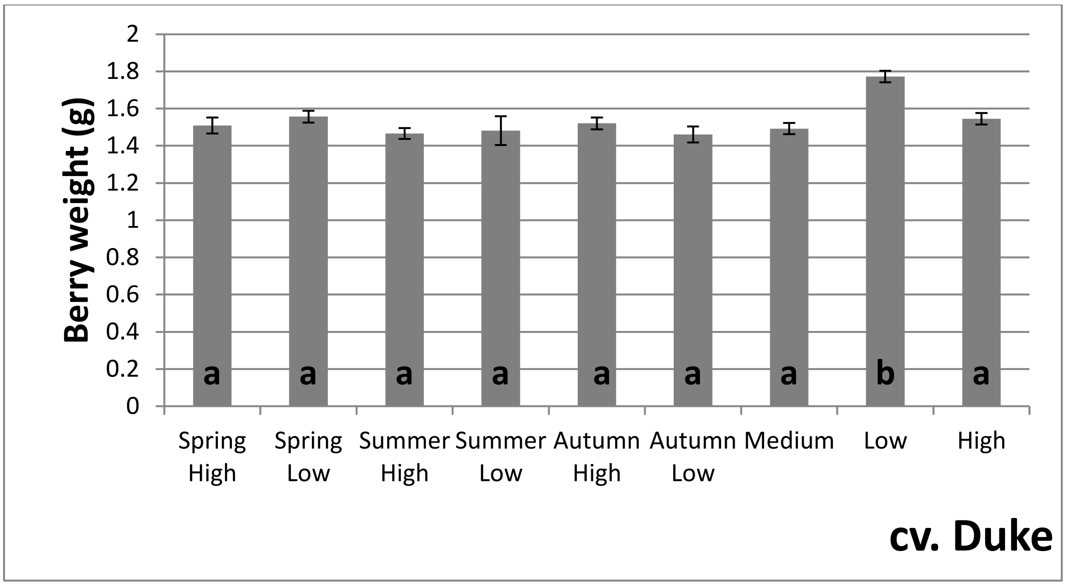

Figure 15. The effect of nitrogen treatment on the average Class 1 berry weight for cv. Duke. Standard error bars are shown and the letters show significant differences between treatments.

Fruit size

The average fruit size (mm) was calculated for each treatment after measuring 25 Class 1 fruit from each treatment plot.

Average Class 1 fruit size (mm) results were not statistically significant for cv. Aurora (P=0.891). See Figure 16. Average fruit size was around 1mm lower than for cv. Duke and ranged from 13.5mm (Autumn High) to 14.0mm (Low).

Average Class 1 fruit size (mm) results were not statistically significant for cv. Duke (P=0.095). See Figure 17. Average fruit size was around 1mm higher than for cv. Aurora and ranged from 14.1mm (Medium) to 15mm (Spring Low and Summer Low).

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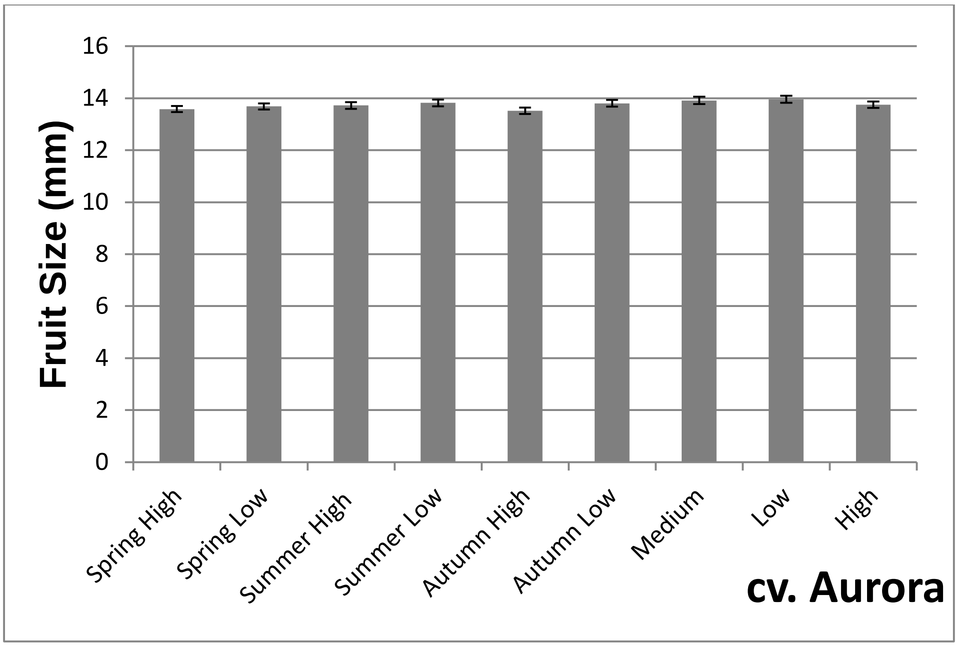

Figure 16. The effect of nitrogen treatment on the average Class 1 fruit size for cv. Aurora. Standard error bars are shown.

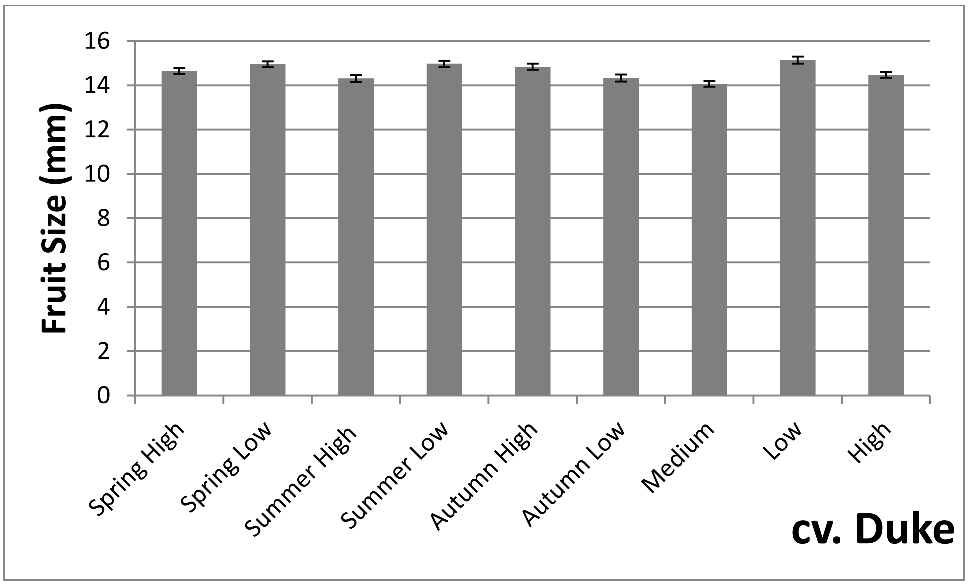

Figure 17. The effect of nitrogen treatment on the average Class 1 fruit size for cv. Duke. Standard error bars are shown.

Total soluble solids (Brix°)

A random bulk sample of ripe fruit was taken from each treatment and 25 fruit assessed for Brix° at the first harvest for each variety: cv. Duke on 7 July and cv. Aurora on 3 September.

The mean Brix° ranged from 9.64° to 10.74° for cv. Aurora with little variation between treatments and no significant statistical differences (see Figure 18).

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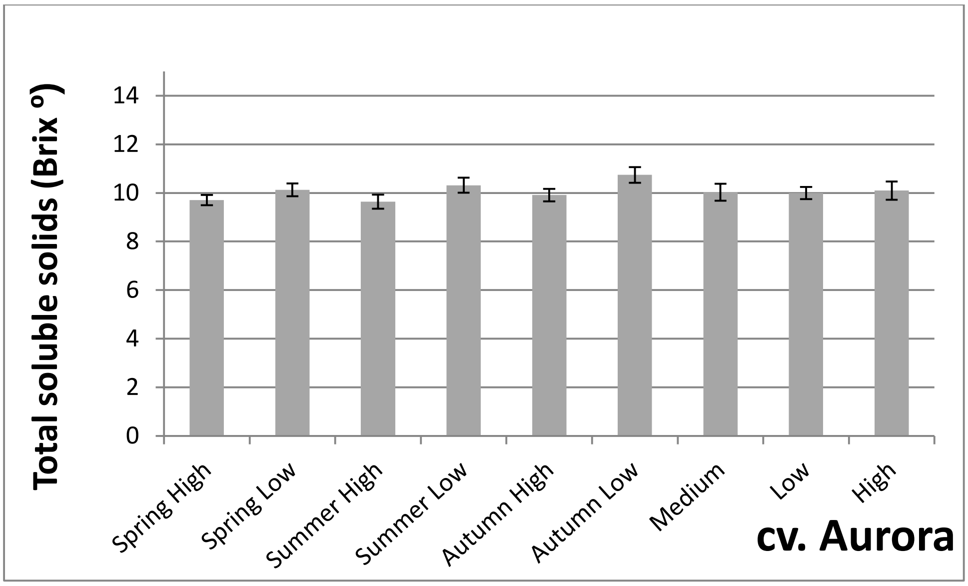

Figure 18. The effect of nitrogen treatment on the total soluble solids (Brixº) of cv. Aurora. Standard error bars are shown.

Brixº levels were higher for cv. Duke fruit (see Figure 19). The highest value of 13.88° was for the Medium treatment. The lowest Brixº of 11.36° was from the Low treatment. There were significant differences between treatments (P=0.0036). Medium was significantly different from Autumn Low, Summer Low and Low. Summer High and Spring High were significantly different from Summer Low and Low. High, Autumn High and Spring Low were significantly different from Low.

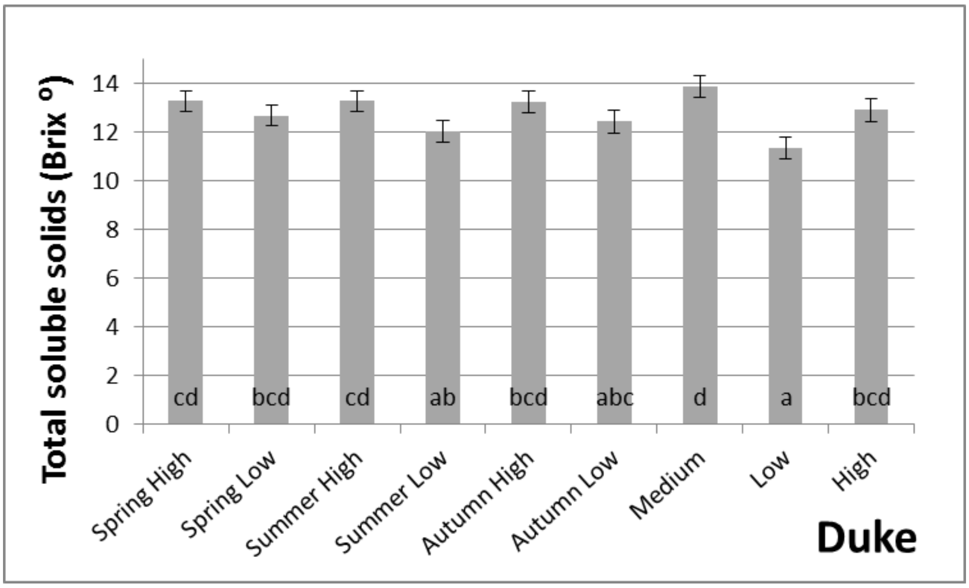

Figure 19. The effect of nitrogen treatment on the total soluble solids (Brixº) of cv. Duke. Standard error bars are shown. The letters indicate homogenous groups and show significant differences between treatments.

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Fruit storage potential

The effect of nitrogen treatment on storage potential was tested by placing a sample of 150g Class 1 fruit into a 2°C air cold store at FAST LLP, Brogdale and assessed fortnightly for eight weeks. Cv. Duke samples were placed into store on 8 July and cv. Aurora on 7 September 2015. Fruit was deemed to be non-marketable based on storage disorder symptoms namely dehydration, fruit collapse and *Botrytis*. Unmarketable was removed from the sample at each assessment. Since no CA stores were available/being closed at harvest time additional assessments were not possible in 2015.

Cv. Aurora

There were no significant differences in results for % non-marketable fruit (see Table 6). Cumulative losses between treatments after two weeks were similar (average 4%). Losses after four weeks ranged from 11% (Medium) and 17% (Summer Low). This trend continued through week 6 and at eight weeks Medium had the lowest losses at 37% and Summer Low had the highest losses at 53%.

There were no significant differences between treatments for % marketable fruit after two, four, six or eight weeks' storage assessment (see Figure 20). % Marketable fruit values were similar after two weeks (around 96%). % Marketable fruit at four weeks ranged from 83% (Summer Low) and 89% (Medium). The general trend continued through week 6 and at eight weeks Medium had the most marketable fruit remaining (63%) and Summer Low the least (47%).

There were no significant differences between treatments for % cumulative loss to dehydration fruit after two, four, six or eight weeks' storage assessment (see Figure 21). Greatest losses for all treatments occurred between weeks 6 and 8. Treatment Summer Low had the highest % cumulative loss to dehydration (26%) and High the lowest (16%).

There were no significant differences between treatments for % loss to collapse in fruit after two, four, six or eight weeks' storage assessment (see Figure 22). The % losses at week 8 were low, average of 6%. Treatment Summer High had the highest losses to fruit collapse (8%) and treatments Spring High, Spring Low and Low the lowest (5%).

There were no significant differences between treatments for % loss to *Botrytis* in fruit after two, four, six or eight weeks' storage assessment (see Figure 23). Losses to *Botrytis* increased more rapidly after week 2. By week 6 Medium had the lowest losses (8%) compared the average of all the other treatments (14%). After eight weeks' storage Medium had the lowest losses to *Botrytis* (13%) and High the highest (24%).

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Table 6. The effect of nitrogen treatment on the percentage sample considered non-marketable throughout storage (Aurora).

Treatment	Cumulative loss after 2 weeks (%)	Cumulative loss after 4 weeks (%)	Cumulative loss after 6 weeks (%)	Cumulative loss after 8 weeks (%)
Spring High	2	14	21	40
Spring Low	4	13	24	45
Summer High	3	12	25	50
Summer Low	4	17	27	53
Autumn High	3	13	23	48
Autumn Low	3	13	25	45
Medium	3	11	19	37
Low	4	14	25	43
High	4	13	25	47
P value	*0.608*	*0.719*	*0.807*	*0.381*

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Figure 19A

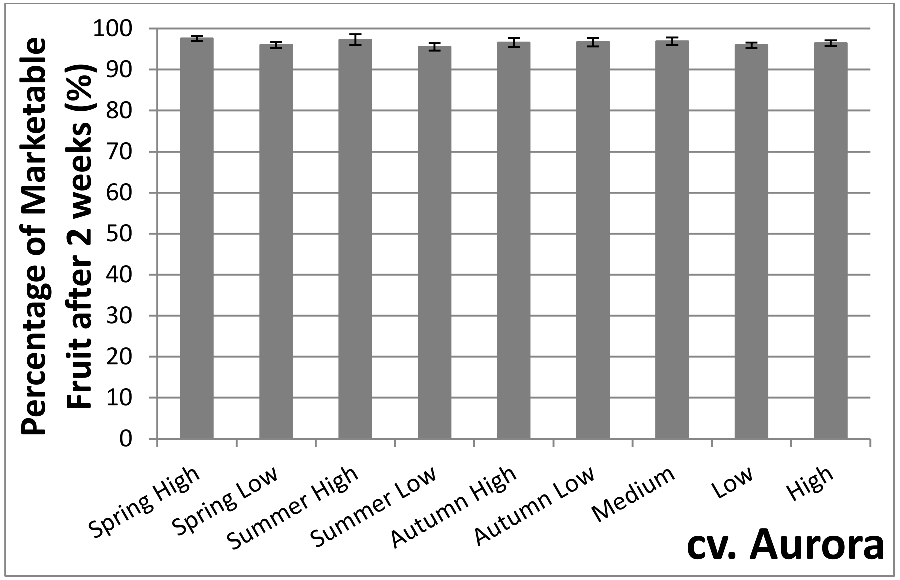

Figure 19C

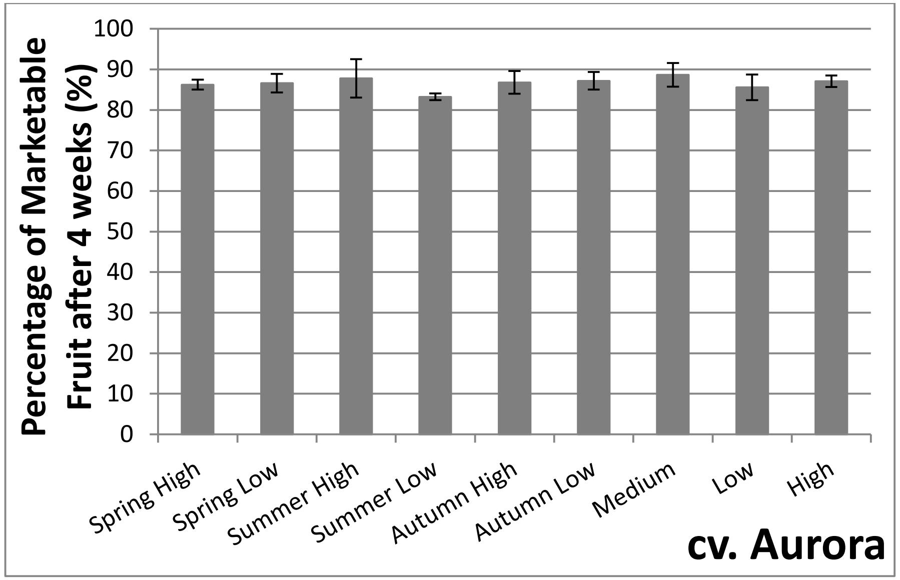

Figure 19B

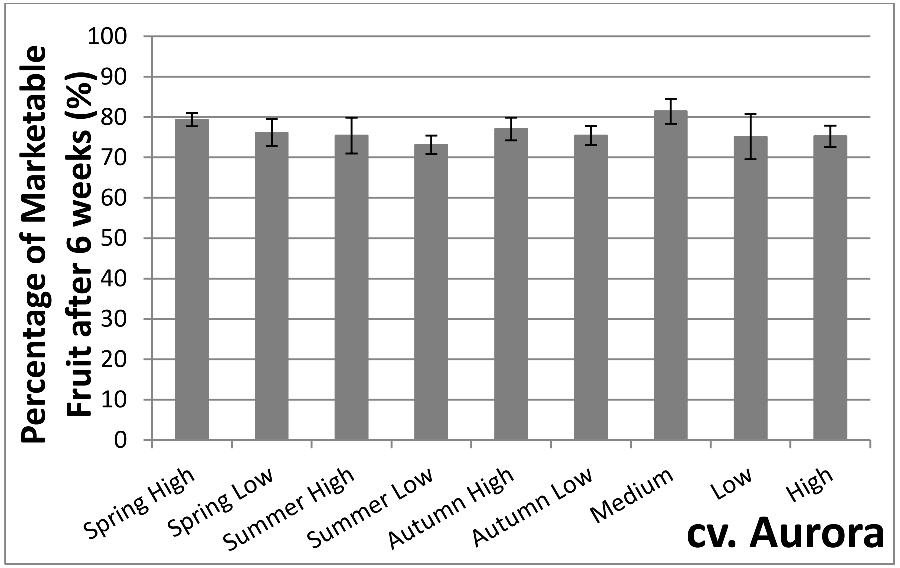

Figure 19D

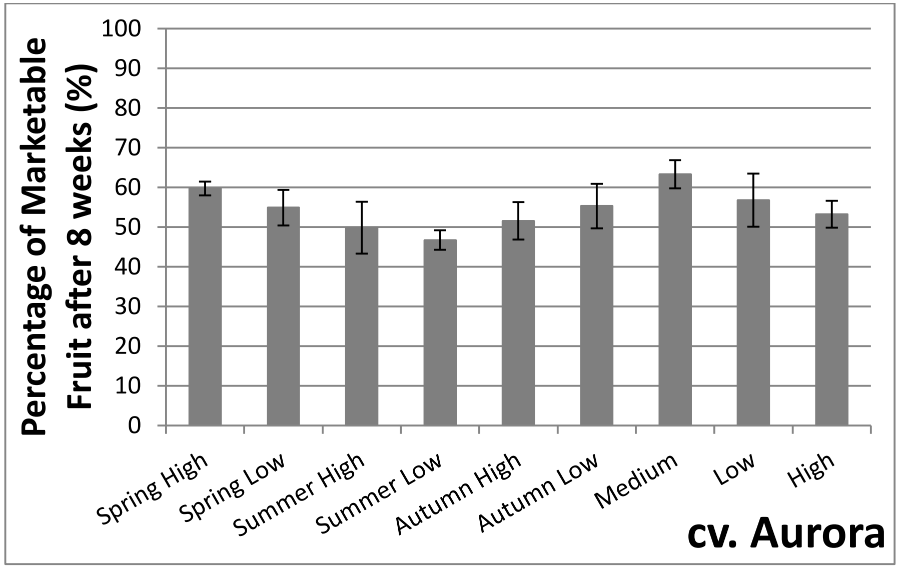

Figure 20. The effect of nitrogen treatment on the percentage of marketable fruit after two, four, six and eight weeks of cold storage for cv. Aurora. Standard error bars are shown.

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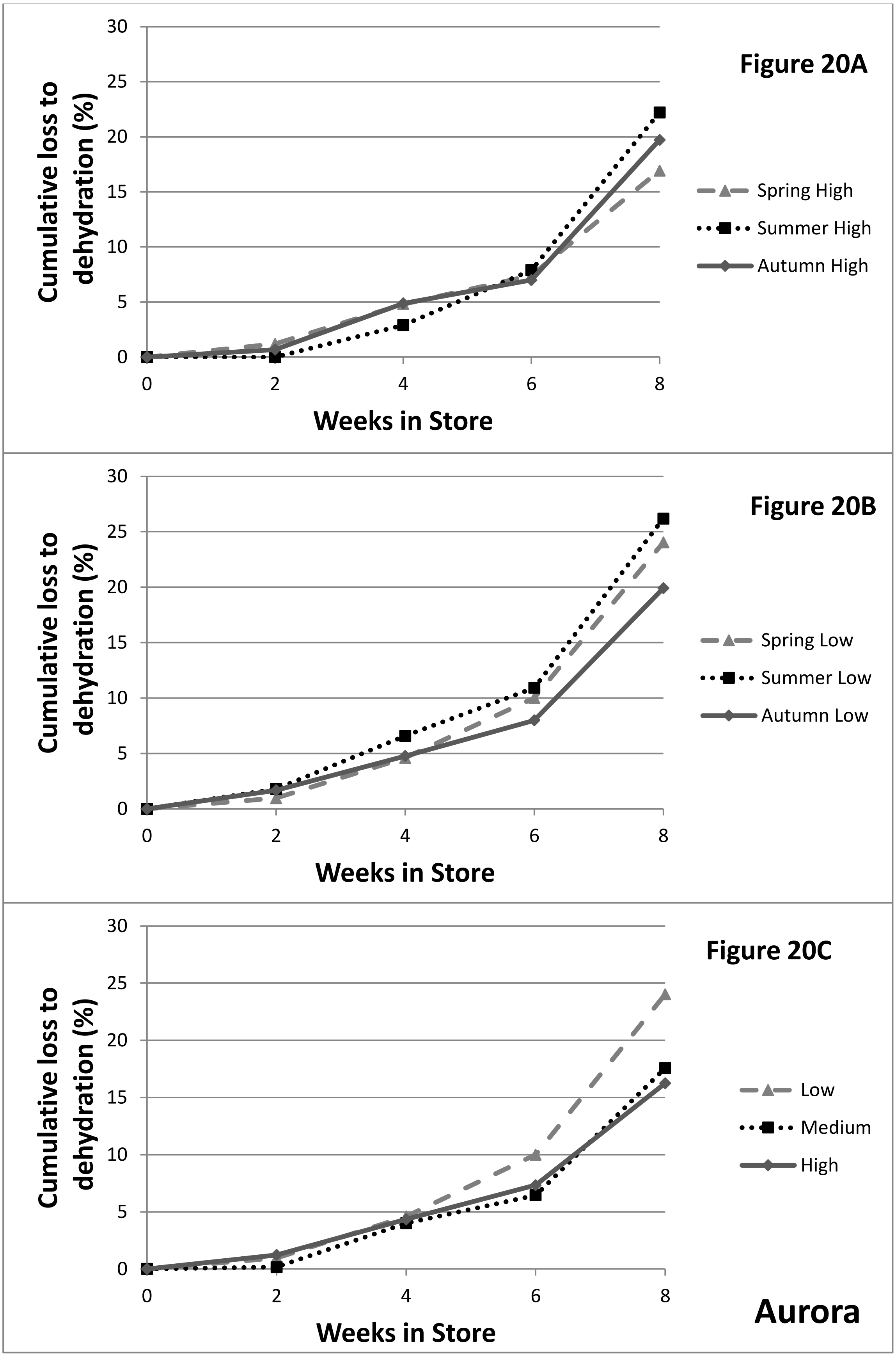

Figure 21. The effect of nitrogen treatment on the loss of storage samples due to fruit dehydration for cv. Aurora.

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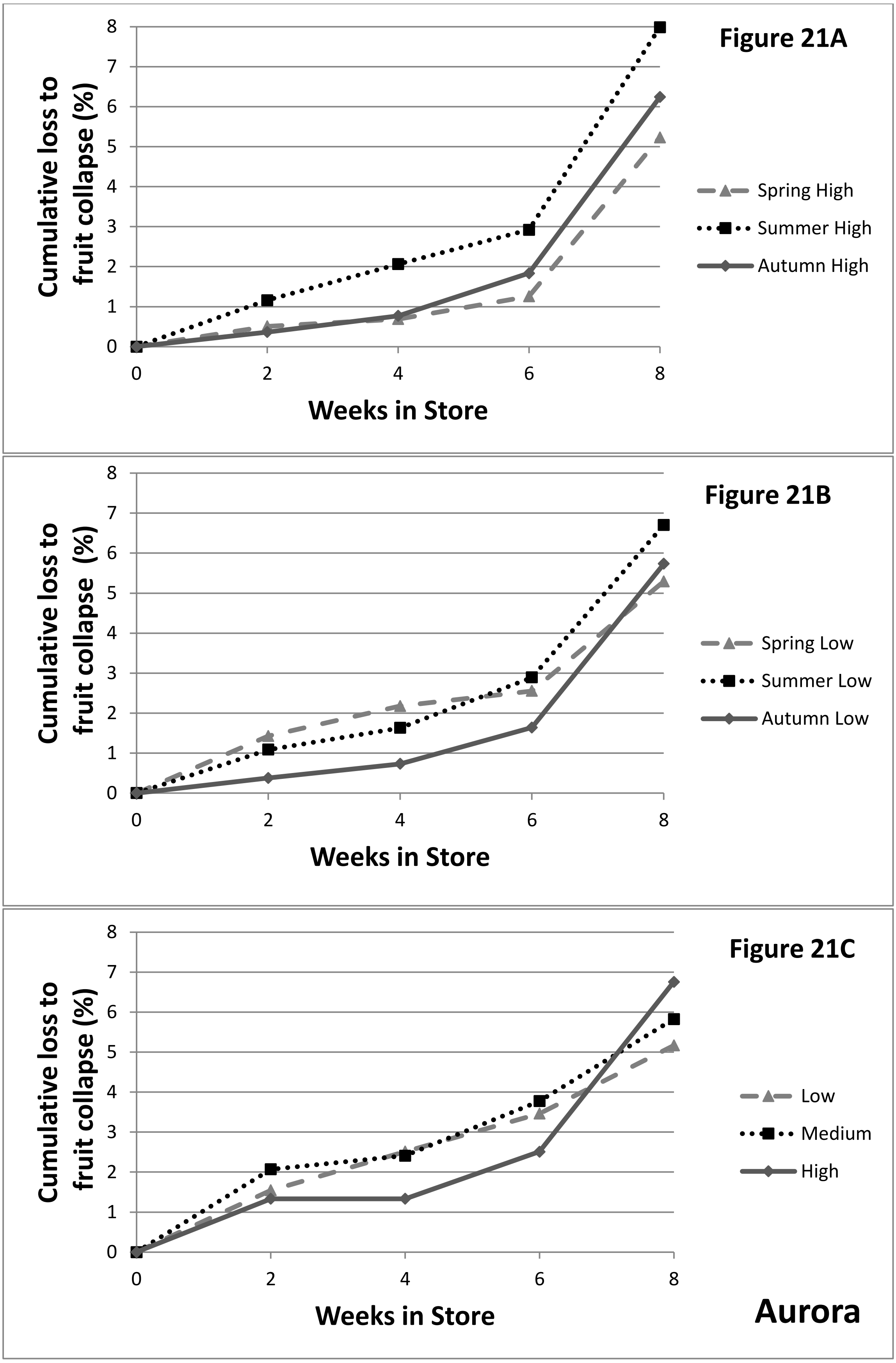

Figure 22. The effect of nitrogen treatment on the loss of storage samples due to fruit collapse for cv. Aurora.

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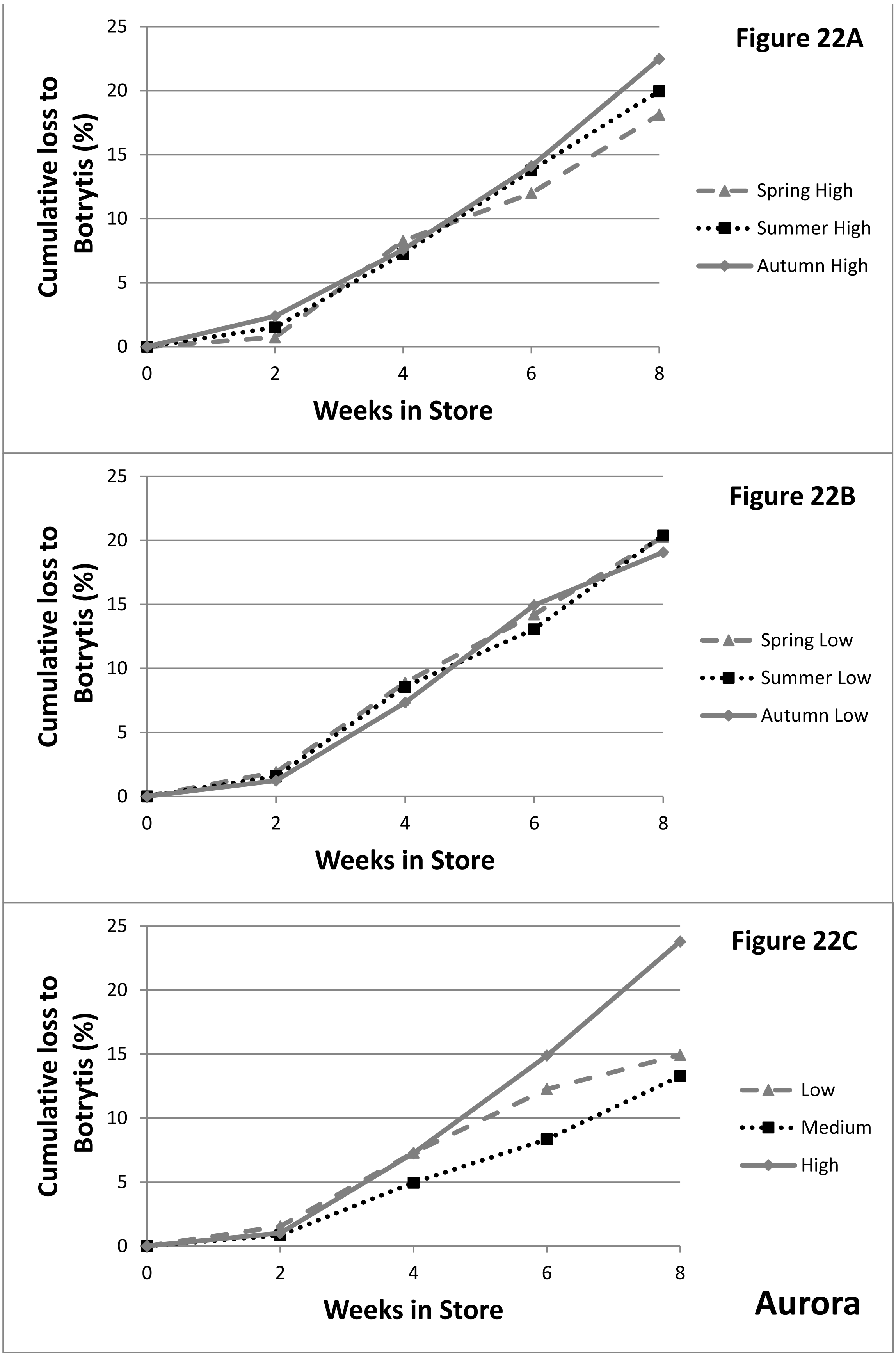

Figure 23. The effect of nitrogen treatment on the loss of cv. Aurora storage samples as a result of *Botrytis*.

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Cv. Duke

There were no statistically significant differences for % non-marketable fruit after two, four, six or eight weeks' storage (see Table 7). Highest cumulative losses after two weeks was for Autumn High (27%) and lowest for Low (15%). Greatest losses occurred between weeks 2 and 4. At eight weeks, all treatments had over 80% non-marketable fruit. Three treatments had non-marketable fruit of 92% (Spring High, Summer Low and Medium). Autumn Low had the least non-marketable fruit (87%).

There were no significant differences between treatments for % Marketable fruit after two, four, six or eight weeks' storage assessment (see Figure 24). At two weeks % marketable fruit values were above 80% except for Autumn High (73%) which also had the least marketable fruit through weeks 4 and 6. At eight weeks total losses were very high for all treatments. Autumn Low had the most marketable fruit remaining (13%). Spring High, Summer Low and Medium had the least marketable fruit remaining (8%).

There were no significant differences between treatments for % cumulative loss to dehydration fruit after two, four, six or eight weeks' storage assessment (see Figure 25). Greatest losses occurred between weeks 2 and 4 and between 6 and 8. At eight weeks, losses to dehydration were moderate. Treatment Summer High had the highest % cumulative loss to dehydration (20%) and Low the lowest (12%).

There were no significant differences between treatments for % loss to collapse in fruit after two, four, six or eight weeks' storage assessment (see Figure 26). % losses at week 8 were low with all treatments under 10% except Low (14%). Spring Low had the least losses to fruit collapse (5%).

There were no significant differences between treatments for % loss to *Botrytis* in fruit after two, four, six or eight weeks' storage assessment (see Figure 27). Incidence of *Botrytis* was high across all treatment with most rapid losses occurring between weeks 2 and 4. Spring Low, Autumn High and High had the highest losses at week 8 (69%). Autumn Low had the lowest losses (60%).

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Table 7. The effect of nitrogen treatment on the percentage sample considered non-marketable throughout storage (cv. Duke).

Treatment	Cumulative loss after 2 weeks (%)	Cumulative loss after 4 weeks (%)	Cumulative loss after 6 weeks (%)	Cumulative loss after 8 weeks (%)
Spring High	20	60	74	92
Spring Low	18	53	69	88
Summer High	18	55	68	88
Summer Low	18	60	76	92
Autumn High	27	61	77	91
Autumn Low	18	48	65	87
Medium	20	56	72	92
Low	15	43	67	89
High	19	57	75	91
P value	*0.615*	*0.392*	*0.688*	*0.866*

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Figure 23A

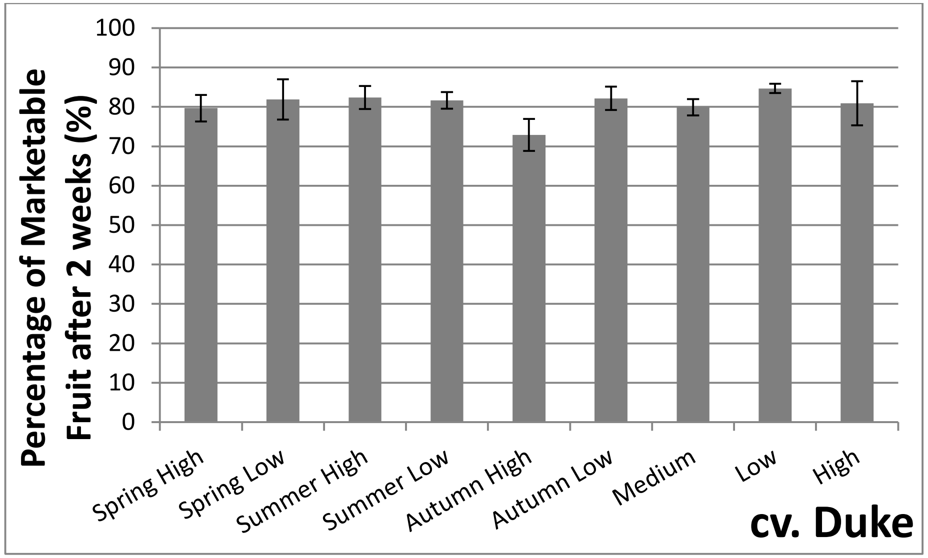

Figure 23B

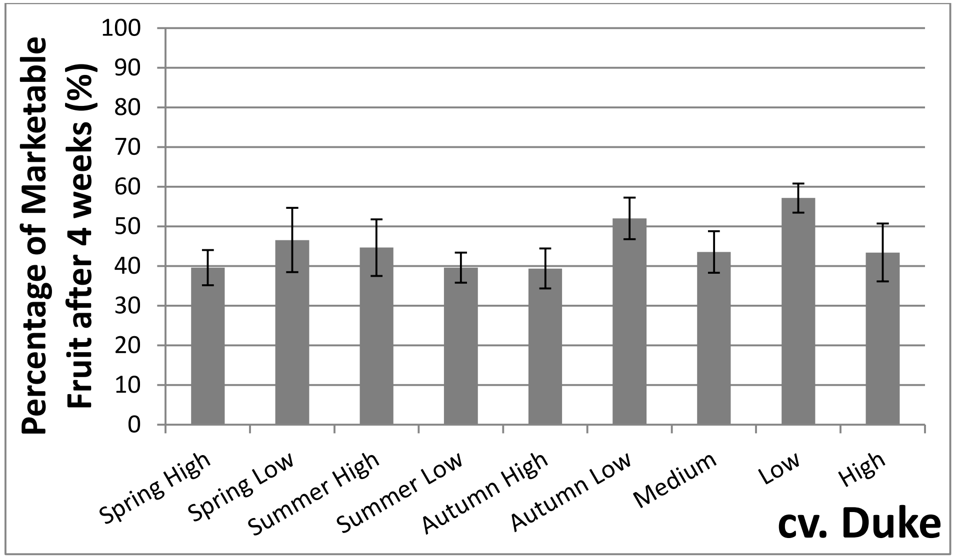

Figure 23C

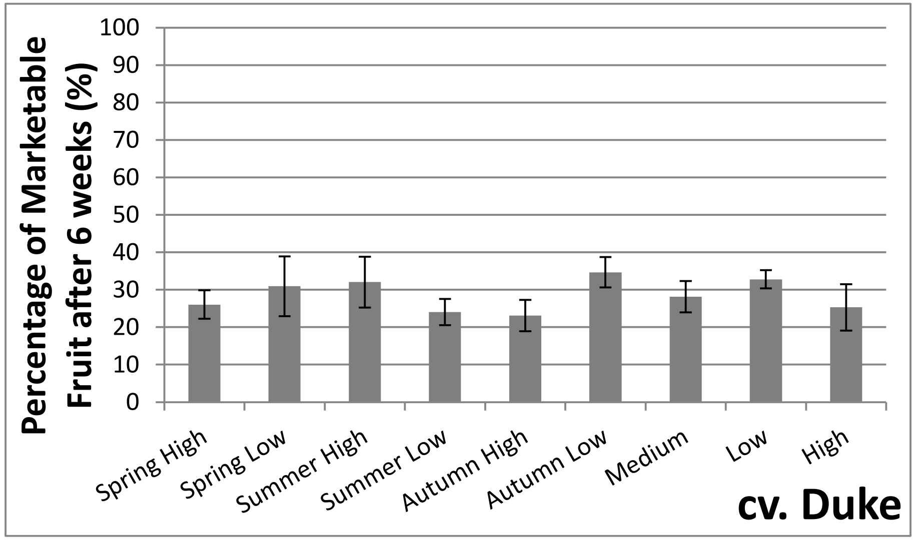

Figure 23D

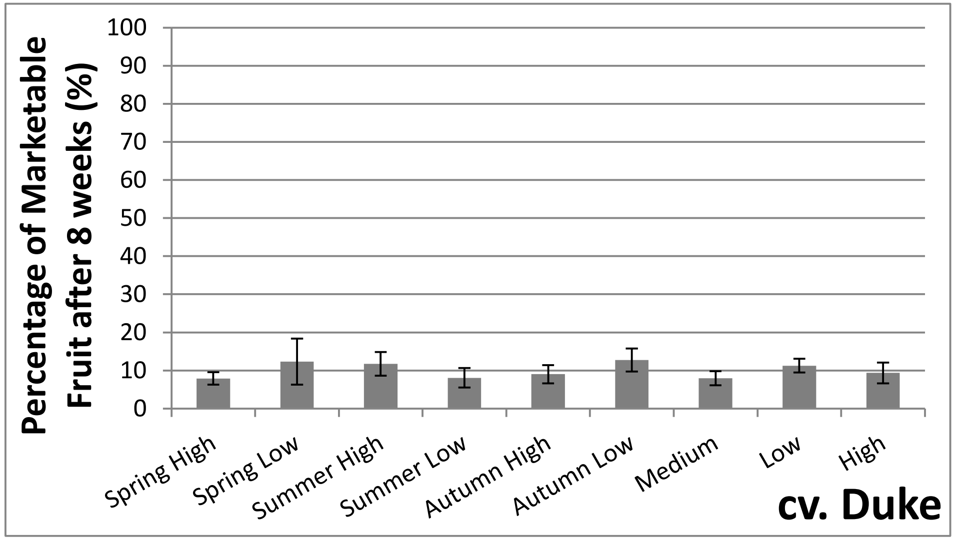

Figure 24. The effect of nitrogen treatment on the percentage of marketable fruit after two, four, six and eight weeks of air storage for cv. Duke. Standard error bars are shown.

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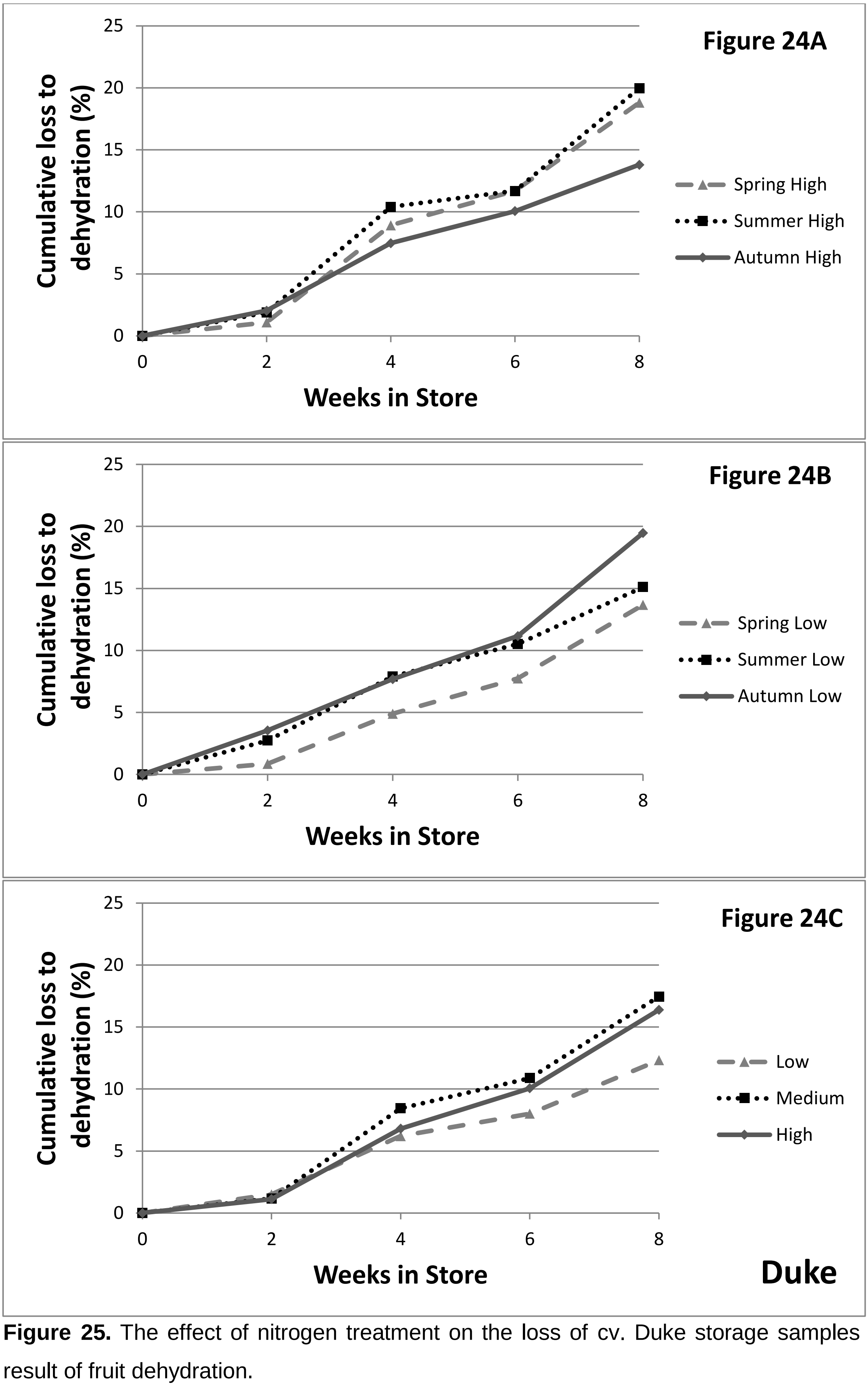

Figure 25. The effect of nitrogen treatment on the loss of cv. Duke storage samples as a result of fruit dehydration.

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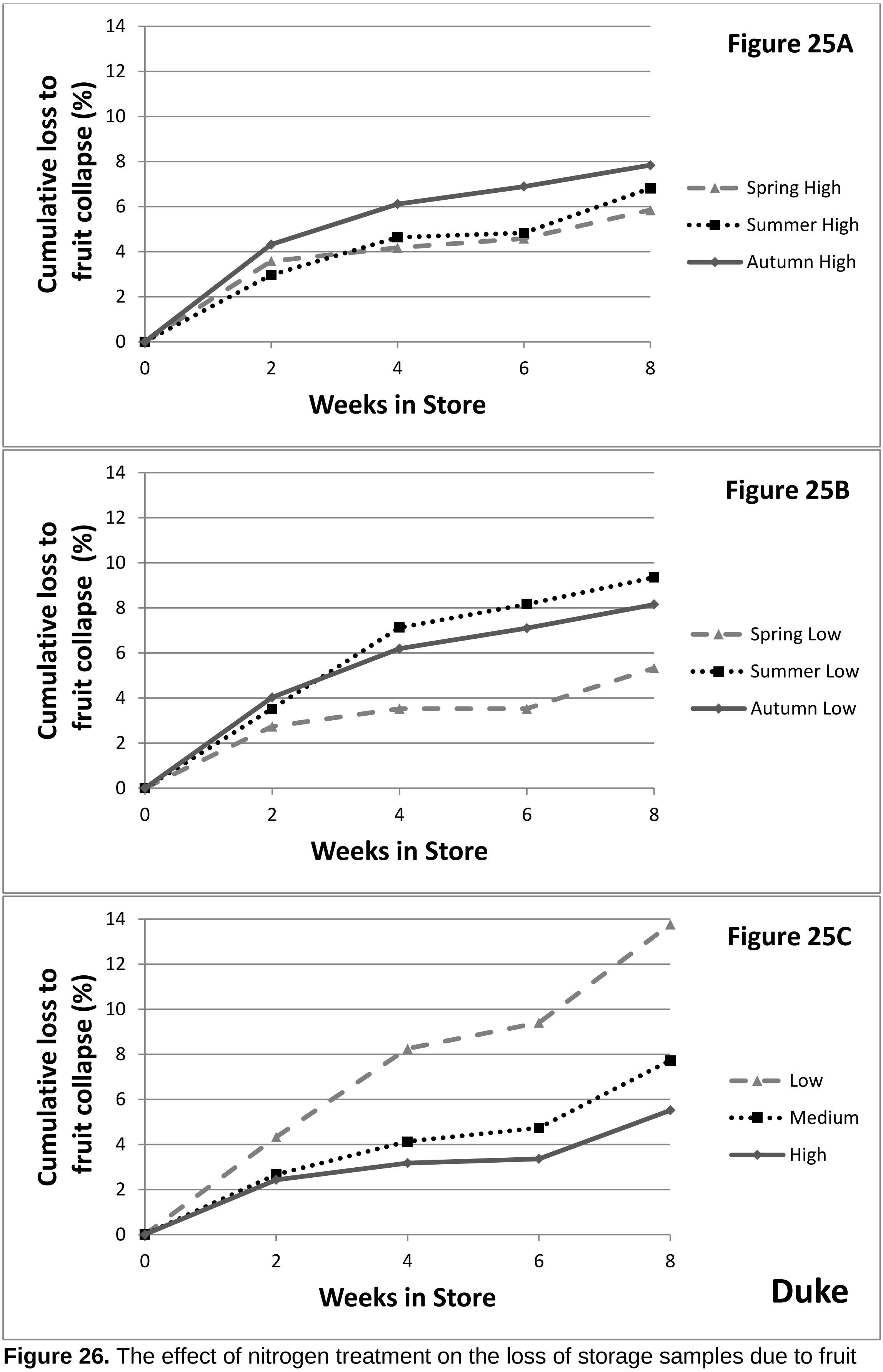

Figure 26. The effect of nitrogen treatment on the loss of storage samples due to fruit collapse for cv. Duke.

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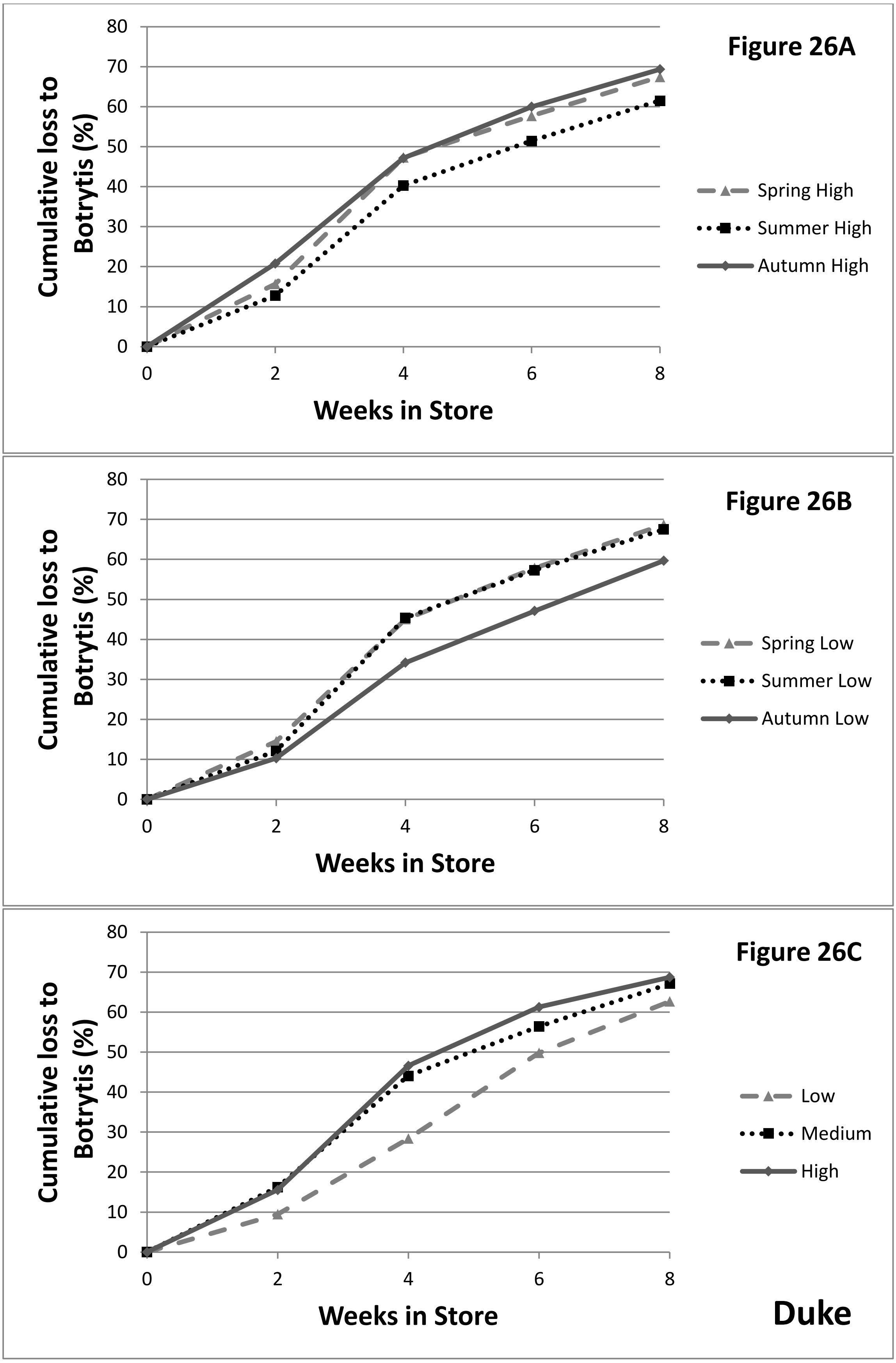

Figure 27. The effect of nitrogen treatment on the loss of cv. Duke storage samples as a result of *Botrytis*.

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Vegetative growth

Three new shoots from each blueberry bush were tagged in spring. Shoot length was measured and recorded on two occasions during the season when nitrogen regimes were changed at first green fruit for fruiting feed and after harvest. Leaf numbers on the shoots were also counted.

Cv. Aurora

Shoot measurements and leaf counts were made on 1 July and 7 October.

There were no statistically significant differences for either shoot growth or leaf number for cv. Aurora.

Low, Autumn Low and Summer Low shoots had the lowest overall growth for cv. Aurora and Autumn High the greatest (10cm) (see Figure 28). Shoot growth at the first event ranged between 26.2cm (High) and 30.5 (Autumn High). This trend continued to the second event when High still had the shortest (33.3cm) and Autumn High still had the longest shoots (40.5cm).

Changes in leaf number throughout the season were similar for most treatments for cv. Aurora (see Figure 29). Average leaf number on 1 July for all treatments was 16. On 7 October, Medium had the most leaves (23) and High the least (20). These differences were not statistically significant.

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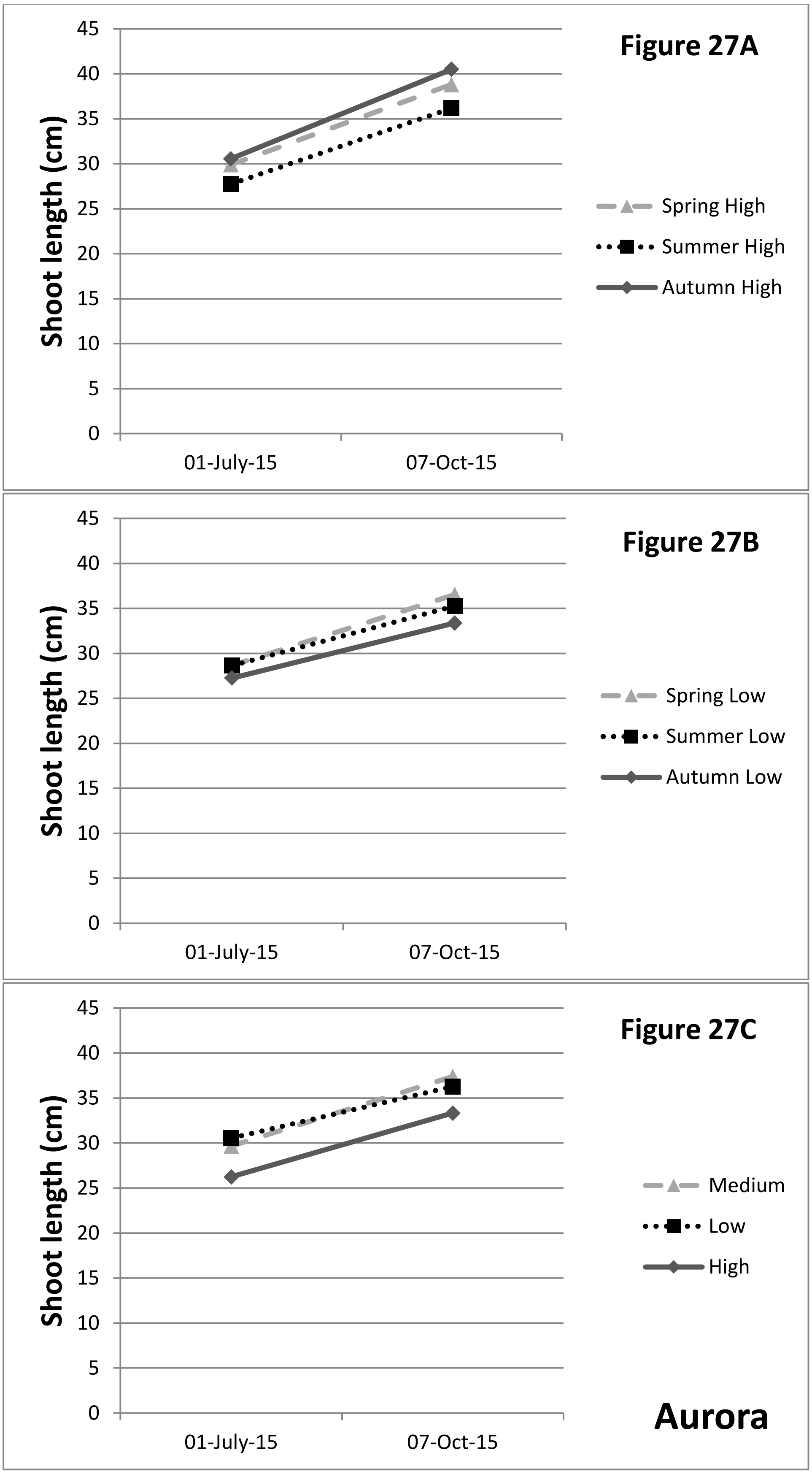

Figure 28. The effect of nitrogen treatment on shoot growth for cv. Aurora.

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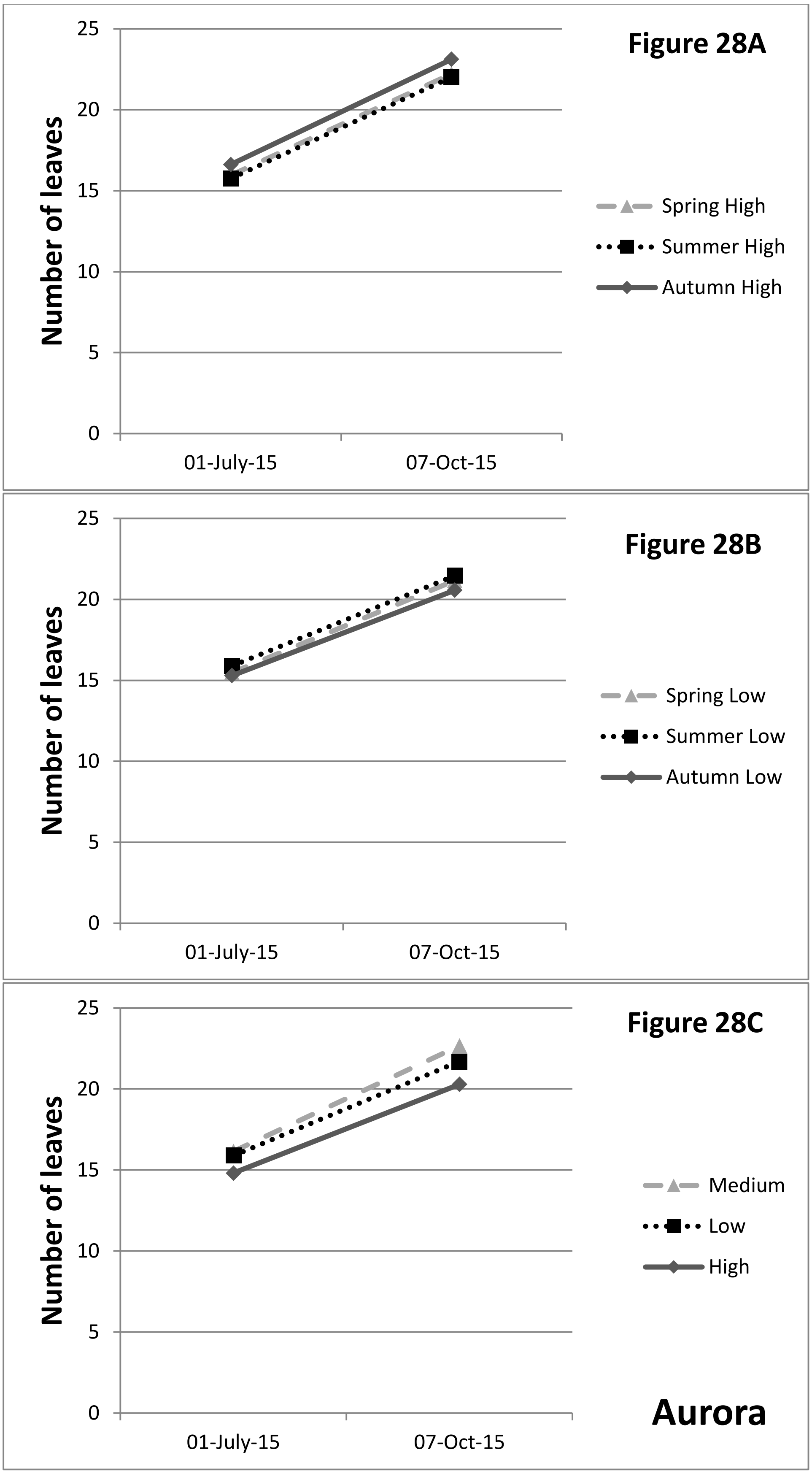

Figure 29. The effect of nitrogen treatment on leaf number for cv. Aurora.

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Cv. Duke

Shoot measurements and leaf number counts for cv. Duke were taken on 3 June and 3 August.

There were statistically significant differences for shoot length between treatments on 3 August (see Table 8) namely:

- Spring Low shoot length was significantly different from Summer Low and Low
- Low N shoot length result was significantly different from all other treatments except Summer Low

Spring Low, Medium and Autumn Low shoots had the lowest overall growth for cv. Duke (see Figure 30). Shoot growth at the first event ranged between 19.4cm (Autumn Low) and 23.6cm (Low). At the second event the treatment with the longest shoot length was Low (47.2cm) and the treatment with the shortest average shoot length was Spring Low (33.4cm).

Changes in leaf number throughout the season were similar for most cv. Duke treatments (see Figure 31). Average leaf number on 3 June for all treatments was 10. On 3 August, Low had the most leaves (21) and Spring Low the least (17). These differences were not statistically significant, however.

Table 8. The effect of nitrogen treatment on shoot length for cv. Duke. The letters show homogenous groups (significant differences between treatments).

Treatment	**Average Shoot Length (cm) 3 June**	**Average Shoot Length (cm) 3 August**
Spring High	22.0	38.1 **ab**
Spring Low	19.8	33.4 **a**
Summer High	20.2	36.2 **ab**
Summer Low	21.8	41.1 **bc**
Autumn High	20.9	36.4 **ab**
Autumn Low	19.4	34.5 **ab**
Medium	21.6	36.4 **ab**
Low	23.6	47.2 **c**
High	21.0	38.7 **ab**
P value		*0.0214*

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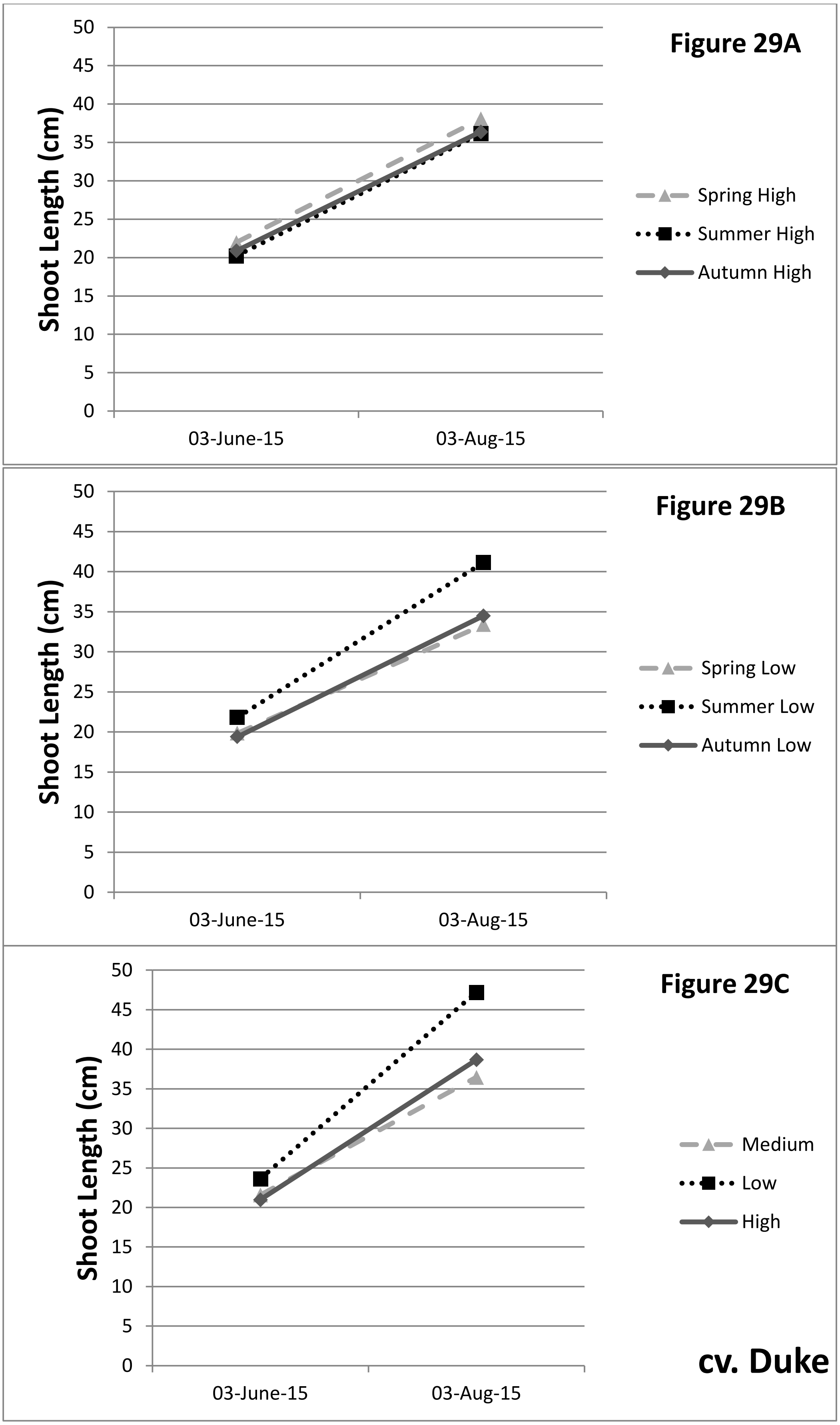

Figure 30. The effect of nitrogen treatment on shoot length for cv. Duke.

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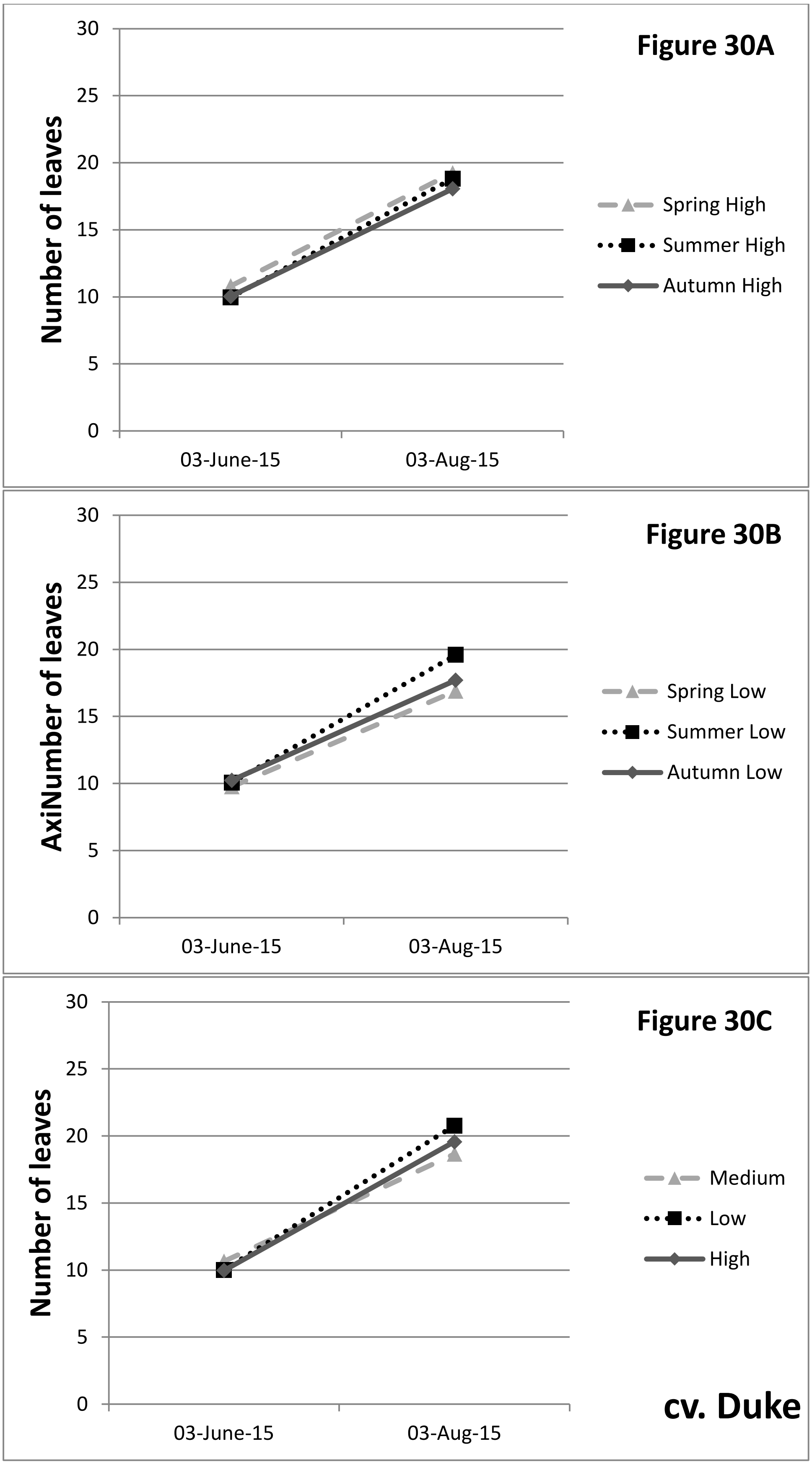

Figure 31. The effect of nitrogen treatment on average leaf number for cv. Duke.

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Feed analysis

The targets for nitrogen concentration were 60, 120 and 180 mg/L for the Low, Medium and High nitrogen regimes. The same feed recipes were used for each regime throughout the season and at the same target ECs. As is often the case with feeding systems, there was variation in the nitrogen levels achieved (see Figures 32 and 33). Clear differences, however, were maintained between Low, Medium and High regimes.

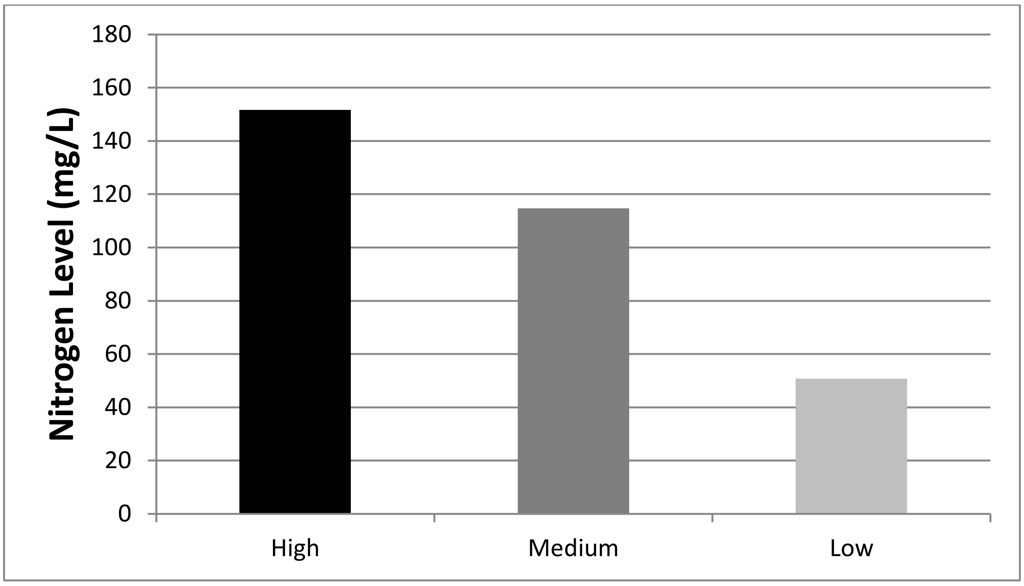

Figure 32. The nitrogen concentration of the three feed regimes on 29 May 2015.

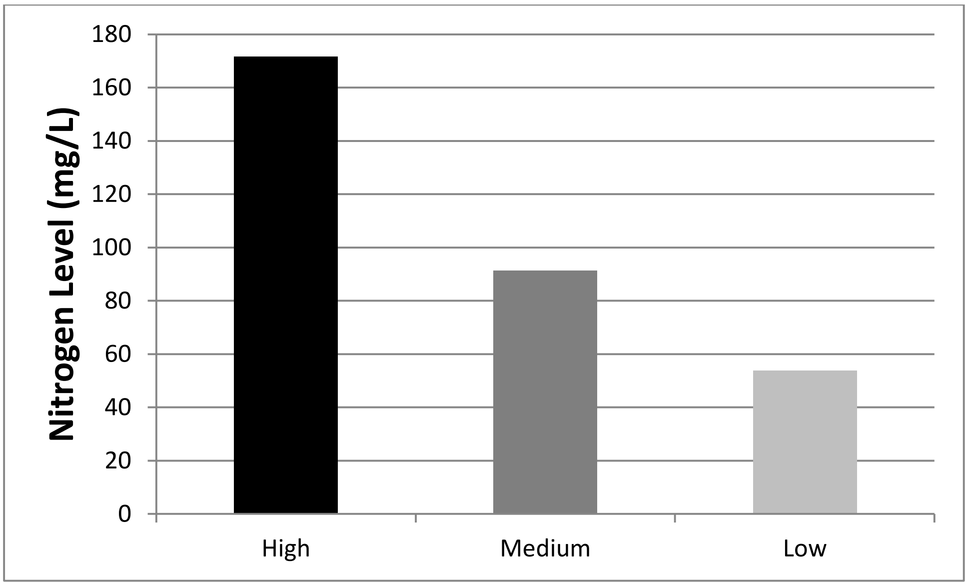

Figure 33. The nitrogen concentration of the three feed regimes on 5 August 2015.

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Nitrogen leaf analysis

Leaf samples were taken from each treatment for both varieties at petal fall and after harvest, cv. Duke on 21 May and 6 August and cv. Aurora on 22 June and 22 October.

Leaf nitrogen at petal fall was higher than after harvest for both varieties and all treatments. See Table 9.

Cv. Aurora

There were small differences between the leaf nitrogen of most treatments. At the first assessment Medium N treatment had the highest levels and Low the lowest (but, unfortunately, leaf samples from High were not assessed on this date). At the second assessment High had the highest levels and Summer Low the lowest.

Cv. Duke

There were small differences between the leaf nitrogen of most treatments. At the first assessment Autumn Low N treatment had the highest levels and Spring High the lowest. At the second assessment Autumn Low had the highest levels and Low the lowest.

Table 9. The effect of nitrogen treatment on leaf analysis (% dry weight N), both varieties.

Treatment	cv. Aurora 22 June	cv. Aurora 7 October	cv. Duke 21 May	cv. Duke 6 August
Spring High	2.48	1.82	2.23	1.79
Spring Low	2.44	1.83	2.27	1.83
Summer High	2.43	1.78	2.31	1.73
Summer Low	2.41	1.39	2.33	1.62
Autumn High	2.45	1.78	2.52	1.76
Autumn Low	2.41	1.78	2.62	1.95
Medium	2.60	1.78	2.43	1.82
Low	2.34	1.48	2.58	1.56
High	-	1.86	2.30	1.80

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Discussion 2015

There were no statistically significant differences for cvs. Aurora or Duke for percentage bud break. Cv. Aurora had higher percentage bud break (around 85%) compared to cv. Duke at around 70%. There were no statistically significant differences for cvs. Aurora or Duke for percentage floral buds. Cv. Aurora had higher percentage floral buds (around 55%) compared to cv. Duke at around 40%. There were no statistically significant differences for cvs. Aurora or Duke for flower number per bud. Cv. Aurora had slightly higher flower numbers per bud (around 6.5) compared to cv. Duke at around 6. The higher values for cv. Aurora compared to cv. Duke are likely to be varietal.

Whilst there was no effect of treatment on overall yield or quality class for cv. Duke, there was an effect for cv. Aurora. There was no effect seen on total yield (kg) or harvest date for cv. Aurora or between treatments for Class 1 fruit. However, there was a significant reduction in the Class 2 fruit for the Low treatment compared to all other treatments except Summer Low. Whilst Low treatment Class 1 fruit was 1% higher than any other treatment the significance is also due to a higher waste percentage (4%).

Cropping profiles for cvs. Aurora and Duke showed reversed trends. Cv. Aurora yields increased on the second harvest except for the Summer Low treatment, which declined. Cv. Duke yield decreased for the second harvest, most noticeably for treatment Low. This may be an effect of Low nitrogen treatment upon fruit ripening but the opposite effect was seen in 2014 and in 2015 is most likely due to the timing of the first pick. There were no significant differences, however, for either cultivar on harvest date.

There were no treatment effects for cv. Aurora on fruit weight. However, there were treatment effects for cv. Duke, with the Low treatment fruit having significantly heavier berries than all other treatments. This result was also obtained in 2014.

There were no significant treatment effects for cvs. Aurora or Duke on fruit size.

Fruit Brix° was not significantly affected by treatments for cv. Aurora but Summer High had the lowest Brix° and the Spring, Summer and Autumn Low nitrogen treatments had the highest values. Overall Brix° in cv. Duke fruit was higher than for cv. Aurora and there were differences between treatments, namely Low had significantly lower Brix° than all other treatments except Summer and Autumn Low. Medium had the highest Brix° and, unlike with cv. Aurora, the high nitrogen treatments had higher values than the low.

Impacts of nitrogen treatment were not found in storage potential for cv. Aurora. Percentage marketable losses were similar until between weeks 6 and 8. Over 50% of fruit was still

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marketable after eight weeks, except for treatments Summer Low and Medium which had over 60% marketable fruit remaining. Losses appeared to be mainly due to dehydration and *Botrytis* rather than collapse, with treatment Low losing most fresh weight and treatment High with the greatest incidence of *Botrytis*.

There were also no impacts of nitrogen treatment on storage potential for cv. Duke. Percentage marketable losses were variable at week 4 and less than 10% of fruit was still marketable after eight weeks except for treatments Spring Low, Summer High, Autumn Low and Low. Losses were mainly due to high incidence of *Botrytis,* which was similar for all treatments at over 60% at week 8 except for Autumn Low. Percentage collapse was generally higher for cv. Duke than for cv. Aurora except for cv. Duke Low (14%). Percentage dehydration was generally lower for cv. Duke than for cv. Aurora. Maximum daytime temperatures around the first harvest date were around 24ºc and there was a peak of 34ºc five days beforehand which could have affected fruit quality for storage for cv. Duke.

Vegetative growth results for cv. Aurora showed no statistical differences for shoot length and leaf number (which were similar for every treatment). High had the shortest shoot length compared to all other treatments. This result was repeated in all previous years except for 2014.

Vegetative growth results for cv. Duke showed no statistical differences for leaf number which were very similar for all treatments. However, at the second assessment treatment Low had significantly longer shoots compared to all the other treatments except Summer Low. As in 2014, this may have been a seasonal effect. Or it could be because in previous seasons shoots were also assessed at leaf fall whereas in 2015 the trial concluded after harvest and continued growth was not measured.

Conclusions 2015

In 2015, the different nitrogen regimes had no effect on bud break, floral buds or flower number for either variety.

Feeding Low nitrogen in cv. Aurora may increase the incidence of waste fruit.

Fruit from plants receiving Low nitrogen treatment may ripen earlier than others.

The yield increase for cv. Aurora and decrease for cv. Duke between each harvest may have been due to climate or growth stage but was probably due to the timing of the first pick.

In cv. Duke, feeding Low nitrogen resulted in higher berry weight (which may decrease picking costs).

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Fruit size between cv. Aurora treatments was very similar. Fruit size was similar between the cv. Duke treatments.

Total soluble solids (Brixº) content may be reduced by applying Low nitrogen in cv. Duke but also increased by applying Medium or High nitrogen for at least part of the season. This could be because of different photosynthetic rates, which may affect accumulation of sugars. But fruit from the Low treatment in 2015 still had higher Brixº than cv. Aurora overall.

Cv. Aurora fruit stored much better in 2015 than cv. Duke. Greater marketable losses for cv. Duke may have been due to hot weather conditions leading to rapidly ripening fruit.

Shoot length in cv. Duke was greatest in Low nitrogen treatment. During the season it was observed that plants on the Low regime had fewer shoots overall compared to plants on other regimes. This could explain the longer shoot length and larger fruit with low Brixº.

Knowledge transfer 2015

A paper will be published in January 2016.

Dan Chiuian will be presenting a summary of the 2015 season and project results at the FAST Members Annual Conference on 4 February 2016.

Abi Dalton will present complete project results at the AHDB Soft Fruit Agronomists Day in February 2016.

Results recap 2012-2015

Flower initiation and bud break

Frost damage

There was very little frost damage observed in 2013 and none in 2014 and 2015.

Percentage bud break

Percentage bud break was not assessed in 2012.

In 2013, percentage bud break was very similar and not significant for cv. Aurora where Low had the highest percentage and Medium the lowest. However, there was a significant effect for total bud number where Low had more buds per shoot than any other treatment.

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In cv. Duke, Autumn Low had the highest and Medium the lowest but these results were not significant nor were buds per shoot where Autumn Low had more than other treatments. Overall cv. Aurora had more buds than cv. Duke.

For 2014 cv. Aurora percentage bud break results were similar and not significant. Spring High had the highest percentage bud break and Autumn Low the lowest. For cv. Duke, percentage bud break was slightly higher than for cv. Aurora but again not significant. Low had the highest % and Autumn High the lowest.

In 2015, cv. Aurora Summer Low had the highest percentage bud break and Spring Low and Summer High the lowest. For cv. Duke, Spring High and Autumn Low had the highest and Spring Low the lowest.

Floral bud production

In 2012 Low produced the largest floral bud number.

Low N treatment had statistically significant greater percentage floral buds for cv. Aurora in 2013. High had the least. Whilst cv. Duke followed the same pattern results were not significant.

During 2014 cv. Aurora High had the greatest percentage of floral buds and Low the least but this was not of statistical significance. Cv. Duke bushes produced more floral buds than cv. Aurora, with most flower buds in the High regime and least in Summer Low.

2015 results showed cv. Aurora Autumn High had lower percentage floral buds and Summer Low, Autumn Low and Medium N regimes the highest. For cv. Duke Spring Low and Summer High had fewest floral buds and High the most.

Flower number

Flower number was not assessed in 2012.

In 2013, there was some variation for cv. Aurora but nothing significant – Low had more flowers per bud and Medium the least. Cv. Duke flowers per bud were very similar and Medium had most and High the least.

Little variation was found between treatments of average flower number during 2014 and no significant differences. Cv. Aurora Low had the fewest flower number per bud and Medium the most. Cv. Duke High had the fewest and Summer Low the most.

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Again, there was little variation in flower number per cluster for either cultivar in 2015. Lowest flower numbers were for Medium and High for cvs. Aurora and Duke respectively. Highest flower numbers were for Autumn High and Low respectively.

Yield and quality

Yield per plant

In 2012 Low nitrogen treatment had the greatest yields for both cultivars but differences were not significant. The High N regime had lower yields.

In 2013 Medium and Spring Low resulted in largest yields for cvs. Aurora and Duke respectively (total and Class 1). Summer Low and High had the lowest yields respectively.

In 2014 there were no treatment effects on overall yield for either cultivary or quality class for cv. Aurora. Cv. Aurora Autumn Low had the largest overall yield and Summer Low the smallest.

During 2015, the final year of the four year trial, yields for cv. Aurora increased and cv. Duke remained approximately the same compared to 2014. There were no significant effects for cv. Aurora or cv. Duke on total yield. In 2015 highest total yield for cv. Aurora was for Autumn Low and lowest for Low. Conversely, for cv. Duke Low had the highest overall yield and Medium the lowest.

Percentage class

Percentage class was not assessed in 2012.

During 2013 waste fruit percentages were higher in cv. Aurora than for cv. Duke. Significant differences were observed between treatments in Class 2 cvs. Aurora and Duke fruit where cv. Aurora High had fewest Class 2 fruit and Spring Low the most and where cv. Duke Low and High and the fewest and most respectively. Cv. Aurora Medium had most Class 1 fruit and Summer Low the fewest. For cv. Duke Class 1 was highest for Low and High the lowest. Waste fruit for both varieties was very low.

Aurora Medium had the least Class 1 fruit in 2014 and Low the most. Medium also had the most Class 2 fruit and Low had the least waste. Whilst cv. Duke High had the largest overall yield and Summer High the smallest Low had the most Class 1 fruit and High the least. Cv. Duke Low also had the fewest Class 2 fruit and High the most. As in 2013, waste fruit

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percentages were very low.

In 2015 cv. Aurora Low had the highest Class 1 percentage and significantly fewer Class 2 fruit compared to any other treatment and Medium had the lowest Class 1 and most Class 2 fruit. But feeding Low nitrogen in cv. Aurora increased the incidence of waste fruit. Cv. Duke Low had most Class 1 fruit and Spring High and Summer High the least. Cv. Duke Low also had the lowest Class 2 fruit and Medium, Summer High and Spring High the most. Waste for cv. Duke in 2015 was very low.

Cropping profile

Cropping declined rapidly for all cv. Aurora treatments after the first harvest and more steadily for cv. Duke treatments in 2012.

Aurora Spring Low maintained steady yields over the cropping profile in 2013 whereas all other treatments declined after the first or second harvest. Harvests for cv. Duke decreased after the third event, except for Autumn Low and Summer High with Autumn High decreasing the fastest.

Feeding High nitrogen in 2014 resulted in significantly earlier harvests for cv. Duke and Low N regime yields were later. Larger yields were recorded early in the picking season for the High nitrogen. In contrast, higher yields were observed later into the season for the Low nitrogen treatment.

In 2015 fruit from plants receiving Low nitrogen treatment ripened earlier than others. Cv. Aurora Low particularly, and cv. Duke Low to a lesser degree, advanced harvest in 2015.

Fruit number per plant

In 2012 fruit number per plant was significantly higher in Low nitrogen treatment for cvs. Aurora and Duke.

In 2013 cv. Aurora Low and Medium had higher fruit numbers and Summer Low the least. For cv. Duke Spring High and Autumn Low had the greatest fruit numbers per plant and Autumn High the least. Neither were significantly different, however.

Feeding High nitrogen throughout the 2014 season resulted in a greater number of total Class 1 berries and significantly higher for cv. Duke under High N regime where Low had the fewest berries.

There were no significant effects of N regime on fruit number for cvs. Aurora or Duke during

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2015.

Fruit weight

Cv. Aurora Low berries weighed more than any other treatment in 2012 and Medium the least. For cv. Duke the opposite was true.

In 2013 Low and Summer Low had significantly lower berry weight than for any other treatment in cv. Aurora. Heaviest berries were from Summer Low, Autumn Low and High. Cv. Duke High had significantly lower berry weight than any other treatment and Low, Spring Low and Summer Low had the heaviest fruit.

In 2014 there was a significant difference in berry weight between treatments for cv. Duke but not for cv. Aurora. Cv. Aurora Spring Low had the heaviest fruit and Medium the least. Cv. Duke Low had the heaviest fruit and High the lightest.

Cv. Aurora Summer Low and Low had the heaviest berries in 2015 and High the lightest but effects of N regime were not significant. In cv. Duke, feeding Low nitrogen during 2015 resulted in significantly higher berry weight compared to all other treatments and Autumn Low had the lowest weight.

Fruit size

No effect on fruit size was observed in 2012 for either cultivar.

Fruit size in 2013 was significant but inconsistent between cultivars. Cv. Aurora Autumn Low had the largest berries and Summer Low the smallest. Cv. Duke Low had the largest and High the smallest.

In 2014 there was a significant difference in fruit size between treatments for cvs. Duke and Aurora. Feeding High nitrogen throughout the 2014 season resulted in smaller size fruit whilst Low nitrogen produced significantly larger fruit in cv. Duke. For cv. Aurora largest fruit were from Spring Low and smallest from High.

During 2015 fruit size between cvs. Aurora and Duke treatments were similar and no effects were statistically significant. Cv. Aurora Autumn High had the smallest fruit and Low the largest. For cv. Duke Medium had the smallest fruit and Spring Low and Summer Low the largest.

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Brixº

In 2012 Brixº was higher in cv. Duke than in cv. Aurora. In cv. Duke, Low nitrogen treatment had the highest average. For cv. Aurora the High nitrogen treatment had highest Brixº and Medium lowest. For cv. Duke the High nitrogen treatment had highest Brixº and Low the lowest. Any differences were not significant.

Brixº in 2013 was significant but inconsistent between cultivars. Cv. Aurora Spring High had the highest and Autumn Low the lowest. Cv. Duke Spring Low was significantly lower than any other treatment and Spring High with Summer High had the highest values. The difference in Brixº values between treatments was reduced compared to other years.

In 2014 there were significant effects on Brixº as a result of nitrogen treatment for cv. Duke but not for cv. Aurora. Cv. Aurora Medium had the lowest Brixº and Spring Low the highest and there was also not great variation between treatments. For cv. Duke Summer High berries achieved highest Brixº levels whilst Low had the lowest.

In 2015 cv. Aurora Brixº was highest in Autumn Low and lowest in Summer High but results were not significant. Total soluble solids (Brixº) content was significantly reduced in cv. Duke by applying Low nitrogen. Medium had the highest value and content was also increased by applying High nitrogen for all or at least part of the season. Fruit from the Low treatment in 2015 still had higher Brixº than cv. Aurora overall.

Storage

No significant effects were observed during 2012 but percentage non marketable fruit was generally greater in Low nitrogen treatment.

There were impacts of N treatment on storage disorders in 2013 for cv. Aurora after eight weeks in store. Cv. Duke fruit were stored in CA and air cold stores. Although losses were small in CA store there were significant differences between treatments. After eight weeks in air cold store cv. Duke had significant differences between treatments for dehydration, collapse and *Botrytis*.

There were impacts of nitrogen treatment on storage potential for cv. Aurora during 2014 but not for cv. Duke. Berries from bushes supplied with Low levels of nitrogen stored considerably better, as seen in 2013. Losses were mostly due to dehydration for cv. Aurora. Cv. Aurora fruit stored much better in 2015 than cv. Duke but there were no significant effects between treatment regimes.

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Marketable fruit

Highest percentage non marketable fruit for cvs. Aurora and Duke during 2012 was from the Low nitrogen treatment, although not significantly so.

In 2013 cv. Aurora Spring Low had the most marketable fruit remaining after eight weeks and High Low had the least. Dehydration accounted for most losses. Percentage marketable fruit in cv. Duke was greatest for High and lowest for Spring Low. Dehydration and collapse accounted for most losses.

In 2014 improved marketable percentage after eight weeks was largely due to fewer incidences of collapse and *Botrytis*. Cv. Aurora Summer High had the least marketable fruit remaining whilst Low the most and which differences were significant. Cv. Duke Low also had the most marketable fruit remaining after eight weeks in store, whilst Spring Low had the least but these differences were not significant.

Cv. Aurora Medium had the most marketable fruit remaining after eight weeks in 2015 and Summer Low the least. Cv. Duke Autumn Low had the most marketable fruit and Spring High, Summer Low and Medium had the least marketable.

Dehydration, collapse and Botrytis

Very little *Botrytis* was seen during 2012.

In 2013, after eight weeks cv. Aurora High lost a smaller percentage to collapse and Low the biggest. Whilst losses to *Botrytis* were low there were also significant differences - Low had a lower percentage lost and High the greatest. After eight weeks cv. Duke High had most fruit lost to dehydration and Medium the least. Low had most fruit lost to collapse and High the least. Autumn High had more fruit lost to *Botrytis* than any other treatment and Low the least. In 2013 Low appeared more susceptible to collapse but less prone to *Botrytis*.

Losses in 2014 were greatest for fruit dehydration in cv. Aurora where Low had the lowest percentage loss and Summer high the highest but these differences were not statistically significant. Statistically significant results were found for cv. Aurora collapse where Autumn Low performed best and Autumn High worst, together with *Botrytis* where Low had the lowest percentage loss and Summer High the highest. Cv. Duke dehydration losses were lowest for Low and highest for Summer High, collapse was lowest for Autumn High and highest for Spring Low and *Botrytis* was lowest for Low and highest for Autumn High but no effects were significant. During CA store there was very little incidence of fruit collapse and *Botrytis* was more noticeable in the Medium, Low and Spring High treatments.

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In 2015 cv. Aurora storage losses were due to dehydration and *Botrytis* more than collapse. Summer Low had the highest cumulative loss to dehydration and High the lowest. Summer High had the highest collapse percentage and Spring High, Spring Low and Low the lowest. Medium N regime had the lowest losses to *Botrytis* and Autumn High the highest. In cv. Duke incidence of *Botrytis* was very high and accounted for most losses. Percentage cumulative dehydration losses were lowest for cv.Duke Low and highest in Summer High. Percentage losses to collapse were lowest for Spring Low and highest in Low. Percentage losses to *Botrytis* were lowest for Autumn Low and highest for Spring Low and Autumn High.

Vegetative growth

In 2012 applied nitrogen rates did not significantly alter growth for cv. Duke but cv. Aurora High shoots were longer than Low.

In 2013 there were significant differences in growth for cv. Aurora but not cv. Duke. Medium and High treatments produced similar amounts of growth

In 2014 there were no significant differences in growth for cvs. Aurora or Duke.

There was no effect of N regime on cv. Aurora shoot length or leaf number in 2015 but there were significant effects on shoot length of cv. Duke.

Shoot length

Shoot length in High nitrogen was slightly longer than for Low in 2012 in cv. Aurora and for cv. Duke High and Medium had the longest and shortest shoots respectively.

In 2013 cvs. Aurora and Duke Low had shortest shoots and Spring High the longest, results being significant for cv. Aurora.

Cv. Aurora 2014 shoot length was longest in Spring High and shortest for Low. Cv. Duke Summer High was longest and High was shortest.

Cv. Aurora Autumn High had the longest shoots in 2015 and High the shortest. In 2015 shoot length in cv. Duke was significantly greater in Low nitrogen treatment and Spring Low had the shortest shoots.

Leaf number

During 2012 the effect of nitrogen treatment on leaf number was not significant but Autumn High had greater numbers than Autumn Low.

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In 2013 cvs. Aurora and Duke Low had the smallest leaf number and Spring High the biggest (but results were only significant for cv. Aurora).

No significant differences were observed in leaf number between the various nitrogen treatments in 2014. Cv. Aurora Autumn High had the most and High the least. Cv. Duke Autumn Low had the most leaves and High the fewest.

In 2015 leaf number was similar for cv. Aurora – Medium had the most leaves and High the least. Cv. Duke Low had the most leaves and Spring Low the least. Differences were not significant.

Summary 2012-2015

Treatment effects on assessments in each year were scored using a 1 to 9 scale (where 1 = best and 9 = worst). These scores were averaged and Table 10 details the results.

Table 10. Summary of treatment effects for all assessments 2012-2015

	cv. AURORA		cv. DUKE	
ASSESSMENT	**BEST**	**WORST**	**BEST**	**WORST**
Percentage bud break	Spring High	Summer High	Autumn Low	Spring Low
Floral bud production	Summer Low	Autumn High	High	Summer High
Flower number	Summer High	Spring Low & Medium	Summer Low	Autumn High & High
Yield	Autumn Low	Summer Low	Low	Medium & High
Class 1	Autumn Low	Low	Low	High
Class 2	Summer Low	Medium	Low	Spring High
Waste	Spring Low	Medium	Summer Low	High
Fruit number	Spring Low	High	Spring High	Medium & Low
Fruit weight	Autumn Low	Autumn High & Medium	Low	High
Fruit size	Autumn Low	Autumn High	Low	High
Brix^0	Spring Low	Medium	Summer High	Low
% Marketable fruit	Spring High	Summer High	Autumn Low & Low	Spring Low & Summer Low
Dehydration	Spring High	Summer High	Low	Summer High
Collapse	Spring High	Summer High	Summer High & High	Low
Botrytis	Low	High	Low	Autumn High
Shoot length	Spring High	Low	Autumn High	Spring Low
Leaf number	Spring High	Spring Low & Low	Autumn Low	Spring Low

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In 2013 significant effects were observed for cv. Aurora, in particular floral bud production. There were no significant effects for either cultivar on bud break, floral buds or flower number in 2014 and 2015. Applying Low N for some or all of the season may increase bud break. Results for floral bud production were variable year to year. The only significant effects observed were during 2013 where Low may be recommended to increase floral bud production and as seen increasing N concentration can inhibit floral bud production. There were no significant effects of N regime in any year for flower number and variability between treatments was so small it is difficult to recommend any one regime above another.

The effects of Nitrogen treatment on frost could not be ascertained during the trial as there was little or no damage.

There were no significant effects on marketable yield for cvs. Aurora or Duke in 2012, 2013, 2014 or 2015. Increasing levels of Nitrogen did not significantly improve yield. There were no significant effects on fruit quality for either variety in 2012. There were significant effects on some quality parameters for cvs. Aurora and Duke in 2013, cv. Duke in 2014 and both cultivars in 2015. Cv. Aurora may be suited to a Medium/Low regime to increase overall yields and cv. Duke a Low regime. Percentage Class 1 yields may be improved by feeding Medium or Low N year round. Low N also appears to reduce waste fruit.

There were no significant differences in cropping profile in any year for either cultivar. Opposite trends were recorded in 2014 and 2015.

There were significant effects of Low and Spring Low N regimes on increasing fruit weight and size.

Brix^{o} is always higher in cv. Duke than cv. Aurora and the lowest value in cv. Duke generally higher than for cv. Aurora. Results within cultivars were inconsistent in each year. Significant effects were noted with Spring High increasing Brix^{o} and Low reducing Brix^{o}.

In all years of the trial cv. Aurora fruit had more marketable fruit remaining than cv. Duke at the ends of the eight week storage periods. Significant effects were seen with Low N regime increasing % marketable fruit. Low N reduced storage losses in 2012, 2013 and 2014 as a result of reduced collapse and *Botrytis*. Fruit from Low N regimes seemed more susceptible to dehydration but had fewer incidences of *Botrytis*. Whilst results were variable, overall Low N may increase % marketable fruit out of store, High N is less affected by dehydration and Low N reduces *Botrytis*.

High N regimes generally increased shoot length except for in 2015 when Low N shoot

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length was highest. The decrease in Low shoot length in cv. Duke observed during 2012 and 2013 was not seen in 2014. This effect on growth did not have any impact on yield.

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Final discussion 2012-2015

Typically, plant growth responds to increasing amounts of a given nutrient as shown in the graph below:

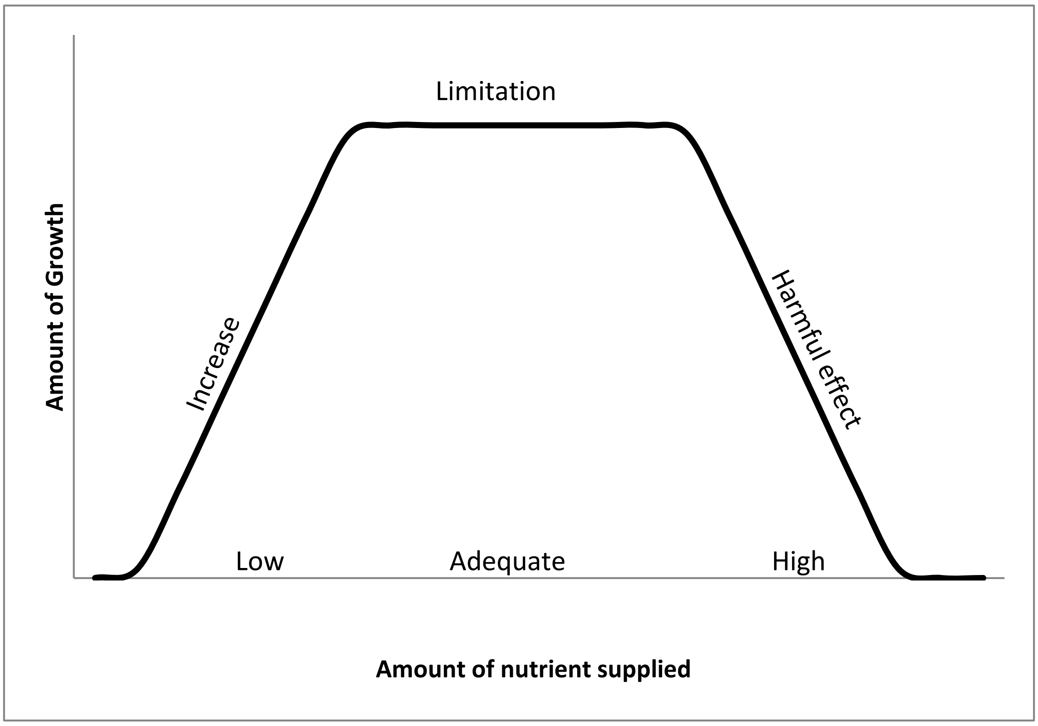

Figure 34. General relation between any particular nutrient or growth factor and the amount of growth made by the plant (Russell 1976)

However, this only applies if the nutrient concerned is a limiting factor in plant growth. Yield response in fruit crops (such as strawberries) follows a broadly similar pattern, with either quadratic or linear plateau (Hocmuth et al 1996). Blueberries are variously reported to give increased yields and or plant growth with increased nitrogen applications up to a certain limit (Bryler et al (2012), Benados et al (2012) and Hart et al (2006)).

According to Hanson (2006) blueberries generally respond best to modest rates of nitrogen ranging between 20 and 140 kg N per ha depending on the region. These results have mainly come from commercial experience or trials with soil grown bushes. In the UK the vast majority of blueberries are grown in pots with little information available as to the optimum nitrogen levels required for this system. In soil-grown strawberries in the UK standard recommendations for appropriate levels of nitrogen fertilisers vary between 0 and 80 kg / ha depending on variety, soil type and SNS index (RB209 2010). For substrate-grown strawberries RB209 suggests guidelines of 117 to 154 mg/L of N. In this project the range of nitrogen fertilisers in the nutrient solutions varied between 60mg/L and 180mg/L.

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Based on the soil recommendations for blueberries compared to strawberries this range of N should be appropriate for substrate grown crops. In addition, Spires (2008) reports an increase in shoot growth over the range 0 to 81 mg N per L when applied to rabbiteye blueberries in sand culture. Hart et al (2006) report that rabbiteye blueberries need much less than highbush blueberries and go on to suggest that rates should halved for rabbiteye blueberries. On the basis of Spires (2008) work an increase in shoot growth would be expected up to 160mg/L of N for highbush blueberries.

During the course of this project there have been few consistent differences between treatments for any of the parameters measured for either variety, including vegetative growth, yield and fruit quality attributes. Exceptions include for cv. Duke Low N regime producing larger and heavier fruit and High N regime producing smaller and lighter fruit, High N producing least C1 and most C2 fruit and Summer High fruit having higher Brix^{o} and for cv. Aurora High N treatments having greater losses to *Botrytis* in store.

In 2012 and 2013 the Low, Spring Low and Summer Low showed lower levels of leaf N in the period following treatment. However, in 2014 and 2015 there was no difference in leaf N between treatments. Townsend (1973) and Hart et al (2006) reported a good correlation between applied nitrogen and leaf nitrogen analysis.

Final conclusion 2012-2015

Looking at Figure 33 above (Russell 1976) it can be expected that provided N is a limiting factor growth and yield will increase linearly or quadratically before reaching a plateau, after which no further response to increased N is seen until levels become supra optimal or toxic leading to a decline in plant performance.

Based on the results over the past four years of the project it seems that even at the lowest regime of 60mg/L nitrogen is not a limiting factor. Similarly, at the highest concentration (180mg/L N) there were no adverse effects on plant growth or cropping. However, as seen in Table 10, there were indications that there was also some consistency in maintenance of improved Brix^{0}, % marketable fruit out of store and C1 yields over the seasons for cv. Aurora Autumn Low / Spring High and cv. Duke Autumn Low

In their guide “Nutrient Management for Blueberries in Oregon” Hart et al (2006) suggest the use of N at the rate of 17g of N per plant in Year 1 increasing to 25.5g per plant by Year 4. Unfortunately, the amount of nitrogen applied per plant is not recorded in this trial as it was based upon a dilution rather than total quantity. However, on a typical summer’s day, when approximately 0.4g N per plant was applied, it is likely, even at the lowest regime, that the

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rates suggested by Hart et al (2006) were exceeded. That equates to just over 12g per month at which rate would have continued for approximately three months. It is important to bear in mind that the recommendations from Oregon were based on the use of granular fertilisers applied to the soil where the percentage uptake is likely to be considerably lower than in pot culture with constant fertigation. On this basis it would appear that the optimum level of nitrogen for bushes of this age and size in 25L pots is less than 60mg/L. The only way this could be confirmed would be by carrying out a similar trial with nitrogen rates below 60mg/L. If this is indeed the case then there is considerable scope for growers to reduce the amount of N being applied commercially without any adverse effects on yield or quality.

A further possibility is that some other factor was limiting plant performance such as another nutrient, light levels, small pot size, support system or plant spacing, for example, even though plants were grown according to commercial best practice.

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Appendix 1

Photo series 1. Tunnels on 19 June 2015 – cv. Duke on left, cv. Aurora on right.

Photo series 2. Cvs. Duke (left) and Aurora (right) fruit.

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