Grower Summary

TF214

Improving nitrogen use efficiency, sustainability, and fruit quality in high-density apple orchards

Final Report 2017

Project title:	Improving nitrogen use efficiency, sustainability, and fruit quality in high-density apple orchards
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Key staff:	Mike Davies, Veronica Martinez, Carlos Angulo
Location of project:	NIAB EMR
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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.

AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

Eleftheria Stavridou

Research Leader

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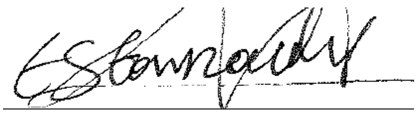
Signature ....  Date ....02/07/2018........

Report authorised by:

[Name]

[Position]

[Organisation]

Signature .... Date ....

GROWER SUMMARY

Headline

- In the final year of this project, application of different levels of nitrogen to Gala and Braeburn did not affect tree Class I yield.

Background and expected deliverables

The adoption of high-density planting systems for apple trees in the UK will increase the use of irrigation to maintain or increase yields against a backdrop of increasing summer temperatures and decreasing water supplies. Broadcast or foliar fertiliser applications have been traditionally used to improve or sustain the nutrition of deciduous fruit tree orchards in the UK. These are often replaced by fertigation in high density irrigated orchards. However, to meet governmental demands for greater environmental protection and to comply with legislation, new production methods that improve water and nutrient use efficiency and utilise 'best practice' are needed. Application of nutrients with fertigation is the most efficient method of nutrient delivery as it offers increased flexibility in managing orchard nutrition programmes because of the potential to more closely synchronise the nutrient application with plant demand.

Nitrogen is often applied in excess of what is required to support optimum productivity and eventually accumulates in the soil and becomes vulnerable to leaching. The major apple growing regions are in areas designated as Nitrate Vulnerable Zones (NVZ's) and growers must reduce their inputs to comply with legislation (The Nitrates Directive Action Programme). As part of the Rural Payments Agency audit, growers in NVZ's have to justify N applications, the relationship between yield and N applications, and prove that industry good practices are followed. Fruit trees recover only about 20% of the applied N fertiliser (Neilsen et al., 2001). The effectiveness of N fertigation in apple orchards is also influenced by the amount of irrigation, as excess water can leach N below the root zone. Apple trees grown on dwarfing rootstocks have low rooting densities and under daily irrigation, the roots congregate close to the surface and the irrigation emitter (Neilsen et al., 1997, Neilsen et al., 2000). Thus, N supply should be targeted to remain in the root zone and allow root interception; effective irrigation scheduling, particularly in coarse-textured soils, will help reduce the deep percolation of nitrogen (N).

There is a paucity of information on the effects of fertigation on the yield, quality and storability of 'Gala' and 'Braeburn'. Daily irrigation decreases leaf N concentration in 'Gala' apple, which implies greater N leaching compared to the intermediate or low irrigation frequencies (Neilsen et al., 1995). Research conducted in the Concept Pear Orchard at NIAB EMR (Else, 2013) has delivered water and fertiliser savings of over 50% by scheduled irrigation without reducing productivity or fruit quality. Else (2016) indicated that scheduled irrigation can be used to improve water use efficiency in apple production. There is a need, however, to assess the effectiveness of any new fertilisation strategies relative to traditional methods and optimise them to ensure yield consistency and quality.

Summary of the project and main conclusions

In the final year of the project, two experiments were carried out on a seven-year-old orchard at NIAB EMR ('Gala'/M.9 and 'Braeburn'/M.9) with a distance of 3.5 m between rows and 1 m between trees within rows. Five N rates (0, 10, 20, 30 and 40 N g in total amounts per tree) were supplied by fertigation taking into consideration the initial soil N content. Irrigation was applied to the trees once the average soil matric potential within the rooting zone had reached -200 kPa but fertiliser was injected for a short period at the end of each irrigation event.

Soil samples were taken after harvest and analysed for nutrient concentration and soil acidification. Foliar and fruit nutrient content was determined during the growing season.

Total and marketable yields were determined. Fruit quality was evaluated at harvest, three and six months after storage. Quality factors evaluated included firmness, percentage and intensity of colour, elemental and sugar (°BRIX) concentrations and disorders.

The Class I yields were not significantly affected by fertilisation treatment on either cultivar (Figure 1A). However, a non-significant tendency for lower yield under the N0 treatment (without N fertiliser) was observed for both cultivars. 'Gala' Class I yield was on average 23 kg per tree, while 'Braeburn' was 18 kg per tree, equating to harvest total of 66 and 51 tonnes per ha, respectively. The lack of yield response to the applied N may be the result of many factors, but especially due to the release of N, from the decomposition of native soil organic matter and senescent leaves. The average number of fruit per tree (Figure 1B) were unaffected by the treatments in either cultivar.

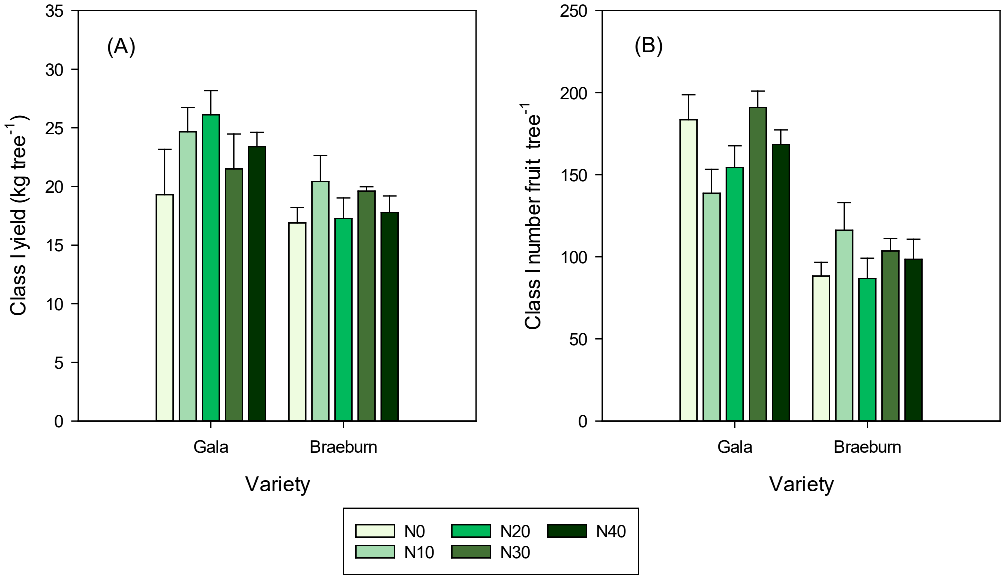


Figure 1. The effects of the fertiliser treatments on Class I yield (A) and the average number of fruit (B) per tree for ‘Braeburn’ and ‘Gala’. Vertical bars are standard errors. There were no statistically significant differences between treatments. Treatments included the following grams of nitrogen per tree: N0=0, N10=10, N20=20, N30=30, N40=40.

Soluble solids content and fruit firmness measured at harvest as well as at 3 and 6 months post-harvest were not significantly affected by fertilisation treatments in either variety (Table 1). ‘Braeburn’ firmness was 87, 82 and 76 N at harvest, 3 and 6 months post-harvest, respectively. While, ‘Gala’ firmness averaged 72, 71 and 70 N at harvest, 3 and 6 months post-harvest, respectively (Table 1). In both varieties, firmness was reduced at the end of the storage period. No differences on soluble solids content were observed during storage. ‘Braeburn’ and ‘Gala’ soluble solid content were on average 11.2 °Brix and 10.5 °Brix, respectively (Table 1). When N application is not excessive, N should not have any detrimental effect on fruit quality and storability. Similarly to Drake et al. (2002) no effect of N levels on fruit firmness and soluble solids, and titratable acidity was found. Raese & Drake (1997) observed that lower rates of N fertiliser promoted greater fruit firmness and soluble solids concentration in 'Fuji' than the higher rates of 113 or 170 kg per ha.

Table 1. Average values of firmness (N) and soluble solid content (ºBrix) for cvs. 'Braeburn' and 'Gala' fruit under different fertilisation treatments at harvest, after 3 and 6 months in storage. Results are mean values of 20 fruits from four plots. There were no statistically significant differences between the treatments.

Cultivar	Treatment	Harvest		3 months after storage		6 months after storage	
		Firmness	Brix	Firmness	Brix	Firmness	Brix
Braeburn	N0	90.3	11.0	82.6	11.1	77.4	11.8
	N10	84.5	11.2	81.4	11.2	75.4	11.0
	N20	86.2	10.9	81.4	10.9	75.8	11.6
	N30	85.9	11.2	81.5	11.3	76.4	11.4
	N40	88.3	11.4	82.0	11.1	76.2	11.2
Significance		*ns*	*ns*	*ns*	*ns*	*ns*	*ns*
Gala	N0	71.4	10.4	72.7	11.3	69.7	9.6
	N10	71.9	10.2	72.2	10.8	71.8	9.1
	N20	71.8	10.6	70.8	11.2	68.6	11.0
	N30	71.8	10.2	71.0	10.7	70.1	10.6
	N40	71.9	10.5	70.8	11.0	70.1	10.3
Significance		*ns*	*ns*	*Ns*	*ns*	*ns*	*ns*

Where ns means there is no significant difference between treatments. Treatments included the following grams of nitrogen per tree: N0=0, N10=10, N20=20, N30=30, N40=40.

The different rates of N on the fertigation have been tested only on one growing season out of the three years of the project; therefore, caution should be taken when interpreting the results. Repeating the experiments for several years should eliminate possible effects of the external environments. Tree N uptake is a result of the association of many factors, such as N release from the decomposition of native soil organic matter and senescent leaves, soil type, tree N reserves, root growth, irrigation management, temperature etc. In order to fully understand tree N requirements and the effect of N fertigation on tree growth and yield as well as fruit quality, long-term studies are needed.

Overall project conclusions from the whole three-year project

Soil solution analysis is a valuable environmental tool that can be used to monitor the changes in soil water chemistry, such as salinity and nitrate, in and just below the root-zone of irrigated crops. The measurements can be used to assist fertilisation and irrigation management decisions. A soil solution sampler comprises a porous ceramic cup connected to a pipe and is easy to construct. Buried beneath the soil surface at the sampling depth of interest, samples are obtained firstly by applying a negative pressure to the soil solution sampler. The sampler is then sealed and left for a few hours and over time the soil solution moves into the sampler. The sample is then collected. A full description of the construction and use of the sampler can be found in the first annual report of the project (Stavridou, 2015). The disadvantage of the sampler is the difficulty of extracting soil solution following prolonged spells of dry conditions, so sampling should be carried out after rainfall or irrigation events.

In the second year of the project, four fertiliser treatments were tested (broadcast fertiliser, commercial fertigation, fertigation scheduled to meet irrigation demand and targeted fertigation). The results indicated that the extent of nitrate leaching differs between apple cultivars. Nitrate concentrations in the soil solution at 50 cm depth were similar or higher to the concentrations in the fertigation solution. At the end of the growing season, soil N content in the 0-50 cm horizon ranged from 73 to 98 kg N per ha, which was prompted to leaching over winter. Leaching of other mobile nutrients such as phosphorus may occur over winter. There were no significant yield and quality differences between fertiliser treatments, in spite of large differences in the volume of nutrients (i.e. nitrogen and potassium) applied.

Taking into consideration that the different N inputs in Year 2 did not affect yield and fruit quality, discussions with the industry representatives led the final years work into investigating optimum levels of N fertigation. N was applied at 4 different rates (0, 10, 20, 30 and 40 g N tree^{-1}), to help to retain N within the root zone and minimise N leaching. The different rates of fertiliser application did not affect tree yield or fruit quality at harvest, after storage in control atmosphere and shelf-life. Sometimes, even when the nutrient availability is lower than the lowest threshold, trees do not respond to fertilisation because of adequate nutrient reserves built up in perennial organs in previous years (Carranca et al. 2018). The lack of yield response to applied N may be the result of many factors, but especially due to the release of N, from the decomposition of native soil organic matter and senescent leaves.

Caution should be taken when interpreting the results, as all the experiments were carried out for only one experimental year. Environmental (i.e. leaching beyond the root zone) and economic (i.e. money spent on fertiliser) considerations highlighted the need to further understand the fate of applied nutrients. Tree N uptake is a result of the association of many factors, such as N release from the decomposition of native soil organic matter and senescent leaves, soil type, tree N reserves, root growth, irrigation management, temperature etc. Repeating the experiments for several years would eliminate possible effect of the external environments. In order to fully understand tree N requirements and the effect of N fertigation on tree growth and yield as well as fruit quality, long-term studies are needed.

Financial benefits

Although there were no significant differences found between the N rates, there was a tendency for lower yield when trees were grown without N fertiliser. Lack of N fertilisation could decrease yield by 20-25% and potentially grower's annual income by up to £5,000 per hectare in a fully cropping orchard. Growers should carefully consider N fertiliser application, as excessive N may reduce fruit quality and increases production costs.

Action points for growers

- There is need to match N application with tree demand, as excessive N fertilisation could cause high nitrate leaching.
- Frequent monitoring using soil suction lysimeters is a useful tool for determining soil solution nitrate concentration in the root zone in response to nutrient and irrigation management. Soil suction lysimeters are easy to install and only disturb a small area of soil. They can be placed at any depth and they are inexpensive if built yourself (Deery et al., 2006, Falivene, 2008).