

Programmed fertigation effects on the growth and production of young cherry trees in central Chile

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Abstract

Nutrient requirements in young trees increase annually during fruit formation. This study was conducted to determine the effect of fertilisation treatments, using fertigation, on the vegetative and reproductive growth of young cherry trees (*Prunus avium*) cv. 'Brooks' grafted onto 'MaxMa 14' rootstocks in Central Chile. The research was conducted at the La Palma Experimental Station in Quillota on 3-yr-old cherry trees spaced at 5 m x 2 m and trained as central leaders with the Solaxe system over the course of two growing seasons. Few of the measured variables were significantly affected by the treatments. The shoot length was affected only after harvest (November), the node number increased with shorter shoots, and the fruit set decreased with no N application. Fertilisation resulted in some negative effects, such as a lower number of nodes (per m⁻¹), decreased fruit set, and increased cracking. Considering the null effect of applying N before harvest and the significant difference in vegetative growth between T₁₀₀ and T₂₀₀ after harvest, it appears that there are at least two different strategies for the fertilisation of young cherry trees: fertilisation should start either after harvest or a few weeks earlier with N applications higher than 100 but lower than 200 kg-N ha⁻¹. This amount should be further investigated, and a combined strategy of less than 200 kg-N ha⁻¹ plus accompanying nutrients applied after harvest should be used.

Keywords: young orchards, sweet cherries, fertigation strategy, N response

1. Introduction

The nutrient requirements of young cherry trees (*Prunus avium* L.) increase during the period of fruit formation, and they continue to increase annually until the trees reach full production. In addition, the nutrient requirements can vary according to training systems, planting density, soil type, climatic conditions and other factors. The availability of nitrogen (N) is one of the crucial aspects of orchard management. The estimated requirements in the first six years range from 8.8 to 44 kg N ha⁻¹ year⁻¹ for pomes and stone fruit trees (Dierend, 2006; Neilsen and Neilsen, 2002), while for adult trees, they range from 39 to 65 kg N ha⁻¹ year⁻¹ (Roversi and Monteforte, 2006). Excess N during the last phase of the annual growth period results in fewer leaves, decreased flowering density, fewer flowers per bud, decreased fruit set and lower yield (Lindhard and Hansen, 1997). Nitrogen excess, although seldom toxic, can cause leaf-yellowing and shoot and tissue death (Agusti, 2004; Coletto, 1995), or it can encourage a too vigorous vegetative growth, lower rates of growth and ripening in fruit, and shorter post-harvest life (Gil, 2000, Hanson and Proebsting, 1996). Experimental results from apple orchards show that N applications before flowering are ineffective. N from the tree reserves at this time is sufficient to meet the requirements at the beginning of the growing season; therefore, it is only after this process has ended that the rapid absorption through the root system begins (Neilsen and Neilsen, 2002). Inadequate dosages and improper timing of N fertiliser application can cause serious negative effects, not only on the trees and fruit but also on the environment, if excess fertiliser is leached out of the soil and reaches local water sources (Domínguez, 1993; Auazo *et al.*, 2006).

For most crops, the amount of available water results in differential effects on both vegetative and reproductive growth. The expansion of the shoots and young branches increases with the amount of water

applied. Conversely, while vegetative growth decreases, foliar abscission increases when the water deficit reaches 50% of ET_c (Livellara *et al.*, 2011). Yield is not affected by moderate water deficit (0.75 ET_c), although the fruit size decreases (Dehghanisanijet *et al.*, 2007, Neilsen *et al.*, 2004). Previous studies on cherry fertigation show that the optimisation of water and nutrient applications is possible. The highest efficiency is obtained with low N applications (50 mg-N L⁻¹) between 0 and 8 weeks after flowering together with irrigation programmed according to the evaporative demand (Hanson and Proebsting, 1996). Leaf N concentration, however, decreases when the total salinity of fertigation solutions exceeds 4 mM (Sotiropoulos *et al.*, 2006). Appropriate applications of water and nutrients allow the temporal adjustment of fertigation requirements according to the phenological state, age and health of the plants, as well as providing an efficient use of water and the reduction of pollution (Neilsen and Neilsen, 2002; Domínguez, 1993).

Climatic conditions, particularly chilling accumulation in winter and temperature and relative humidity in spring, affect shoot growth, flowering and fruit set, as well as the fruit growth and ripening rate (Albuquerque *et al.*, 2008). Soil conditions affect local nutrient availability, particularly for micronutrients, the air/water balance, and root formation capacity, among other factors. Considering that many nutrient uptake studies have been conducted under significantly different climatic conditions from Central Chile, there is a need for local experimentation.

The objective of this study was to determine the effects of nutrient solution applications (by fertigation) on the vegetative growth and reproductive behaviour of young 'Brooks' sweet cherry trees grafted onto a 'MaxMa 14' rootstock (*Prunus avium* L.) grown in Central Chile.

2. Materials and methods

The experiment was conducted in a cherry orchard that was planted in 2003 at the La Palma Experimental Station¹ located in Quillota, Central Chile, during the 2004/2005 and 2005/2006 growing seasons. The area has a marine Mediterranean climate with 339 mm of rainfall annually occurring between March and November, a 15.3°C average annual temperature, and an 853 mm average annual potential evapotranspiration (ET₀). The temperature reaches 27°C in January (mid-summer) and 5.5°C in July (mid-winter). The degree-day accumulation is 3700 (base 5°C) and 1 900 (base 10°C), while the winter chilling accumulation reaches only 500 hours between March and November (Novoa *et al.*, 1989).

The soil is Inceptisol in type and colluvial in origin, with three layers. The first layer is clay loam in texture (to a depth of 50 cm), the second is sandy loam (between 50 and 80 cm), and the third is clay (between 80 and 100 cm). The soil profile depth varies between 80 and 100 cm. The volumetric moisture content (θ , v/v) at field capacity (θ_{FC}) is 0.26, 0.38 and 0.30 at 30, 60 and 90 cm depths, respectively, while the volumetric moisture content (v/v) at the permanent wilting point (θ_{PWP}) at the same depths is 0.11, 0.15 and 0.13, respectively (Livellara *et al.*, 2011).

The orchard used in the study was planted in 2003 with 3-year-old 'Brooks' cherries grafted on a 'Max-Ma 14' rootstock spaced at 5 m x 2 m and trained as Central leaders with the Solaxe system. Each experimental unit consisted of three plants occupying an area of 30 m². As 5 treatment and 3 replicates were used, the area of each treatment was 90 m² plus borders, totalling 450 m² plus borders for the experimental site, within a 1 hectare orchard. The orchard was managed using standard commercial practices for sweet cherry production (Ellenaet *et al.*, 2006; Livellara *et al.*, 2011).

Irrigation was applied from August to November of each season, three days per week with watering of the soil with 100% of the crop evapotranspiration (ETc). The ETc was estimated with the Penman-Monteith method for ET₀ using data from an automated weather station, monthly adjusted with the corresponding crop coefficient (Kc) (Allen *et al.*, 1998) and shade factor (Fs) (Vermeiren and Jobling, 1986). Irrigation took place at night once the volumetric soil humidity (θ) between 20 and 60 cm deep fell to 0.75 of field capacity (FC). The irrigation system was designed into two parallel lines, 60cm from the tree row on either side, and 8 drippers/plant (4 L h⁻¹ each), which were 50cm apart along the lines (Livellara *et al.*, 2011). Nutrients were applied through the irrigation system during the whole irrigation period in a constant proportion. For the second growing season under study (2005/2006), the irrigation water applied totalled 394 mm.

Five different nutrient treatments were applied (Table 1): T₀ – control (no fertiliser); T₅₀ –50% of the programmed fertilisation; T₁₀₀ –100% of the programmed fertilisation; T₂₀₀ –200% of the programmed fertilisation and, T_{100N} –only N equivalent to 100% of the programmed fertilisation. The field experiment was set up using a randomised complete block design with 5 treatments and 3 replicates. To assess the effects of nutrient treatments on vegetative growth, four branches were randomly chosen and marked for measuring length (weekly), basal diameter (monthly) and the number of leaves (counted once during the growing season). The trunk diameter was measured monthly at 15 cm above the graft union. Reproductive growth was evaluated with the same four marked branches used for vegetative measurements by measuring the following: the flowering rate (number of flowers/branch, counted daily between 25 to 29 August), the fruit set number (once during the growing season after drop) and total yield per tree (postharvest). The number of spurs was determined at the beginning and at

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the end of the growing season. The fruit quality was evaluated by measuring soluble solids ($^{\circ}\text{B}$) and by the percentage of fruit with cracking and/or bird damage (%) in random samples of 25 cherries/tree from whole trees. Leaf samples of 10 mature leaves per tree, from the middle third of the corresponding branches, with no visible disease symptoms, were taken for nutrient analysis just before leaf-yellowing at the end of the second growing season (2005/2006).

Table 1. Programmed fertilisation. Reference to develop the 5 different fertigation treatments.

Nutrient	Growing season	
	2004/2005	2005/2006
	kg ha ⁻¹	kg ha ⁻¹
N	60.0	150
P	15.0	30
K	60.0	100
Mg	7.5	20
Zn	7.5	20

3. Results and discussion

Only a few of the measured variables were significantly affected by the nutrient treatments. The shoot length showed differences only after harvest (8 to 22

of November 2005); whereas it was not affected by the amount of N applied through fertigation from the start of shoot growth (August) to harvest (November) (Figure 1). The shoots of the high fertiliser treatment T_{200} grew significantly longer than the others between harvest and the end of the growing season (March); however, no differences were found among the T_0 , T_{50} or T_{100} treatments. T_{100N} had the lowest cumulative length (Figure 1), while the mean growth rate for the most rapid period of growth (November 4 to January 3, approximately) showed a ratio of 1.0 : 1.5 : 3.0 for (T_{100N}) : (average T_0 , T_{50} , T_{100}) : (T_{200}), respectively. These results indicate that, first, there are no measurable effects of the fertiliser applications before harvest, which is in accord with Neilsen *et al.* (1998). Second, after harvest, the application of N_{100} without other nutrients (P, K, Mg, Zn) in the fertigation solution results in only one-third of the vegetative growth of the higher rate treatment (T_{200}) and two-thirds with respect to the other treatments, including the unfertilised treatment (T_0). This effect of the lack of other important nutrients provokes physiological imbalance. Another remarkable result is that the 60 or 150 kg ha⁻¹ of N (T_{100} , depending on the growing season) was not enough to increase growth with respect to the unfertilised treatment (T_0), which is also in agreement with the results of Neilsen *et al.* (1998).

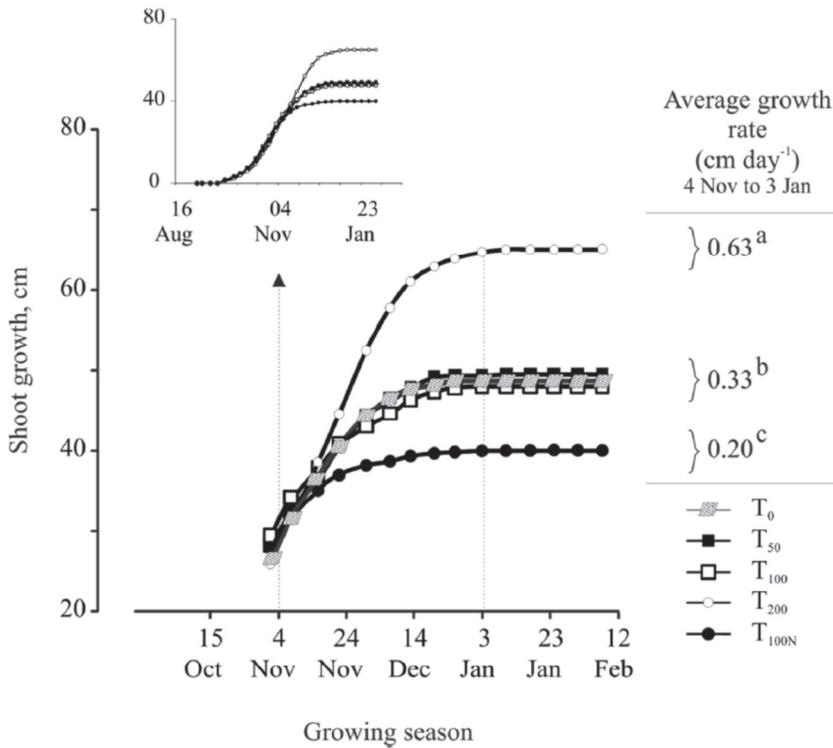


Figure 1. Effect of the 5 fertigation treatments on the shoot growth of young ‘Brooks’ sweet cherry trees on a MaxMa 14 rootstock.

In addition, over fertilisation may result in negative effects. We found that the highest N fertilisation produced an increase of shoot growth (Figure 1), but we also found a reduction in the number of nodes (No. m⁻¹) (Figure 2A), which means that the excess of N provokes an imbalance towards vegetative growth and reduced flowering and fruitset for the following season (Figure 2B). In addition, cracking damage increases as

a result of high N fertilisation (Figure 2C). With respect to fruit production, there was no significant difference between treatments. However, the fruit size distribution showed differences between the two treatment groups: T₀ and T_{100N} with respect to T₅₀, T₁₀₀ and T₂₀₀ (Figure 3). These last two variables, however, were less relevant, as the trees were still very young (1 to 2 years) and had only just started to produce a small amount of fruit.

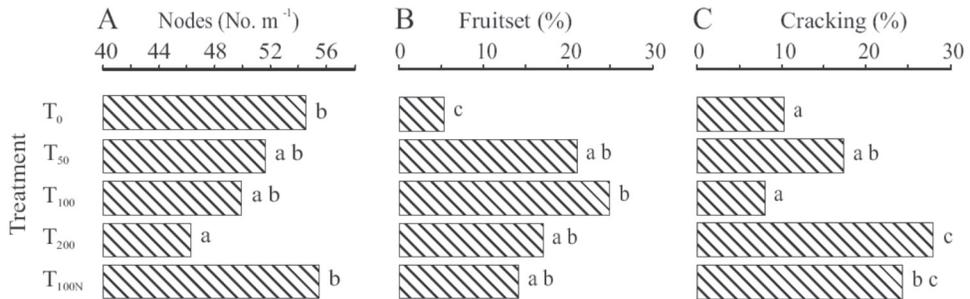


Figure 2. Effect of the 5 fertigation treatments on the number of nodes (A), fruitset (B) and cracking (C) of young ‘Brooks’ sweet cherry trees on a MaxMa14 rootstock.

Considering the null effect of fertilisation before harvest and the significant difference in vegetative growth rates between T₁₀₀ and T₂₀₀ after harvest, it seems that there are at least two different strategies for the fertilisation of young cherry trees: either fertilisation should begin after harvest or a few weeks earlier,

or the N application rate should be higher than 100 but lower than 200 kg ha⁻¹, although this rate should be further investigated and refined. Finally, perhaps the best results would be obtained with a combined strategy of using less than 200 N kg ha⁻¹ in addition to accompanying nutrients applied after harvest.

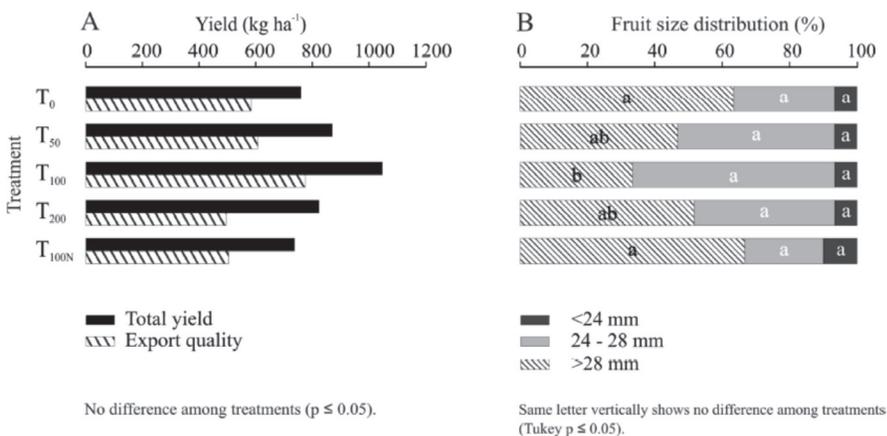


Figure 3. Effect of the 5 fertigation treatments on the yield of young Brooks sweet cherry trees on a MaxMa14 rootstock (A) and their fruit size distribution.

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