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Preliminary observations regarding the effect of daily drip irrigation by pulsing on the optimisation of almond tree management in sandy soils in Australia

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SUMMARY – The issue of crop water usage is becoming increasingly important in Australia, as in many countries with dwindling water resources. This study aims to investigate and quantify the commercial advantages of optimizing water usage per ton of almonds produced, as opposed to the more common approach of minimizing water usage per hectare. In defining the optimal irrigation to apply, there is a need to ensure that tree water uptake efficiency is maximized, that there is a demonstrated economic marginal return for each kilolitre of water applied and that all other facets of almond orchard management compliment each other as well as the irrigation management. This work seeks to adapt previous findings by Assaf *et al.* in apples and stone fruit in Israel to conditions typical in commercial almond orchards in Australia. These conditions include a Mediterranean climate and sandy to sandy loam infertile soils, usually overlaying a calcareous subsoil and summer daily temperatures of 30°C to 46°C. Our initial findings appear to concur with those of Assaf, who found both soil aeration and wetted soil profile to be around 60% greater using this irrigation technique. Lateral distribution of the water was found to be up to 2.5 m when using 4 l drippers at one meter spacing, effectively giving nearly full orchard floor coverage. This paper outlines some preliminary observations regarding the importance of daily pulse irrigation techniques in maximizing the volume of the wetted soil profile, developing extensive and healthy root systems, maximizing the utilization by the trees of the water applied, and minimizing overall losses through the soil profile. Through these gains, the production of almonds per liter of water can be optimised. Considerable benefits were also observed in increasing the efficiency of other management inputs such as nutrition and canopy management, resulting in better tree health and a significant improvement in cropping performance.

Key words: Irrigation, almond, sandy soils, orchard management.

RESUME – *"Observations préliminaires concernant l'effet de l'irrigation localisée journalière par intervalles sur l'optimisation de la conduite des amandiers dans les sols sablonneux d'Australie". La question de l'utilisation de l'eau des cultures est de plus en plus importante en Australie, comme dans nombre de pays où les ressources en eau diminuent. Cette étude vise à examiner et quantifier les avantages commerciaux de l'optimisation de l'utilisation de l'eau par tonne d'amandes produites, en opposition à l'approche plus répandue de minimisation de l'eau utilisée par hectare. Dans la définition de l'irrigation optimale à appliquer, il est nécessaire de veiller à maximiser l'efficience d'absorption d'eau par l'arbre, à qu'il y ait un rendement économique marginal démontré pour chaque kilolitre d'eau appliqué, et à que toutes les autres facettes de la conduite des vergers d'amandiers se complémentent de la même façon que la conduite de l'irrigation. Ce travail cherche à adapter des découvertes préalables faites par Assaf* et al. *chez les pommes et les fruits à noyau en Israël, aux conditions typiques des plantations commerciales d'amandiers en Australie. Ces conditions comprennent un climat méditerranéen et des sols infertiles sablonneux ou limo-sablonneux, en général sur un sous-sol calcaire, et des températures diurnes en été de 30 à 46ºC. Nos résultats initiaux semblent concorder avec ceux de Assaf, qui avait trouvé que l'aération du sol et le profil humide du sol étaient tous deux supérieurs de 60% en utilisant cette technique d'irrigation. La distribution latérale de l'eau s'est avérée aller jusqu'à 2,5 mètres lorsque l'on utilisait des tuyaux de 4 litres à un mètre d'espacement ; en effet ceci permet une couverture du sol dans pratiquement toute la plantation. Cet article souligne certaines observations préliminaires concernant l'importance des techniques d'irrigation à intervalles journaliers pour maximiser le volume de profil humide du sol, et développer des systèmes racinaires extensifs et sains, maximisant ainsi l'utilisation de l'eau appliquée par les arbres, et minimisant les pertes globales à travers le profil du sol. Grâce à ces gains, la production d'amandes par litre d'eau peut être optimisée. Des avantages considérables ont également été observés en augmentant l'efficacité des autres éléments de conduite tels que la nutrition et la conduite de la canopée, donnant lieu à une meilleure santé de l'arbre et à une amélioration significative des performances de la culture.*

Mots-clés : *Irrigation, amandier, sols sablonneux, conduite du verger.*

Introduction

Generally, the recent improvements made in the management of almond orchards have been based upon implementing changes to specific and often isolated aspects such as nutrition, irrigation and canopy management. While significant gains have been made, the study of the interaction of the various aspects has rarely been made, possibly due to it being more complex and involving many disciplines.

However, if the commercial performance of orchards is to be significantly advanced further, this interaction may prove to be the key to defining the synergies that may ultimately lead to the optimization of management inputs. This optimization should provide the most efficient and commercially profitable almond orchards.

This trial is designed to specifically study the key management components of irrigation, nutrition and canopy management and their interaction. This paper is confined to reporting on the preliminary observations regarding the effects of daily pulsing irrigations on soil wetted profile, tree growth, yield and kernel size.

Materials and methods

The trial was set up in 2002 on a 3-year old commercial almond orchard with trees spaced 6.7 m x 6.09 m. Soils are sandy to light sandy loams varying in depth from 50 cm to 1.6 m (typically 60 cm) above a well drained calcareous marl of pH 8.5 to 9.0. Readily available water (RAW) values are 30 to 35 mm per meter. The cultivars are 'Nonpareil', 'Ne Plus Ultra' and 'Carmel', all on 'Nemaguard' rootstocks. Roots do not extend into the calcareous layer.

Experimental design is randomized block with 4 replicates (10 trees in each replicate) and 6 treatments plus control (Table 1). Treatments consist of 3 levels of irrigation overlaid by 3 levels of nutrition, with treatment 4 being an "open" treatment, which in the future will be modified to incorporate the most commercially desirable findings from treatments 1,2,3,5 and 6. The control emulates "average" orchard management practices typical in Australia.

Table 1. Treatment design

Treatment	Irrigation	Nutrition
1	100%	Low
2	100%	Medium
3	100%	High
4	100%	Medium ("open" treatment)
5	160%	Medium
6	60%	Medium
Control	Scheduling by Enviroscan®	Industry standard

Irrigation is by drippers, with the control continuing with the original aboveground dual laterals using 2.35 lph inline drippers spaced at 60 cm, while the 6 treatments had new 4lph pressure compensated drippers, spaced at 1 m installed. The dual laterals were installed 10 cm below ground and at 1 metre on each side of the trees. Precipitation rates are 1.17 mm per hour for the control and 1.19 mm per hour for the treatments.

Soil moisture monitoring is by neutron probe, with tubes being installed at 0, 20, 40, 60 and 80 cm from the drippers for one site in each of the three irrigation treatments, plus a single tube replicate at 20 cm from the dripper in each treatment and block. This gives a total of 32 tubes. Readings are taken weekly and at 10 cm intervals up to 1.6 m. Additionally, the control has an Enviroscan® capacitance soil moisture monitoring system installed, with this being used to schedule irrigations for the control.

Irrigation scheduling for the treatments is by the use of daily Class A evaporation pan readings, combined with the use of specific crop factors, determined by the stage of the annual growth cycle and tree canopy development and crop load. Neutron probe readings combined with curves correlating probe readings and soil moisture content determined for our soil conditions enabled the calculation of the volume of actual water usage.

The standard irrigation treatment (100%) aimed to work with a soil moisture content of field capacity, plus or minus 5%. Treatments 5 and 6 are then calculated from the daily amounts applied to treatment 2, using the relevant factor for each treatment to adjust.

Irrigation applications

The initial application in spring aims to specifically build the soil moisture profile. All treatments (except the control) received approximately 80 mm of irrigation to build the initial profile and give field capacity over as greater volume of soil as possible. This process was undertaken just prior to the initiation of root growth. Thus both the soil moisture and aeration were at an optimum level to encourage rapid and extensive root growth.

After this initial application, no irrigation was applied until the commencement of fruit set, at approximately 20% flowering. From this point on irrigation was applied as dictated by daily tree usage.

All irrigation applications, except for the control are by daily pulses. That is, irrigation is applied each day, with as much of the application being during daylight hours as possible. Pulses are normally 1 hour on and one hour off alternately, except for the occasions in the middle of summer when daily demand exceeds the ability to apply the water required in the time available per day, that is 12 hours.

Any discrepancies between the calculated amount required and that applied are reconciled weekly and adjustments made each Monday.

The control receives water as defined by the trends shown on the graph produced by the Enviroscan®. Application volumes and frequency vary according to demand, with the exception that no water is applied for the 36 hour period prior reading the accompanying neutron probe on the Friday morning. This was to overcome extreme variation in readings caused by the erratic application pattern for the control and subsequent difficulties in comparing trends with the treatments, which have a more stable soil moisture profile.

Results and discussion

Results to date are preliminary, and truly represent the first season only and have not yet been fully statistically analysed. The trees will take at least a further year, possibly two, to adjust fully to the treatments. At this time, the data should be both more conclusive and show a more defined difference in the treatments. However, initial results appear to indicate some interesting trends and seem to support the earlier findings of Assaf *et al.*

Water application

In the initial season (2001/02), water volumes were applied equally across the treatments, although the fertilizer regimes were as per design. Initially all scheduling was by Enviroscan® until the neutron probe tubes were installed for 2002/03. Irrigations were applied once per day until the commencement of pulsing in February 2002 when a computer controller able to manage the complex programming became available. Initial root establishment and efficiencies would therefore be influenced. Pulsing irrigations have been used since this date.

All water applications for the 2002/03 season were as per treatment design. Water applications for the standard irrigation treatments (100%), treatment 5 (60%) and treatment 6 (160%) in 2002/03 were 19.25 megaliters per ha, 12.25 megaliters and 27.75 megaliters respectively. Under similar conditions, commercial growers used up to 16.0 megaliters per ha.

Root growth and development

The root development was assessed and measured by digging six inspection trenches randomly under the tree drip lines on the northern side of the selected trees of the control and treatments 2 and 6.

In all instances where pulsing irrigation had been applied, the root system was extensive, covering the majority of the orchard surface. In the case of the control, the root system was compact and in some instances, exceedingly dense. In all cases, the extent of the root system lateral development directly reflected the soil moisture profile (Table 2). In no instances did the 'Nemaguard' roots penetrate the calcareous layer. This was not due to any physical barrier, since drainage and aeration were good. Nemaguard appears to be very sensitive to the high pH levels experienced in the subsoil.

Table 2. Root system development

Treatment	Mean width	Lateral spread from drip lines	% area covered	Root development
Pulsing	6 m	2 m	89.5	Extensive and evenly spread
Control	3.5 m	0.8 m	52.2	Concentrated under drippers, little lateral spread

Crop yields

Yields were influenced by frost severely affecting approximately 1/3 of the trial block in September 2003. Further statistical analysis will be necessary to overcome this problem. However, the following data (Tables 3 and 4) provides interesting trends although the influence of the nutrition treatments is also a factor.

Table 3. 2001/2002 Season yields ('Nonpareil')

	T1	T2	T3	T4	T5	T6	Control
Kernel/tree (kg)	5.76	5.63	5.51	5.32	5.45	5.62	5.49
Kernel/ha (tonnes)	1.410	1.376	1.346	1.300	1.332	1.373	1.344
Kernel % (of total fruit)	28.95	29.39	28.61	28.38	29.35	29.25	30.09
Mean kernel weight (g)	1.34	1.42	1.37	1.35	1.38	1.36	1.36

Table 4. 2002/2003 Season yields ('Nonpareil')

	T1	T2	T3	T4	T5	T6	Control
Kernel/tree (kg)	11.00	12.34	12.63	11.18	10.90	11.03	5.69
Kernel/ha (tonnes)	2.690	3.018	3.087	2.735	2.667	2.697	1.349
Kernel % (of total fruit)	31.97	32.30	32.91	32.51	32.01	30.51	26.95
Mean kernel weight (g)	1.42	1.40	1.41	1.43	1.45	1.37	1.20

2001/2002 was the first season, and since tree size and cropping potential had been set by the previous season's management and growing conditions, little or no effect could be expected from the trial treatments in regard to yield. Tree growth during this season did, however, show significant differences (see below).

Yields overall compared to the previous year are significantly increased. Importantly, kernel size has remained high with all treatments and this is also reflected in the kernel percentages. This indicates that although the crop load was high, the trees were not under significant stress and were able to fill out the kernel very well. Again it is too early to evaluate the treatments and the respective yields as the trees are adapting and the most significant difference at this early stage is in tree growth and development. This will have a much greater influence on yields in the next and subsequent seasons.

Table 5 shows that there appears to be an effect of the irrigation regimes on the increase in yield from 2001/2002 to 2002/2003. Treatment 6 did not increase yields as much as treatment 2, with increases being 96% and 119% respectively. The control compares poorly with a 1% increase. Additionally, treatment 2 increased the kernel percentage by 10%, while treatment 6 had a 4% increase. Comparatively, the control decreased by 10%. This seems to suggest a relationship between soil moisture levels and kernel filling. A similar relationship is shown with kernel size in Tables 4 and 5. It is possible that mean kernel weights of 1.4 to 1.45 grams indicate the genetic potential of 'Nonpareil'.

Table 5. % increase in season yields: 2001/2002 to 2002/2003 ('Nonpareil')

	T1	T2	T3	T4	T5	T6	Control
Yield	91	119	129	110	100	96	1
Kernel % (of total fruit)	10	10	15	14.5	9	4	-10

Tree growth

Tree growth is measured annually, in winter. Measurements are taken of the trunk circumference at 20 cm from the soil.

The development of the trees and thus cropping potential for future seasons shows a similar correlation to irrigation treatments, as does the increase in crop, discussed previously (Table 6). After 2 years, treatment 2 trees are both larger than either treatment 6 or the Control and are developing more rapidly. Development in 2002/2003 is less overall than that experienced in 2001/2002, this being due to the trees approaching full canopy size.

Table 6. Mean trunk circumference (mm)

	T1	T2	T3	T4	T5	T6	Control
2001	380	352	371	369	364	362	369
2002	507	484	516	498	498	487	471
% increase 2001/2002	34	38	39	35	37	35	28
2003	603	584	619	600	600	564	538
% increase 2002/2003	19	21	20	20	21	16	14

Conclusions

It is too early to draw conclusions regarding the relative performance of the treatments. Unfortunately large sections of the control were subject to frost damage in September 2002. Further statistical analysis may be able to remove the effect. However, initial data appears to show an encouraging correlation between the irrigation treatments and yields, kernel weight and kernel percentage.

The greatest short term results are shown by tree growth and development. The treatments resulting in faster tree canopy development, highly ramified canopies and well developed buds should provide the most productive trees in the long term. An important aspect of the trial will be to ensure consistency of yields, by ensuring that the trees are not stressed under the heavy crop loads they are expected to carry.

Irrigation as per the treatment design commenced at the beginning of the 2002/2003 season and the first yield to be truly influenced by the trial treatments will be the 2003/2004 season.