Timing Nutrient Inputs for Best Effect

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Summary

Soil solution monitoring beneath an Almond irrigation and nutrition trial identified key considerations for managing fertigation in high input/high yield almond production systems. This factsheet reports issues relating to the timing of nutrient applications.

It was found that nutrient applications in late winter, following profile establishment irrigations, are susceptible to leaching due to rainfall and irrigation, as a result of very low uptake of nutrients at this time.

Crop nutrient demand was high during spring and early summer, up until hull split, corresponding to the peak growth stages of the almond nut. Fertigation applications during this period that are well matched to crop requirements result in good crop uptake and minimal leaching losses.

Crop nutrient demand declined after hull split, and applications of fertiliser after this time are susceptible to leaching from rainfall and irrigation.

Post-harvest fertiliser applications in April and May are susceptible to leaching due to very low uptake of nutrients at this time, and throughout winter. Applications may be best applied in March.

Introduction

The Almond Board of Australia, with assistance from Horticulture Australia Limited (HAL), established a trial, "Sustainable Optimisation of Australian Almond Production" at CT Farms near Berri, South Australia. The aim of the trial was to investigate the impact of different rates of water and fertiliser on Almond growth and productivity.

A number of questions were raised by the results of the trial:

- Yield increased from the low (60% Etc) to medium (100% Etc) irrigation treatments, but the difference was not significant.
- There were no significant yield differences between fertiliser treatments, in spite of large differences in the amount of nutrients (i.e. nitrogen and potassium) applied.
- Soil analysis indicated nitrogen and potassium were accumulating within the deeper layers of the soil profile between seasons.
- Nitrogen and potassium increased over the life of the trial, and were well above levels generally seen across the Almond industry, and above the recommendations of Robinson, Treeby, and Stephenson (1997).
- Nutrient analysis of harvested fruit indicated exported nitrogen levels were 12% greater than the amount of nitrogen fertiliser applied in Treatment 1 (240 kg/ha N).
- Nutrient analysis of harvested fruit indicated exported nitrogen levels were less than the amount of nitrogen fertiliser applied in Treatment 2 (320 kg/ha N).
- Exported potassium levels were consistently lower than the amount of potassium fertiliser applied across all treatments.
- 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.

All of these considerations suggested better understanding of nutrient movement and uptake were needed in order for Almond growers to make better decisions about fertiliser applications and irrigation management.

In response, the South Australian Research and Development Institute (SARDI) were invited to establish a

Table 1: Irrigation and Nutrient Treatments

Treatment	Irrigation (% of Target)	Nutrient (N:K) (kg/ha/yr)
T1	100	240:400
T2	100	320:600
T3	100	480:800
T6	60	320:600
T7 (2001/02 to 2007/08)	Irregular	180:87
T7 (from 2008/09)	100	240:400

Table 2: Nutrient Treatment Details

Fertiliser Application	Timing	Amount of N : K Applied (kg/ha)					
		T1		T2 & T6		T3	
		N	K	N	K	N	K
Postharvest	21/4/09 – 15/5/09	75	132	75	132	75	132
Profile Establishment	5/8/09 – 12/8/09	32.5	95	32.5	95	32.5	95
Growing Season	1/9/09 – 6/11/09	132.5	173	132.5	173	132.5	173
	7/11/09 – 8/1/10	-	-	80	200	80	200
	9/1/10 – 19/2/10	-	-	-	-	160	200
	Sub Total	132.5	173	212.5	373	372.5	573
Annual Total		240	400	320	600	480	800

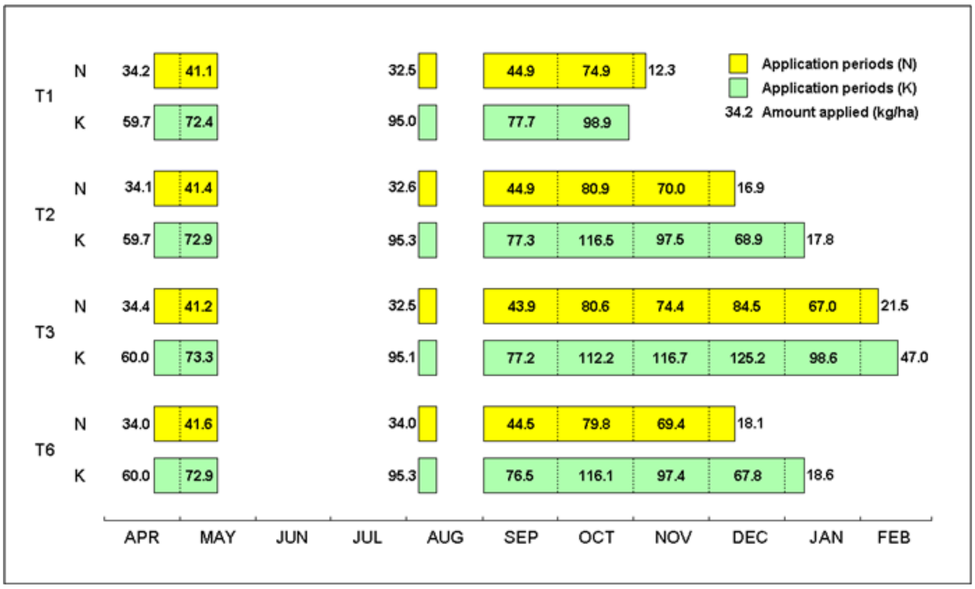

Figure 1: Monthly nutrient applications (kg/ha) by treatment

SoluSamplers® were installed at depths of 30 and 60 cm within the active root zone, and at 90 and 150 cm beyond the root zone (Figure 2), and sampled weekly throughout the season. Samples were unable to be taken when soil water content fell too low (i.e. <60kPa), as happened during the dry winter of 2009.

Concentration of specific ions were analysed in the samples collected, and used to evaluate a number of hypotheses regarding the movement and fate of nutrients at the trial site.

This Factsheet discusses the results of soil solution analysis as they relate to issues of timing of fertiliser applications. The hypotheses proposed address the efficacy of fertigation applied at various stages of the growing season.

All About Almonds –Balancing Nutrient Input and Output: CT Trial Results discusses soil solution results as they relate to nutrient balance within the soil/water/plant system.

Hypothesis 1

If 250 kg/ha of potassium nitrate is applied in late winter following the profile establishment irrigation, then nitrogen and potassium will remain in the root zone for early season uptake.

Findings and Lessons Learnt

Immediately following the beginning of the potassium nitrate applications on 5th August 2009, the nitrate concentration increased rapidly at 30cm and continued to increase until the completion of the applications on 12th August (Figure 3).

The increase in nitrate concentration at 30cm during profile establishment was expected, due to the large application of fertiliser. The continued rise in nitrate concentration between profile establishment and the beginning of spring irrigations corresponds to a slow decline in soil water content, leading to an increase in nitrogen per volume of stored water (i.e. mg/L).

Once spring irrigations began on 21st August, the nitrate concentration at 30cm progressively declined, but simultaneously began to rise at 60 and to a lesser extent 90cm (Figure 3).

The large rise in nitrate concentration at 60 cm suggests some of the decline at 30 cm was due to movement of fertiliser through the profile. It is not clear how much nitrate was actually taken up by the trees during and following profile establishment, but it was clear that not all the nitrate applied was taken up, and as a result it was vulnerable to leaching from the root zone by rainfall or irrigation.

Potassium levels were elevated prior to the application of the profile establishment fertigation, and subsequently declined during application (Figure 4).

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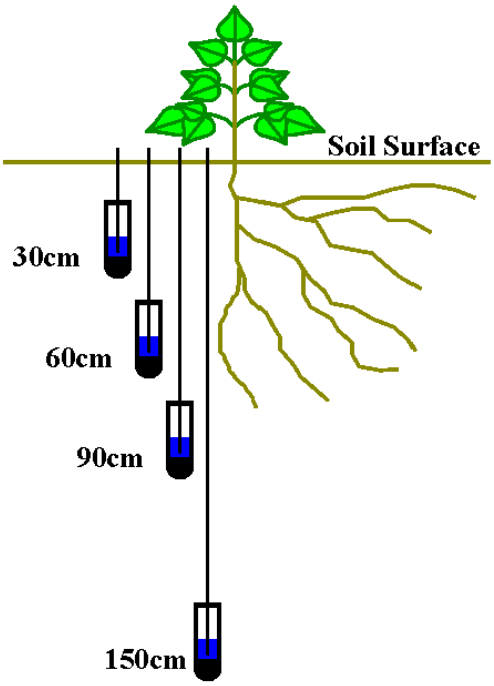


Figure 2: Layout of SoluSamplers within the trial site

The soil at the trial site was naturally high in potassium. In addition, the trial received spring and post harvest fertiliser applications of potassium over a number of seasons. As a result, natural abundance and prior applications of potassium combined with the low mobility of potassium resulted in relatively high concentrations of potassium in the soil throughout the season. The decline in concentration during profile establishment fertigation was likely due to increased soil water content and a reduction in concentration, and leaching to 90cm where concentrations increased.

Although slightly delayed, there was a rise in potassium concentration at all soil depths following application of potassium nitrate in August 2009 (Figure 4), followed by a decline in concentration once spring irrigations commenced.

The rise in potassium concentration at 60 cm depth during and following profile establishment indicates that potassium initially moved through the soil profile. Results indicate potassium reached 90 cm and 150 cm.

Further Work

Further work should focus on the nutritional requirements of almond trees at profile establishment, to identify the most appropriate timing of fertiliser applications and the amount of fertiliser required.

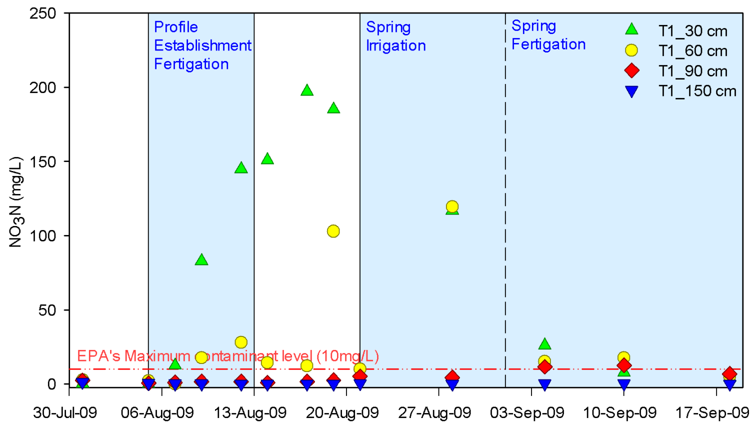


Figure 3: Nitrate concentration in Treatment 1 (240:400) associated with profile establishment

Hypothesis 2

If the concentration of nitrogen and potassium did not increase at depth prior to hull split, then spring and early summer fertiliser applications were well matched to crop requirements and efficiently utilised by the crop.

Findings and Lessons Learnt

Nitrate concentration declined at 30 and 60cm in late August and early September, and remained relatively low and stable during September and October (Figure 5). Nitrate concentrations remained relatively low and stable at 90 and 150cm during late August, September and October.

Given nitrate concentrations slightly increased at 60cm in early September and concentrations subsequently remained relatively constant at all depths, nitrate was likely to have been partially leached beyond 60cm and removed from solution by plant uptake.

Low nitrate concentrations in deeper soil layers suggest minimal leaching occurred, which combined with the observations above, suggests the majority of nitrate applied between August and the end of November was taken up by plant roots.

Nitrate concentrations increased in late November and early December at 30cm and 60cm. However, nitrate concentrations remained relatively low at 90 and 150cm through November, December and early January (i.e. hull split).

The high nitrate concentrations at 30 cm soil depth were likely a result of high crop water use, soil surface evaporation, and reduced soil water content, leading to increased nitrate concentration.

Potassium concentrations remained relatively stable in September and October at all depths (Figure 6). Concentrations rose briefly at 30 and 60cm in the beginning of November, then returned to pre November levels and remained relatively stable until early January.

Potassium concentrations were generally higher than nitrate, reflecting the greater soil content of potassium. High concentrations at 30 and 60 cm in early November may have been due to concentration as a result of crop water use and surface evaporation, as described previously. Potassium concentrations increased at 90cm from early November, suggesting some leaching. The absence of large changes at 90 and 150 cm suggested minimal leaching.

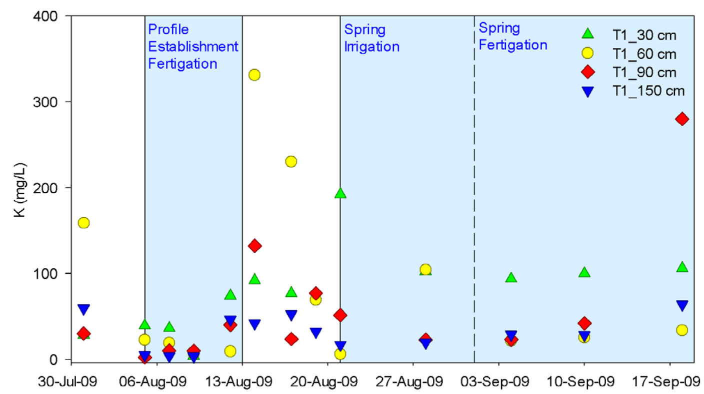
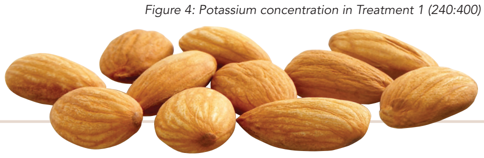


Figure 4: Potassium concentration in Treatment 1 (240:400) associated with profile establishment



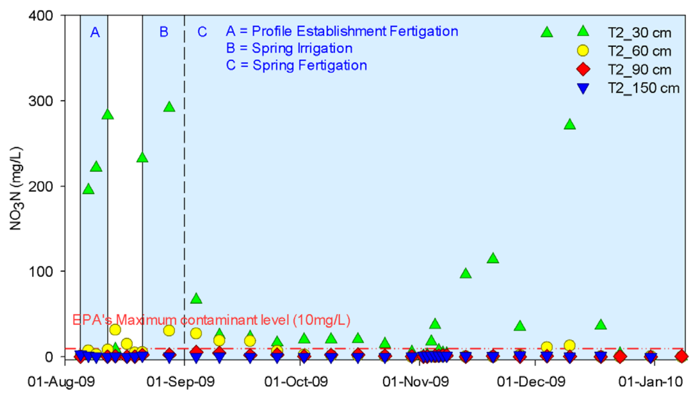


Figure 5: Nitrate concentration in Treatment 2 (320:600) associated with spring and summer fertigation

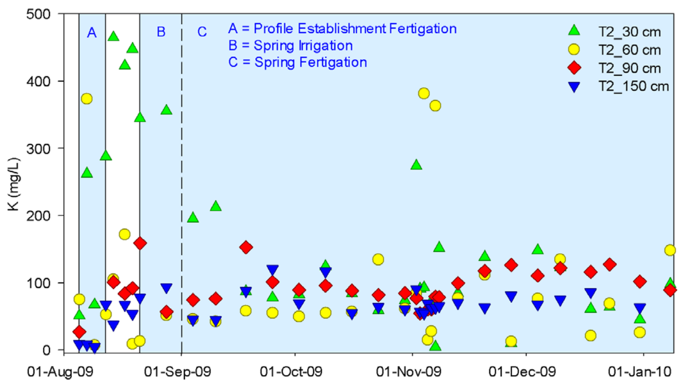


Figure 6: Potassium concentration in Treatment 2 (320:600) associated with spring and summer fertigation

Further Work

Further work should focus on the water and nutrient requirements of almonds during spring and early summer. The results suggest nitrogen and potassium applications in spring and summer were well matched and water was limiting in November, a conclusion supported by soil water data.

Hypothesis 3

If fertiliser applications continue after kernel development and hull split (e.g. Treatment 3), then fertiliser will be unutilised and accumulate in the profile.

Findings and Lessons Learnt

Figure 7 illustrates the development of Almond fruit over the course of the season, as determined by Hawker and Buttrose (1980). Approximate dates were transferred to Figure 8 and Figure 9 to assist in comparison with soil solution data.

When fertigation was extended beyond embryo/kernel extension (early December), nitrate concentration increased briefly at all depths, and then declined (Figure 8).

The sudden increase in T3 nitrate concentration in early December (Figure 8) coincided with the end of Endosperm growth (Figure 7), and could either suggest a concentration effect caused by high crop water use and poorly matched water applications, or a decline in crop nutrient requirements at this point, allowing accumulation of nitrate throughout the soil profile.

The subsequent decrease in concentration at 30 and 60cm, and increase at 90cm suggests nitrate leached out of the root zone. This does not correlate well to the pattern seen in T2 (Figure 5), where the increase in early December was only seen at 30 cm, with no suggestion of leaching beyond that depth.

When fertigation was applied beyond hull split (early January), nitrate concentration increased at all depths (Figure 8).

Following the completion of kernel growth and beginning of hull split, (Figure 7), nitrate concentration increased at all depths. The gradual increase in concentration at all depths, particularly at 90 and 150 cm, suggests leaching through the soil profile. This strongly suggests the nitrate requirement of Almond trees is considerably less following hull split, a conclusion supported by the decline in active fruit growth shown in Figure 7.

Following the completion of embryo/kernel growth (early December), the concentration of potassium was variable with no clear trend (Figure 9).

Potassium concentration increased at all depths following hull split in late January (Figure 9), a pattern remarkably similar to nitrate (Figure 8).

The rise in potassium concentration at all depths following hull split, particularly at 90 and 150 cm, suggest potassium applications were above crop requirements and leached through the profile. Soil water data indicates the increased concentration was not due to drying of soil.

Hypothesis 4

If fertiliser is applied immediately following harvest and prior to defoliation, then the fertiliser will be utilised by the crop.

Findings and Lessons Learnt

T6 Nitrate concentration during postharvest and profile establishment are shown in Figure 10. Nitrate concentration increased considerably at all depths during postharvest fertigation.

Although T6 was the reduced irrigation treatment, all treatments received similar irrigation and fertigation programs during postharvest and profile establishment (Table 2). The increase in concentration at all depths (no data available for 150 cm) indicates some of the nitrate applied during postharvest fertigation leached beyond the active root zone, to at least 90cm. This suggests irrigation applications at this time were higher than crop water use. The quantity of leached nitrate is unable to be determined from this data.

Following the completion of fertigation in May 2009, nitrate concentration decreased at 30 and 60cm depth, and remained relatively unchanged and high at 90 cm. When irrigation resumed in late July 2009, nitrate concentrations at all depths decreased rapidly.

The decrease at 30 and 60cm suggests nitrate was either taken up by roots or leached by irrigation and rainfall. The slower decline at 60 cm and the high concentration at 90 cm for a month after fertiliser applications ceased, combined with relatively static soil water data, suggest that there may have been some uptake during this period, combined with slow leaching due to rainfall.

The decline in nitrate concentration at all depths in July indicates a portion of the fertiliser applied in May was leached through the profile and not taken up by the tree. The higher concentrations at 150 cm further indicate leaching of residual fertiliser occurred rather than uptake.

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Further Work

The focus of further work should be on changes in crop nutritional requirements across the course of the growing season. It would appear that nutritional requirements reduce following embryo/kernel growth, and decline further following hull split, but it is not clear by how much. A clear understanding of requirements relative to the physiological growth stages of almonds would be a most useful tool for growers in managing nutrient applications.

Following the completion of fertigation in May 2009, potassium concentration decreased at 30 cm depth, and remained relatively unchanged and high at 60 and 90 cm depth. When irrigation resumed in late July 2009, potassium concentrations at all depths decreased rapidly.(Figure 11)

The data appears to be similar to nitrate, with a portion of potassium applications being leached through the profile and not taken up by the plant in May, and further leached beyond the active rootzone following profile establishment irrigations in July and August.

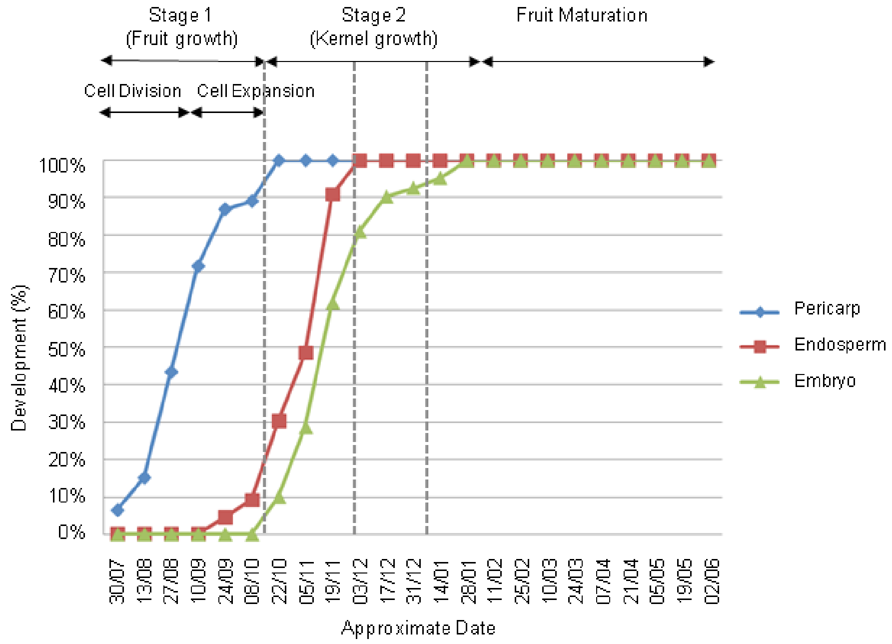

Figure 7: Almond fruit development (adapted from Hawker & Buttrose, 1980)

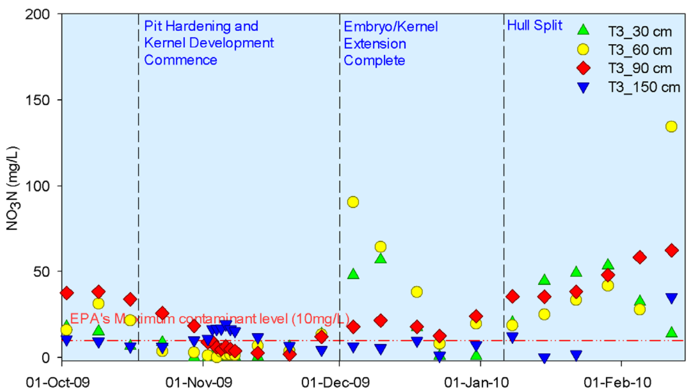

Figure 8: Nitrate concentration in Treatment 3 (480:800) associated with spring and summer fertigation

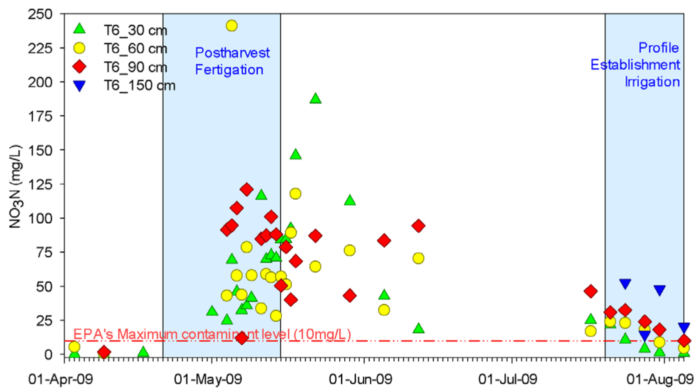

Figure 10: Nitrate concentration in Treatment 6 (60%ETc, 320:600) associated with postharvest fertigation

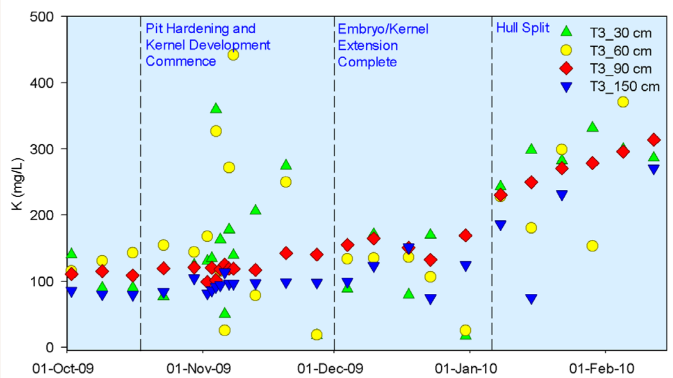

Figure 9: Potassium concentration in Treatment 3 (480:800) associated with spring and summer fertigation

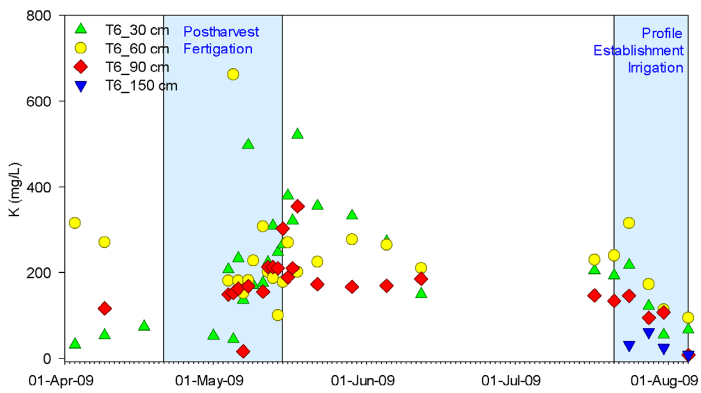

Figure 11: Potassium concentration in Treatment 6 (60%ETc, 320:600) associated with postharvest fertigation

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