Angle Vale Leaf Tatter

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Scholefield Robinson
HORTICULTURAL SERVICES

FINAL REPORT
Angle Vale Leaf Tatter and Defoliation Disorder (LTD)

Prepared for	:	Horticulture Australia Ltd
HAL Project No.	:	AL07006
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HAL Project No. AL07006

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PURPOSE OF REPORT

This Final Report concludes the third year of industry-supported field research undertaken to investigate the cause and control of an almond disorder currently confined to the northern Adelaide Plains (NAP). The Angle Vale Leaf Tatter and Defoliation disorder (LTD) has been the subject of investigations over four seasons. This project was a single-season extension of project AL05003c, approved for the purpose of repeating the field trials of 2006/07, a season in which LTD did not develop. Until season 2006/07 the LTD disorder had been widespread on the NAP, and had resulted in economic losses over the previous four seasons.

This report includes information on the 2007/08 field trial established. It should be read in conjunction with the Final Report for project AL05006c, which includes field and laboratory research results from seasons 2004/05 - 2006/07.

ACKNOWLEDGMENTS

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APRIL, 2008

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MEDIA SUMMARY

The Angle Vale Leaf Tatter and Defoliation disorder (LTD) causes economic losses in almonds on the northern Adelaide Plains (NAP). No other production district has reported similar losses or symptoms. The losses result from defoliation and diminished photosynthetic capacity, bud and twig dieback, reduced yields as a direct result of bud death and indirectly as a result of affected trees having higher levels of sticktight nuts at harvest.

The failure of LTD to develop on feral trees, during any season to-date, suggests chemicals or a chemical-biological interaction may be involved in the LTD disorder. Investigation of these was the focus of initial field trials. These and subsequent trials have been described and discussed in the Final Report of project AL05003c (May 2007).

The results of investigations from 2005-2007 confirmed several characteristics of the disorder: Non-pareils are the earliest and most severely affected variety; the onset of the chlorotic spotting is sudden and widespread in susceptible varieties by the time of first detection within any one season; affected leaves fall while still green; feral almond trees do not develop symptoms; fungal organisms consistently recovered from necrotic LTD lesions are not primary almond pathogens; a fungicide with two active constituents of differing chemistry, delayed (or avoided) the onset of LTD; symptoms indistinguishable from those observed in many affected orchards were induced by the application of particular chemicals to selected branches; and LTD symptoms do not develop on young trees, suggesting neither planting material nor nurseries, are likely mechanisms for LTD introduction or spread.

The orchard utilised for LTD trial work from 2004/05 - 2006/07 had an extended and consistent history of LTD until season 2006/07. The extended dry period from winter through February, 2007 and again throughout season 2007/08, resulted in few chemical crop protectant applications, negligible development of common almond diseases and lower orchard humidity generally. It is considered likely that these conditions and the lack of applied chemicals had an effect on LTD development.

The treatment regimes of the 2006/07 trial were applied again in 2007/08, with additional consideration given to the timing of applications and leaf wetness durations. There was no development of LTD in 2007/08.

The specific nature of the cause of LTD remains ill-defined. It is however our opinion that the cause is most likely abiotic in nature, and potentially related to the application of particular crop protectant/s and/or foliar nutrients, in certain environmental conditions.

TECHNICAL SUMMARY

The Angle Vale Leaf Tatter and Defoliation disorder (LTD) has been an economic problem in almonds growing on the northern Adelaide Plains (NAP) for four of past six seasons. The first investigation (of LTD) was peripheral and took place late in the 2003/04 season, as a result of enquiries about widespread 'bacterial spot' on the NAP. Bacterial spot, it was concluded, was not present in the affected trees. Subsequent trials and investigations aimed to determine potential causes and therefore focussed on identifying characteristics of the disorder and the conditions under which symptoms developed. These field and laboratory investigations are detailed in the Final Report for project AL05003c.

Symptoms of LTD develop on young and old leaf tissue of most almond varieties, with Non-pareil being the most susceptible. The typical symptoms of LTD are small, round-irregular translucent, chlorotic lesions randomly spread across leaf blades. These later develop necrotic centres which may fall out giving affected leaves a tattered and shot-holed appearance. Symptom onset and the subsequent defoliation are usually sudden and widespread. Twig dieback and bud death results in yield losses.

Field trials in 2005/06 demonstrated the effectiveness of one fungicide (BAS 51604F), in delaying or avoiding, the onset of LTD in an affected orchard. The trees treated with BAS 51604F remained free of LTD until 6 weeks before harvest. At no time did these trees defoliate. Symptoms identical to those of LTD were induced by applications of above-label rates of canola oil, and by a product with chlorothalonil as its active constituent. These observations and others of unsprayed, feral trees have provided evidence suggestive of an association between LTD and applied chemicals, under certain environmental conditions. The potential for a complex cause has been recognised, i.e. interaction between applied chemicals and/or nutritional products, environmental conditions, and/or micro-organisms. Understanding the interactions and contributing environmental factors would assist in the management of LTD.

Identification of the cause of LTD remains essential since symptoms alone do not define a disease/disorder.

1 INTRODUCTION

The almond disorder referred to as Angle Vale Leaf Tatter and Defoliation disorder (LTD) has been examined since 2004. During the 2007/08 season, the treatments in the 2006/07 trial were repeated, with some additional evaluation parameters included.

This report includes details of the 2007/08 season and field trial. Comprehensive coverage of the disorder symptoms and the three seasons of previous field and laboratory investigations, are included in milestone, Interim and Final Reports of project AL05003c.

1.1 Background

1.1.1 General

This disorder of almonds was first reported in the Angle Vale area of the northern Adelaide Plains (NAP) in 2003. It was brought to the attention of Scholefield Robinson Horticultural Services Pty Ltd (Scholefield Robinson) in February 2004. At that time, many growers had assumed the symptoms to be those of 'bacterial spot' and accordingly, had applied copper on multiple occasions to affected trees.

The symptoms observed by Scholefield Robinson in February 2004 differed from those typically caused by bacterial spot, and copper phytotoxicity initially appeared the most likely cause of the observed symptoms. Subsequent observations and investigations however confirmed late copper was not the cause of LTD, and 'bacterial spot' was not present in the majority of symptomatic trees.

At the end of three trial seasons, the following conclusions had been drawn and documented (in Final Report of project AL05003c):

- Onset of LTD is sudden and uniform within a variety.
- There are no edge effects or apparent point sources of LTD within orchards.
- Feral trees do not develop LTD.
- Refined canola oil applied at above-label rates, and captan/copper in combination, induce lesions visually identical (to the naked eye and at the microscopic level) to field LTD lesions.
- Copper, canola oil and captan applied independently have not been primary causes of LTD on the NAP, when appropriately applied.
- Fungicide BAS 51604F delayed the development of symptoms on susceptible almonds in a severely-affected orchard, in 2005/06.
- The basis of the effectiveness of fungicide BAS 51604F is unknown; i.e. direct (fungal control) or indirect (avoidance, induced host response).
- Environmental conditions within orchards likely affect the development of LTD.
- Potential abiotic causes (applied chemicals +/- nutrients) have not been sufficiently tested under a range of spray and micro-climatic conditions (humidity, presence of dew).
- Non-pareil is the most susceptible variety. Keane's Seedling and Price demonstrate a useful degree of tolerance to LTD, even when planted adjacent to and treated similarly to, severely-affected Non-pareils.
- Isolates of *Alternaria* and *Cladosporium* spp. consistently recovered from necrotic LTD lesions are not primary pathogens of almond.
- *Chryseomonas luteola* is unlikely of significance, but has been isolated from LTD lesions.
- The cause of LTD is complex, and likely to include applied chemicals +/- nutrients and particular micro-climatic conditions.

In the 2007/08 trial plan, leaf wetness was included as an evaluation parameter in order to provide further information on the potential of micro-climatic conditions to influence LTD onset and development. In seasons 2006/07 and 2007/08, trials were designed and established to determine the role of specific chemicals (and nutrients) on LTD development, but the disorder did not develop at the trial site.

1.2 Research 2006/07

1.2.1 Objective

In 2005/06, a fungicide BAS 51604F delayed (or avoided) LTD onset. The objective of research in 2006/07 was to investigate this result further through a range of laboratory and field trials, in an effort to define the nature of the cause of LTD. This fungicide and its two active constituents, and other chemicals/chemical combinations with similar efficacy ranges were applied on a 'commercial' scale, at the trial orchard. Other trees received no treatment and/or no nutrients. These served as controls.

1.2.2 Results

LTD did not develop in the trial area (or region), and therefore quantification of the LTD presence and severity, and evaluations of BAS 51604F, its constituents, and foliar nutrients, were not possible.

LTD-like lesions were induced by 'superimposed' captan/copper applications, regardless of the underlying block treatment. Trees not receiving this over-treatment remained of healthy appearance, even when adjacent to the symptomatic trees.

The captan/copper induced lesions in the 2006/07 trial were indistinguishable visually (naked eye and microscopically) from those caused by high (off-label) rates of canola oil in the 2005/06 trials, and from LTD lesions seen previously.

Pathogenicity work confirmed that neither of the fungi consistently isolated from LTD lesions were primary almond leaf pathogens or likely causes of LTD.

It was noted that the extended dry weather from winter through February resulted in few chemical crop protectants being applied in any orchard, negligible development of common almond diseases and lower orchard humidity generally. Water restrictions affected watering in the trial orchard and indirectly, the humidity.

1.2.3 Conclusions

At the conclusion of the 2006/07 season, it remained likely (although untested) that specific products (crop protectants and/or foliar nutrients), the time of their application, and orchard humidity, directly influenced the development of LTD.

2 RESEARCH 2007/08

2.1 Background

Environmental conditions are known to contribute to the impact of some applied chemicals and nutrients, i.e. the leaf burning attributed to the application of sulphur in hot conditions. Similarly, canopy humidity and the presence of heavy dews influence not only leaf wetness periods but also the degree of copper solubility and duration and frequency of release periods. Copper (and zinc) toxicities result from free ions in solution. The solution concentration, its time in contact with the leaf, and presumably osmotic potential, influence the effect at the leaf surface. It has been shown in other crops that the extent of damage may also relate to leaf age (i.e. urea on grapes, citrus) and variety. The potential also exists for certain trace elements in tank-mixed combinations with

crop protectants, to affect the pH of solutions at the leaf surface. It is considered possible that similar sensitivities occur in some almond varieties.

Early evening and night spraying of crop protectants and foliar nutrients (as tank mixes), are often undertaken on the NAP, due to windy conditions during the day. This has been true for the trial site and in many other orchards that have suffered LTD.

The contributions of crop protectant choice, tank mix components, and time of application (and the associated leaf wetness duration) to the development of LTD, were the foci of the 2007/08 field trial.

3 MATERIALS AND METHODS

3.1 Field Trial 2007/08

3.1.1 Treatments

The crop protectants trialled in 2007/08 included the fungicides applied in the 2006/07 trial. The 2007/08 trial was established for block treatments on a commercial scale, as shown on the orchard spray plan (Figure 1). The treatments were crop protectants (pyraclostrobin, boscalid, chlorothalonil and BAS 51604F) and foliar nutrients included potassium nitrate, urea, boron and zinc. Zinc and boron were applied twice during the growing period, and potassium nitrate was applied more frequently. Calcium was applied through fertigation. Two rows received no nutrients. The other variables were the three almond varieties to which the treatments were applied (Keanes, Price and Non-pareil), and the timing of applications (evening or daytime).

Evening treatments were applied after sunset and usually after 9:00 pm. These were intended to maximise the chance of long periods of leaf wetness and higher canopy humidity, as well as to reproduce the evening spray practice carried out on the NAP at times, to avoid high wind conditions.

Data and samples were collected from the Non-pareils in each treatment block, and other varieties were regularly inspected and observed. Figure 2 and Table 1 include the trial treatment rates and timing.

During the pre-season and early pink bud stage, nutrients (superphosphate, hydro-complex and sulphate of ammonia) were broadcast across the trial area. Table 2 details these early season applications.

Figure 1 : NAP Almond Trial 2007/2008 – Block Treatment spray plan

NP[+]	NP	K	NP	NP	P	NP	NP	K	NP	NP	P	NP	NP	K	NP	NP	P	NP	NP	K	NP	NP	P	NP	NP	K	NP	NP	P	NP	NP	K
- nutrient		- nutrients			+ nutrients			- nutrients			+ nutrients			+ nutrients						+ nutrients						+ nutrients						
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			H			H			H			H	*	*		Y						A							O			
N			L			L			L			L	*	*		R						S							S			
O			O			O			O			O	*	*		A						5							C			
			R			R			R			R	*	*		C						1							A			
N			O			O			O			O	*	*		L						6							L			
U			T			T			T			T	*	*		O						0							I			
T			H			H			H			H	*	*		S						4							D			
R			A			A			A			A	*	*		T						F										
I			L			L			L			L	*	*		R																
E			O			O			O			O	*	*		O																
N			N			N			N			N	*	*		B																
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[+]Varieties: NP=Non-pareil; K=Keane's Seedling; P=Price

* Potential over-spray region – pyraclostrobin over chlorothalonil

Figure 2 : NAP Almond Trial 2007/2008 – Treatments and timing

TREATMENT & APPLICATION TIME	WHITE	CHLOROTHALONIL 2.5L/ha DAY		CHLOROTHALONIL 2.5 L/ha EVENING		PYRACLOSTROBIN 20.5 ml/100L @1200 L/ha DAY/EVENING		BAS 51604F 40g/100 L @ 1200L/ha DAY/EVENING		BOSCALID 20g/100L @ 1200L/ha DAY/EVENING	
		Fungicide only - no nutrient (DAY)	Fungicide + nutrient (DAY)[1]	Fungicide only - no nutrient (EVENING)	Fungicide + nutrient[2] (EVENING)	+ nutrient (EVENING)	+nutrient (DAY)	+ nutrient (EVENING)	+nutrient (DAY)	+ nutrient (EVENING)	+nutrient (DAY)
Green Tip		FUNGICIDE AND NUTRIENT TREATMENTS AS USUAL - to FULL LEAF OUT (see Table 2)									
Pink Bud											
Early–Mid Bloom											
Full Bloom Aug 18th											
Petal Fall – Shuck Fall											
Post-Bloom from Sept 26-28	NO FOLIAR NUTRIENTS or FUNGICIDES	Foliar Nutrients, including - Urea (5 kg/ha) , Zinc chelate (5L/ha), Boron (1.5 kg/ha), Potassium nitrate (15 kg/ha)									
Post-Bloom October 2		Fertigation –applied nutrients - Calcium (10 kg/ha)									
Treatments in trial October 24 Nutrients: Pot. nitrate (8kg/ha) + urea (2 kg/ha)	NO FOLIAR NUTRIENTS or FUNGICIDES	Morning		Evening		Morning/evening		Morning/evening		Morning/evening	
		- Nutrients	+ Nutrients	- Nutrients	+ Nutrients	+ Nutrients	+ Nutrients	+ Nutrients	+ Nutrients	+ Nutrients	+ Nutrients
	Rain (Nov 2-3) - 21 mm										
Treatments and nutrients as above November 22	NO FOLIAR NUTRIENTS or FUNGICIDES	Morning		Evening		Morning/evening		Morning/evening		Morning/evening	
		- Nutrients	+ Nutrients	+ Nutrients	+ Nutrients	+ Nutrients	+ Nutrients	+ Nutrients	+ Nutrients	+ Nutrients	+ Nutrients
Late Nov – Feb	No further sprays in orchard or trial area										

● Nutrients applied as specified during daylight [1] Day applications during daylight (morning = after 7 am) [2] Evening applications during dark, usually 9-10 pm.

Table 1: Trial 2007/07 - Treatment rates and timing

BLOCK TREATEMENTS			FOLIAR NUTRIENTS[X]		
ACTIVE CONSITUENT	RATES	DATES APPLIED	NUTRIENTS	RATES	DATE APPLIED
Treatment Control – no fungicides	n/a	-	Nutrient Control – no nutrients (during trial period)	n/a	
BAS 51604F	40g / 100L*	Oct 24; Nov 22	Pot. nitrate +	15 kg/ha +	Multiple occasions
Pyraclostrobin	20.5ml / 100L	Oct 24; Nov 22	Urea	5 kg/ha	
Boscalid	20g / 100L	Oct 24; Nov 22			
Chlorothalonil	2.5 L/ha	Oct 24; Nov 22	[Calcium in irrigation – Oct. and Nov rates]	40 kg/ha 50 kg/ha	

[x]Foliar nutrients . * Spray volume 1200 L/ha

Table 2: Orchard treatments to full leaf out - 2007/08

ORCHARD TREATEMENTS			
DATE	TREE STAGE	NUTRIENTS[X]	RATES
03/07/07	Dormant	Super phosphate + Hydro-complex	500 kg/ha 400 kg/ha
11/07/07	Early bud swell	Sulphate of ammonia	200 kg/ha
31/07/07	Green tip (CPS) – 5% blossom (Keanes+Nem. r/s)		
03/08/07	Mid-bloom	Copper+oil	3kg+3L/ha
18/08/07	Full bloom	Calcium nitrate	600 g.conc
23/08/07	Bloom-early leaf	Chlorothalonil	3L/ha
02/09/07	In leaf	Calcium nitrate	800 g conc.
05/09/07	Full leaf	Chlorothalonil+zinc+urea	3L +5L+10 kg/ha
Bad mite problem; weather very dry			
18/09/07		Chlorothalonil+potassium nitrate+miticide	2.5L+8kg+750 ml/ha

[x]Foliar and fertigation applied nutrients

3.1.2 Monitoring

3.1.2.1 Leaf Wetness and Humidity Monitoring

To allow assessment of the potential association of humidity and leaf wetness periods with LTD development, leaf wetness sensors that digitally record the presence of free moisture at the leaf surface were hung in the canopy of two trees within the treated rows (Photo 1). The chosen trees were 'internal', and not exposed to edge effects.

The loggers were placed in the canopies on October 19, 2007. The instruments and trees were regularly inspected between mid-October and January 4, 2008. There were seven inspection periods during this time and the leaf wetness sensors were downloaded to provide a hard and electronic copy of the recorded leaf wetness periods, and humidity within the canopy.

Photo 1 : Relative humidity, temperature and leaf wetness sensors

3.1.2.2 Lesion Monitoring

To assist with the identification of correlations, and quantification of LTD (severity and incidence), the trial plans included provision for photographically recorded spray droplet distribution and size. The objective was to compare at various times during the season, the initial droplet distribution pattern and size, with the size and distribution of greasy LTD spots and subsequent translucent LTD yellow lesions.

To achieve this, a fluorescent dye was added to the tank prior to the application of the chlorothalonil treatment on November 22. The leaves were sampled soon after the spray dried and these leaves were stored for later comparative photography under ultraviolet light.

4 RESULTS

4.1 Field Trial Treatments

No LTD developed in the trial area during the 2007/08 season. Trees within the trial were observed from September to January for any signs of induced LTD. There was no visible response to any of the applied crop protectants or foliar nutrients, regardless of their application time (evening, daytime), or the composition of the tank mix.

Mite damage was observed in mid-November but no other almond pests or diseases were observed in the trial. Some mottled leaves were observed on Price trees, regardless of their treatment. Tip burn, presumably due to salt accumulation, was prevalent in some rows.

The fluorescent dye applications confirmed that the spray distribution was generally uniform across leaf surfaces.

At another orchard in the general Angle Vale vicinity, some suspect LTD was observed in mid-November, on Non-pareil trees recently sprayed with a ‘generic’ form of chlorothalonil. These trees were observed until January. Non-pareil trees unsprayed on one side, allowed useful comparison. It was apparent that only those trees receiving direct spray had developed the characteristic LTD spotting. The LTD on this occasion was minor and no defoliation occurred.

At this site, it was planned that, when crop protection was next required, two comparative chlorothalonil sprays would be applied to the same trees. One application would be made using the same ‘generic’ form of chlorothalonil, and the other with a ‘brand name’ form of this active

constituent. The purpose was to compare the chemical carriers in each product, rather than the active constituent itself. It was agreed, that several branches within the treated trees would be shielded from the treatments by plastic coverings. However these treatments were not applied as the grower found no further crop protectant treatments were required for the season.

4.2 Monitoring – Leaf Wetness Duration

Since LTD did not develop at the trial site, assessment of the effect of leaf wetness periods of specific products, on LTD development, was not possible. It was however possible to determine the variability in leaf wetness within the canopy of trial trees.

The leaf wetness recordings clearly indicated the variable periods of free water at the leaf surface. The registered wetness periods were attributable to the times of evening spray applications, irrigations and the December 21-23 rain event. Early in the season, leaf wetness periods lasted for as long as 12 hours after an evening crop protectant spray or night irrigation, despite the season being very dry. As the season progressed, sunrise was earlier and higher temperatures developed earlier in the day, the duration of leaf wetness periods fell to an average of 6-7 hours. The absence of LTD, rendered not possible, assessment of the contribution of micro-climatic conditions to LTD onset or development.

Figures 3 and 4 are representative of the recorded wetness, temperature and humidity recordings for October and November, 2007.

Figure 3 : Leaf Wetness periods (October 21- 29, 2007)

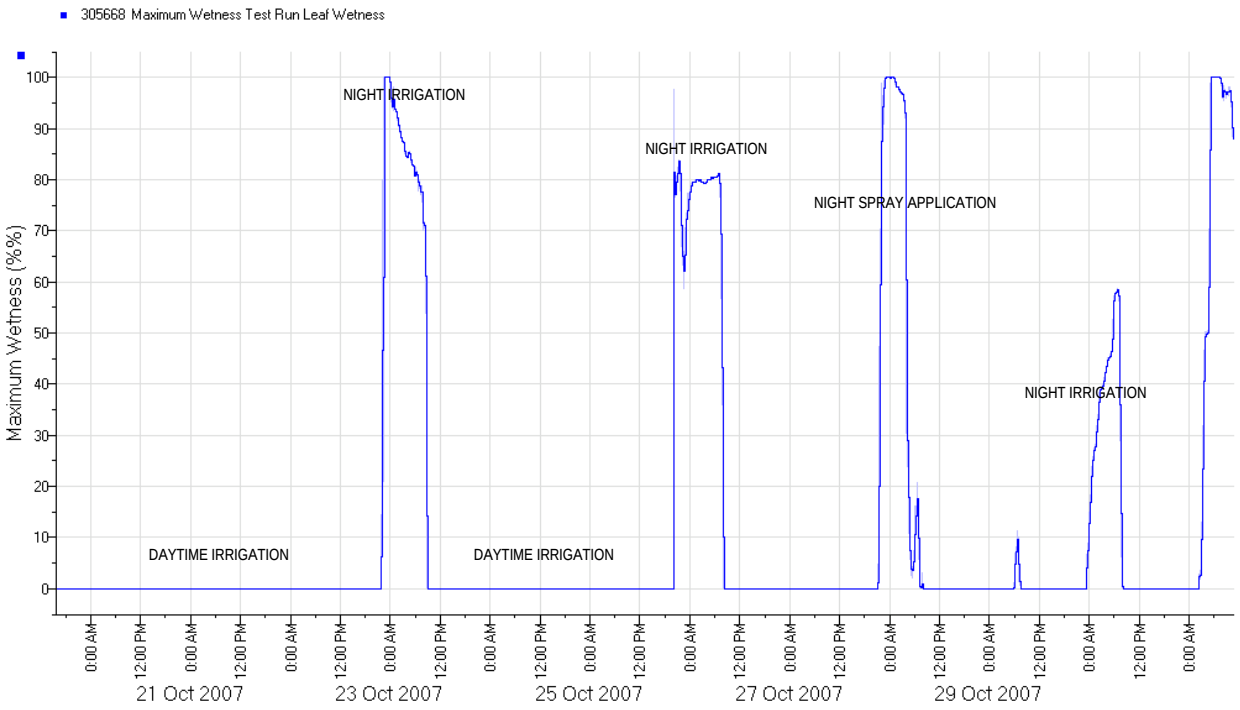
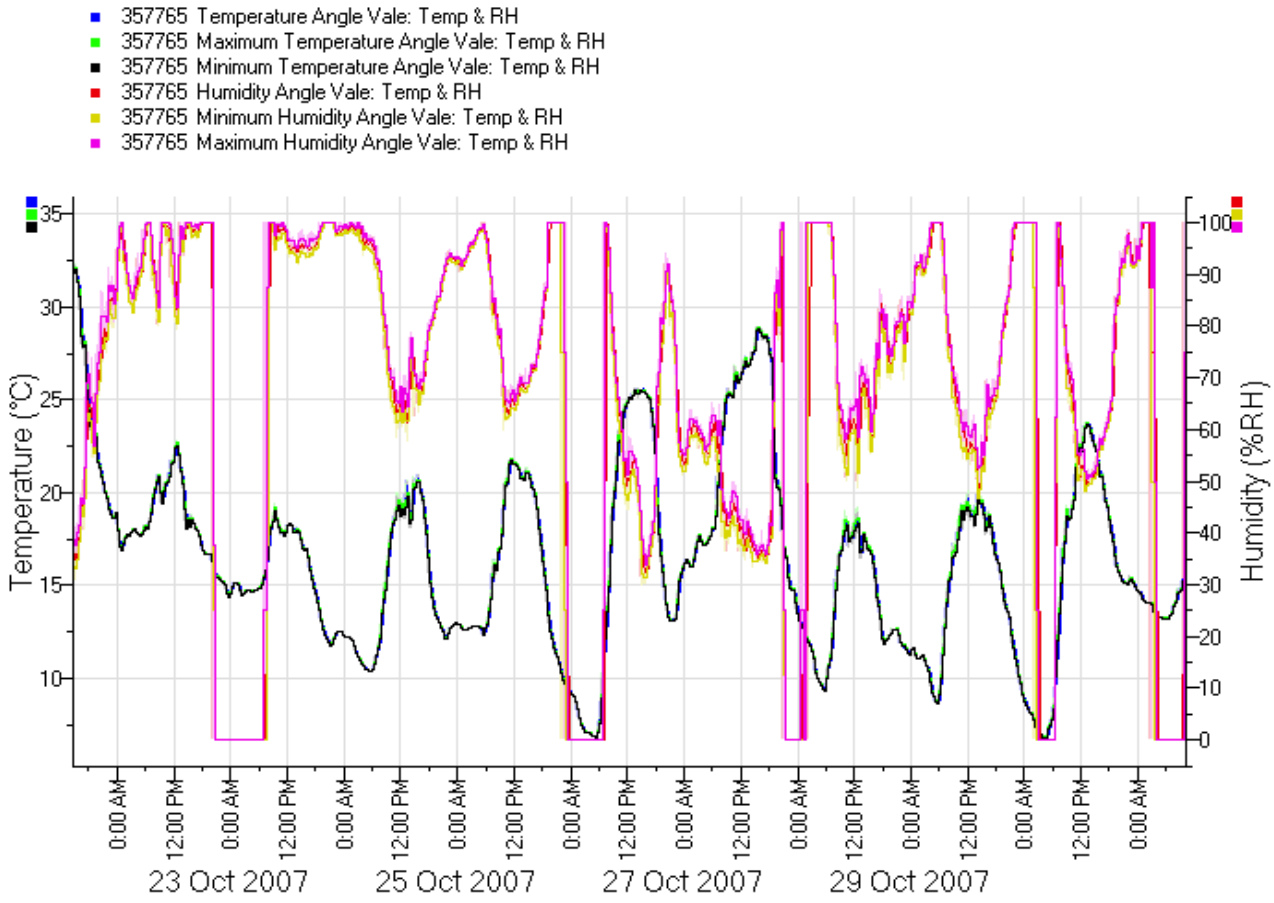


Figure 4 : Temperature and relative humidity in canopy (October 21- 29, 2007)



4.3 Monitoring – Lesion Development

Although LTD did not develop, the fluorescent pigment in the chlorothalonil treatment solution, allowed the spray droplet distribution to be recorded. The droplet distribution and size were relatively uniform across the leaf surfaces as would be expected from an efficient and correctly-calibrated spray rig. There was no cluster of droplets at the leaf margin, tip or along the midrib. Since LTD did not develop, it was not possible to correlate the size and distribution of LTD greasy and chlorotic lesions with the initial location and size of the spray droplets. However it has been apparent over the four seasons of trials that most LTD greasy spots and LTD yellow lesions are uniform in size and shape, and that they have generally been uniformly distributed across leaf blades. They have closely resembled in size, shape and distribution, the spray deposition recorded in 2008.

Our observations over several years suggest that the greasy spots and yellow lesions are related, that there is no consistent increase in lesion size until the lesions become necrotic (at which time we have demonstrated the presence of *Alternaria* and *Cladosporium* spp.) and that the 2007/08 pattern of spray deposition, closely resembles that of LTD lesions in previous seasons. There is however a lack of quantitative data supporting this last observation. The trial and monitoring were terminated in January, 2008 due to the absence of LTD.

5 DISCUSSION

LTD did not develop during the 2007/08 season, in the trial area. This season was preceded by a season in which LTD also did not develop. The two seasons were particularly dry and irrigation restrictions were in operation. None of the usual almond diseases developed in either season, and therefore few crop protectants were applied on the NAP from August 2006 to January 2008. Within the field trials however, various combinations of nutrients and fungicides were applied in an effort to 'induce' LTD. Despite the treatments, and application times aimed at increasing leaf wetness duration and variability, LTD did not develop.

Although the trials over four seasons, laboratory investigations and grower surveys have allowed comprehensive consideration of grower practices and inputs to the production of almonds, orchard compositions and layouts and the NAP growing environment, the cause of LTD remains ill-defined. The Discussion section of the Final Report AL05003c chronologically reviewed the hypotheses and evidence attained during these investigations.

From the 2006/07 and 2007/08 trials, it is apparent that dry conditions and/or a minimal presence of crop protectants, are not conducive to the onset and development of LTD. The specific nature of the potential abiotic causes (i.e. applied crop protectant +/- nutrients) and the conditions that may affect their impact (i.e. micro-climatic conditions – relative humidity in canopy, leaf wetness and /or dew duration etc.) have not been sufficiently tested.

The potential effects of tank mixing various crop protectants and nutrients have not been sufficiently evaluated in this research. The trials have provided evidence that supports the current advice to avoid applications of captan and/or copper mid-late season or within 10 days of any oil applications. In the United States growers are advised not to apply any miticide (esp. propargite) with propiconazole. They also recommend the use of chelates in nutrient mixes, rather than potentially incompatible oxide or sulphate forms of nutrients. The effects of potassium nitrate and trace elements on the pH of some tank mix combinations utilised on the NAP (i.e. those including chlorothalonil), need further investigation.

The potential toxicity of sprays containing copper and zinc are now better understood by the NAP almond growers. Zinc and urea are still applied as defoliants, but it is now rare to hear of late season copper applications.

On the NAP there continues to be speculation over the suitability of several forms of chlorothalonil that have carrier and origin of material variability. There is no evidence supporting the speculation that the 'generic' forms of chlorothalonil alone, and in normal use patterns, are capable of 'causing' LTD. There is however evidence from another horticultural crop (potatoes) that in situations of long wetness periods, such solutions can result in significant leaf damage. It has also been confirmed from the orchards in which the dry season (2006/07 and 2007/08) LTD was observed, that 'generic' chlorothalonil had been applied (in unknown conditions) to the affected trees. Where leaves remained unsprayed, lesions did not develop.

There is visual evidence to suggest that the size and pattern of the 'natural' and chemically-induced LTD lesions (from previous seasons) closely resemble the 2007/08 size and distribution of spray deposits.

Although the LTD cause remains ill-defined, valuable outputs from the research have occurred and are available for further industry uptake. NAP growers are now more aware of:

- the benefits of strategic application of crop protectants, based on prior consideration of environmental conditions as they relate to almond disease development and the presence of susceptible varieties
- the potential damage associated with the application of oil-based products with, before or soon after the application of some fungicides
- the risk associated with late season copper applications

- the potential effects of unproven tank-mixing of crop protectants (i.e. propiconazole, chlorothalonil), nutrients and/or trace elements (i.e. copper, zinc, potassium nitrate)
- the need to apply winter oil to combat mite problems
- BAS 51604F as a potential product suitable for addition to the existing almond disease control armoury, especially because of its dual chemistry and benefit in resistance management.

6 CONCLUSIONS: 2007/08 TRIAL

The 2007/08 trial did not allow definition of the LTD cause, but demonstrated:

- dry conditions are not conducive to the development of LTD
- the applied nutrients and crop protectants do not induce LTD lesions in dry conditions
- spray deposition spots resemble LTD lesions in size and distribution

7 CONCLUSIONS: 2004 - 2008

The conclusions drawn from previous seasons have been reported in the Final Report for project AL05006c.

It is our opinion after review of all trial data and observations over four seasons, that the cause of LTD is most likely abiotic, rather than biological, in nature. It is our opinion that applied chemicals in particular environmental conditions promote LTD.

The key observations and data that have led to our conclusions are:

- Sudden, but extensive onset within particular rows/varieties
- Consistent failure of LTD to develop on both the unsprayed portions of susceptible trees, and on (unsprayed) feral trees
- Induced lesion formation following the application of some crop protectants
- Similarity of the chemically-induced lesions and the LTD lesions, at the microscopic level
- The uniform size and distribution of the greasy and translucent LTD lesions
- The size and distribution of spray droplets which closely resemble the size and distribution pattern of early LTD lesions
- The consistent failure to recover primary almond pathogens from LTD lesions

For a more complete understanding of the disorder however, it remains necessary to evaluate LTD severity and intensity under variable micro-climatic conditions, in which crop protectants have been applied independently and in combination (i.e. with other crop protectants, foliar nutrients and/or trace elements).

Somewhat counter to the above conclusions is the observed effectiveness of fungicide BAS 51604F. It however remains likely that the basis of this effectiveness is indirect avoidance (i.e. avoidance of the presence of another tank-mixed crop protectant or foliar nutrient; avoidance of conducive leaf wetness periods; or an induced host response), rather than direct control of a fungal pathogen.

8 NEXT STEPS

The trial established in 2007/08 was approved in order to repeat that of 2006/07. In neither season did LTD develop. Although it is not recommended that the trials again be established in 2008/09, it is important that industry is assured LTD field research may again be established at short notice and with sufficient resources, during the next 'wet spring'. The field trial/s should again include BAS 51604F and its components, 'generic' chlorothalonil, and foliar nutrient combinations. Water only, nutrient only and crop protectant only controls will also be required.

Recent US data suggest that an antibiotic treatment should be trialled (i.e. polyoxin) and that phosphorous acid treatment also be included in the research trials. For the period October to December of a trial season, resources to collate a representative regional sample of spray diary information, and LTD presence, severity and lesion size data, must be available if the research is to be useful and the output from it, maximised.

Industry needs assurance at this time, that a quick research response to LTD could again be mustered, should the conditions believed to be conducive, arise in late spring. The grower co-operator who has assisted with all trial work to-date, has given commitment that his block will again be made available for future research for the benefit of the entire industry.

Note: The data on potential transmission of LTD through grafting, remains outstanding. The data are expected by the end of the 2008/09 season.

9 TECHNOLOGY TRANSFER

This process has been on-going with articles, presentations and field days provided throughout the project (Appendix 1).

10 RECOMMENDATIONS (SCIENCE AND INDUSTRY)

It is strongly recommended that the almond growers on the NAP apply crop protectants strategically, record their application and product (i.e. batch numbers) details and any observations of LTD-like symptoms.

It is recommended that the industry as a whole maintains awareness of LTD, and that it be heightened again during a wet spring. The industry is encouraged to provide assistance where necessary to progress the registration of BAS 51604F, and similar products, regardless of the LTD situation.

It is recommended that in the interim, the industry becomes more aware of (by conducting research if necessary) the potential effects of various tank mixes that are in common use.

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F:\SRHSDATA\Clients\Almond Board of Australia\Angle Vale LTD Trial\Trial 2007-2008\Reports\Rpmc190108Final Report.doc

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REFERENCES

1. Prue McMichael and Lucy Pumpa. May 2007. Angle Vale Leaf Tatter and Defoliation disorder (LTD). Final Report project AL05003c for Horticulture Australia Ltd. 29 pp.

2. Prue McMichael and Lucy Pumpa. May 2006. Angle Vale Leaf Tatter and Defoliation disorder (LTD). Interim Report project AL05003c for Horticulture Australia Ltd. 19 pp.

3. Prue McMichael and Lucy Pumpa. March 2006. Angle Vale Leaf Tatter and Defoliation. Australian Nutgrower 20 (1) pp16-19.

4. McMichael, PA and L Pumpa. 2005. Milestone Report 3 (AL05003c) Angle Vale Leaf Tatter and Defoliation (HAL, March 2006).

5. McMichael, PA and L Pumpa. 2005. Milestone Report 2 (AL05003c) Angle Vale Leaf Tatter and Defoliation (HAL, December 2005).

6. Stuart Pettigrew and Prue McMichael. June 2004. Bacterial Spot on Almonds. Australian Nutgrower 18 (2) pp 24-25.