SENATE RURAL & REGIONAL AFFAIRS & TRANSPORT REFERENCES COMMITTEE

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Inquiry into the suture of beekeeping and pollination service industries in Australia

Murray Bridge, SA
Tuesday, 15 April 2014

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Australian Government

Rural Industries Research and Development Corporation

Economic Analysis of the Australian Lucerne Seed Industry

RIRDC Publication No. 08/103

Australian Government
Rural Industries Research and Development Corporation

Economic Analysis of the Australian Lucerne Seed Industry

by Rural Solutions SA and the Department for Trade and Economic Development

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FOREWORD

Primary industries and the rural communities they support are essential to the survival, growth and prosperity of Australia.

New industries, new ways of doing things – especially during this difficult period in our rural and metropolitan landscape, will ensure the continued survival of those industries and communities, and most importantly, the families that rely upon them.

The Rural Industries Research and Development Corporation invests in both new and established industries on behalf of government and industry stakeholders. These provide opportunities to be captured by rural producers and investors. They also provide avenues for farmers facing adjustment pressure to diversify and to manage change. The establishment of new, or expansion of current industries, contributes to community resilience and regional development. Increasingly, industries are contributing to a distinctive regional character in rural Australia.

Primary industries face a number of challenges – developing product quality and quantity, developing markets and supply chains, and industry leadership. However, rising to these challenges requires an understanding of the industry and its intended directions. Underpinning the growth of industries is research and development. Often, such research and development is hampered by a lack of basic statistical information, which is why RIRDC has invested in this report.

This report is the first step in considering the contribution, and therefore the basis for growth, of the lucerne seed industry in Australia.

The importance of this report is that it provides baseline information for an emerging industry sector. This report will be a useful basis for those contemplating investment or formulating policy and will help to inform RIRDC as it plans its research and development priorities into the future.

This project was co-funded by the Australian Government and Lucerne Australia which provided cash and in-kind contribution.

This report, an addition to RIRDC's diverse range of over 1700 research publications, forms part of our Pasture Seeds R&D Program, which covers levied temperate pasture seeds of which the major crops comprise lucerne, medicago species, clover and sub-clover seeds.

Most of our publications are available for viewing, downloading or purchasing online through our website:

- downloads at www.rirdc.gov.au/fullreports/index.html
- purchases at www.rirdc.gov.au/eshop

Peter O'Brien
Managing Director
Rural Industries Research and Development Corporation

ACKNOWLEDGMENTS

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The assistance and feedback provided by the Executive Committee of Lucerne Australia, Peter Smith (Seed Services Australia), Tim Teague (Teague Australia), Luke Kirkby (Premier Seeds) and Annette Sugden (RIRDC) is gratefully acknowledged.

ABBREVIATIONS

ABARE	Australian Bureau of Agricultural and Resource Economics
ABS	Australian Bureau of Statistics
AOSCA	Association of Official Seed Certifying Agencies
ASA	Australian Seeds Authority
FOB	Free On Board
FTE	Full Time Equivalent
GDP	Gross Domestic Product
GSP	Gross State Product
GVP	Gross Value of Production
OECD	Organisation for Economic Co-operation and Development
PIRSA	Primary Industries and Resources South Australia
RIRDC	Rural Industries Research and Development Corporation
RSSA	Rural Solutions SA
VNS	Variety Not Specified

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EXECUTIVE SUMMARY

What the report is about

This report is the culmination of an analysis of the Australian lucerne seed industry, providing an insight into its increasing growth and success. The report prepared by Rural Solutions SA was commissioned and co-funded by Lucerne Australia and RIRDC. It provides an important first step in establishing a baseline dataset to show the value and economic position of the industry.

Background

Lucerne Australia strives to become an integral part of the information distribution and research extension networks and to provide a single contact point where lucerne information can be accessed by growers. It also presents an efficient vehicle for researchers to distribute results to growers.

With this report, Lucerne Australia establishes the overall lucerne seed industry's value, not only to growers, but its worth to specific regions (in this case South Eastern South Australia). It also shows the significant economic impact that lucerne seed production has on the communities that benefit from the revenue and flow-on effects generated by the industry.

The Australian lucerne industry has been an extremely feasible and important pasture specification for over 40 years, and has continued to expand through constant improvement in farming systems, allowing the industry to become more efficient and resulting in greater yields. The lucerne industry contributes significantly to the RIRDC budget with approximately 51 percent of its Pasture Seeds R&D Program budget coming from levies generated by lucerne seed production.

In South Australia the lucerne seed industry is a major economic contributor to the towns of Keith, Naracoorte, Tintinara and Bordertown with those regional communities relying on lucerne seed production for employment, wealth generation and strength of social character.

The industry is experiencing an increase in demand for lucerne seed on the local market, and very strong export demand driven by the United States as their growers turn away from producing lucerne seed in favour of more lucrative crops that are supplying the ever growing biofuel industry. Other factors such as lucerne being a difficult crop to grow and the average age of the lucerne grower in the US between 60-65 have resulted in the reduction in lucerne crops and provided Australia with a new customer rather than competitor as in previous years.

It is therefore imperative that information on the current lucerne seed industry in Australia, and its contributors, is reported and updated. This will ensure that current and future investors understand the potential of the industry and invest accordingly in the industry's direction and success.

Using economic indicators, economic impact analysis, consultation and general research, this report provides an understanding of this growing industry. Whilst some data has been presented on an Australia-wide basis, much has been confined to more data-ready regions, such as South East South Australia. It is recommended that similar analysis is undertaken in other regions as the required information and relevant data becomes available.

Findings of this Report:

- The overall lucerne seed industry in Australia is currently worth around $AUD 95 million per year, with exports contributing around $AUD 30 million and domestic sales of $AUD 8.7 million. The remainder of the value lies in associated inputs and the allied industries (eg. seed processors and marketers) that are crucial to the lucerne seed value and supply chain.

- A comparative economic contributor is the overall value of the hay which is cut from the lucerne plant before seed is produced. Current volatility in hay market has seen average prices double in recent years as demand and the economic condition of the industry has increased. The current value of production for lucerne hay in Australia is estimated to be around $AUD 210 million per year.

- Production of lucerne seed in the period 2002/03 (5652 tonnes) to 2006/07 (7913 tonnes) increased by 40%, while the total value grew by a massive 179.6% from $13.9 million in 2002/03 to $38.86 million in 2006/07.

- The average price for lucerne seed is at an all time high of between $5.00 and $5.50 per kilogram due to very strong demand resulting in an increase in total value of 14.7 percent between 2005/06 and 2006/07 from $AUD 33.89 million to $AUD 38.86 million.

- During the period 2002/03 to 2005/06 (12 months ending 30 September) the quantity of lucerne seed exported increased by 16.8 % from 6386 tonnes to 7459 tonnes while the total value increased by 56% from $AUD 18.3 million to $AUD 28.5 million.

- Due to the limited availability of production data for other key lucerne growing regions, the regional contribution and economic impact has been estimated for the major growing region of south eastern South Australia. The allied industries in this region contributed approximately $AUD 21.2 million in 2006/07 flowing through those regional economies and contributing significantly to the prosperity of townships and communities.

From the research and investigation undertaken in this report it has become evident that there are a certain limitations to collecting accurate production and industry data for economic analysis. Apart from the Australian Seeds Authority (ASA) that publishes statistics on certified varieties of lucerne seed, there appears to be no other organisation that collates and publishes lucerne seed data from either the private or public sectors.

In preparing this report we have provided a number of recommendations that aim to decrease the information gap regarding economic and production data thereby allowing the lucerne seed industry to be aware of the trends and vital economic indicators required to analyse the industry's future success.

Future priorities identified in this report:

- For this continually growing industry to realise its full potential within Australian agriculture, the producers and industry bodies need to direct investment and lobbying toward encouraging agricultural and data collection agencies (ABARE, ABS, Department of Primary Industries) and industry players (processors/marketers) to increase their scope and accuracy of reporting for industries, such as lucerne seed, to allow for meaningful analysis so that the economic status can be tracked at any given time.

- In order for the lucerne seed industry to accurately report on the economic indicators and overall contribution to Australian agriculture, industry players (producers, cleaners, marketers) should be encouraged to collect and report vital economic information on lucerne seed production (ie. tonnages for certified and un-certified seed) so that reports such as this can be

updated as required with the aim of building solid quantitative and qualitative data for future analysis.

- Industries such as rice and honey currently spend between 0.8% and 1% of their gross value of production on research and development through RIRDC projects. This may provide a key performance indicator for the lucerne seed industry and a benchmark for future investment taking into consideration the level of producer and in-kind contributions.

- Honeybee pollination services provide significant value to agriculture and horticulture in Australia which in 1999/2000 was estimated to be worth $1.7 billion per annum (Gordon & Davis 2003). Further research should be conducted into the value of bee pollination services specifically for the lucerne industry as to analyse the direct correlation between improved crop pollination and higher seed yields. The research will also need to report on the costs and risk to the lucerne industry associated with a possible varroa mite incursion and strategies for combating this threat such as the introduction of the American leafcutter bee which is resilient to the varroa mite.

Lucerne Harvest (photo supplied by Shane Oster)

1 INTRODUCTION

1.1 Study Background

Rural Solutions SA (RSSA) has been commissioned by Lucerne Australia through RIRDC funding to undertake an economic evaluation of the Australian lucerne seed industry.

The objective of this report, *Economic Analysis of the Australian Lucerne Seed Industry*, is to provide an outline of the industry's economic performance based on desktop research, consultation and an industry survey of lucerne seed service providers.

The aim of the study is to present a set of economic performance indicators for the lucerne seed industry as well as to develop a consistent time series of economic information to assist Lucerne Australia with strategic planning in future years.

1.2 The Australian Lucerne Seed Industry

The Australian lucerne seed industry produces in excess of 7,500 tonnes of seed per year of which over 85% is produced in South Australia with the remaining 15% produced in New South Wales, Victoria and Western Australia (Figure 1). In Australia 83% of total lucerne seed production is produced around Keith, Naracoorte, Tintinara and Bordertown in South Australia, encompassing more than 16,000 hectares (ha) of both irrigated and dryland area. This region hereafter will be referred to as South East SA.

The majority of seed production in New South Wales takes place between Forbes and Wagga Wagga with dryland enterprises found at Cootamundra and irrigation enterprises at Forbes. Traditionally, there has been no lucerne production in Western Australia, however the recent benefits derived from lucerne production in higher rainfall areas has also led to increased lucerne plantings in WA in recent years, (RIRDC 2001).

Centre pivot irrigation of lucerne crops (photo supplied by Shane Oster)

Figure 1 – Lucerne seed production regions within Australia (Source: RIRDC, 2001)

The increasing value of lucerne seed to the Australian pasture seed industry has made it a commodity requiring research and industry development to improve yields and grower returns. Being a high input crop it requires sustainable and efficient management practices that aim to reduce environmental impacts and look to best use resources, particularly in the current drought conditions that are having such a negative influence on primary production in Australia.

Growth of the Australian lucerne seed industry in recent years has been driven by a significant increase in export demand with approximately 86% of all lucerne seed produced going offshore. In 2005/06 the amount of lucerne seed exported was over 7000 tonnes returning over $AUD 28 million for the industry and the Australian economy. Currently the US is the largest importer of Australian lucerne seed, and that trend looks set to continue as US farmers decrease lucerne seed production in favour of lower risk crops, such as corn, that can be utilised for human consumption or the growing demand in ethanol fuel.

1.3 Seed Certification

Seed certification is a process that sets out to protect the genetic identity of seed. This means that plants grown from certified seed can be expected to look and perform in the way that the breeder originally described for that cultivar. Certified Seed produced in Australia is in accordance with national and international certification schemes that meet stringent standards for:

- varietal purity
- physical purity
- germination

These standards are recognised both nationally and internationally and are an essential component of trade. The Organisation for Economic Co-Operation and Development (OECD) only recognises OECD standards for certification, so for seed exported to OECD countries OECD certification must be provided.

The certification scheme ensures that seed produced consists wholly of the variety named on the bag, that it does not differ significantly from the original variety released by the breeder and does not contain excessive quantities of other crops or varieties. The scheme also ensures that the seed is viable and a sample of the crop is tested for undesirable weeds or seed exposed to down-gradable contaminants.

Final stage of seed processing (photo supplied by Shane Oster)

All crops of certified seed are inspected during the growing season by certification personnel to determine varietal purity and to detect the presence of unwanted weeds and other crop types. Certified seed which has been cleaned at an approved premises is sampled by an accredited sampler and submitted to a certification agency laboratory for purity and germination testing.

All certified seed must carry a coloured tag, which may be pre-printed or carry an adhesive label which gives details of the seed line. If the tag is not pre-printed and does not carry an adhesive label the seed has not completed certification and therefore should not be sold as certified seed.

Table 1 - Areas registered for lucerne seed certification, 2005 to 2007

	Area (ha)			
Varieties	**2005**	**2006**	**2007**	**2008**
Aurora	2731	2543	1530	1377
CUF 101	92	70	36	61
Hunterfield	1121	1016	254	177
Hunter River	845	862	551	641
Sequel	974	936	496	517
Siriver	4189	3617	2705	2897
Trifecta	479	419	178	162
Proprietary Varieties	12,397	16,267	9843	14876
Total Certified Lucerne*	**22,828**	**25,730**	**15,593**	**20,708**
Total Lucerne**	**26,134**	**27,959**	**24,576**	**28,194**

Source: Australian Seeds Authority (Certified Seed Report) & Lucerne Australia

Assumption: * Final Area for certified lucerne taken: 2005 - 1 Mar, 2006 - 3 Feb, 2007 - 24 Jan, 2008 - 31 Jan

** Total lucerne includes the estimate for uncertified areas of production

Table 1 shows that the area registered for certification in Australia between 2005 and 2007 decreased by 10,137 hectares (39%). This has been largely due to drought conditions which have reduced the overall dry land crop area suitable for lucerne seed production.

Whilst the area registered for seed certification decreased between 2006 and 2007, the production for certified lucerne seed has increased, as reported in the next section, which may provide an indicator that improved crop management of irrigated lucerne seed combined with favourable weather conditions at critical stages of production has resulted in better than expected yields.

As shown in Figure 2 the area for certified lucerne seed production rebounded from 15,593 hectares in 2006/07 to 20,708 hectares in 2007/08 (32% increase). A strong export market, record prices and better seasonal conditions have been the leaders in this recovery which has given producers confidence that this perennial crop will maintain its high level of demand.

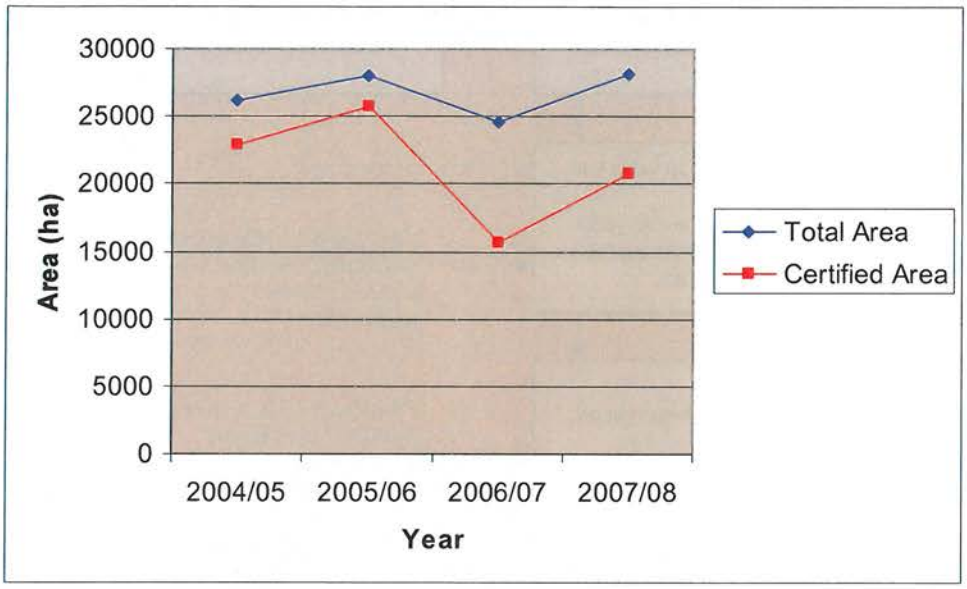

Figure 2 – Areas registered for lucerne seed certification in Australia, 2005 to 2007 compared with total area for lucerne seed production

1.4 Bee Pollination

Honeybees are the most significant pollinators of some crops due to the efficiency of their foraging activities (Gibbs and Muirhead 1998). Indeed, 65 per cent of horticultural and agricultural crops introduced in Australia since European settlement require honeybees for pollination (Jones 1995, cited in Gibbs and Muirhead 1998). Given the importance of primary industries to the Australian economy, the value of pollination services carried out by honeybees is likely to substantially exceed the value of honey and other apiary products into the future.[1]

Honeybee pollination services provide significant value to agriculture and horticulture in Australia which in 1999/2000 was estimated to be worth $1.7 billion per annum. When crops such as lucerne are added this estimate becomes even larger.

Valuation of honeybee pollination services will allow identification of what is potentially being put at risk should Australia's honeybee populations be threatened. For example, an incursion by varroa mite is a real threat to the honeybee and the lucerne industry which would see bee numbers and pollination of crops severely reduced.

Although the value of bee pollination services to the lucerne industry is unknown, it is important to note that interdependencies exists between lucerne production and pollination services which are currently being developed to increase value for both industries into the future. A recommendation

[1] Gordon,J. & Davis,L., 2003, *Valuing honeybee pollination*; RIRDC Publication No. 03/077

from this report is that research should be conducted into the value of this vital role for lucerne production.

Figure 3 shows a flow diagram of the role that bee pollination plays in broadacre industries.

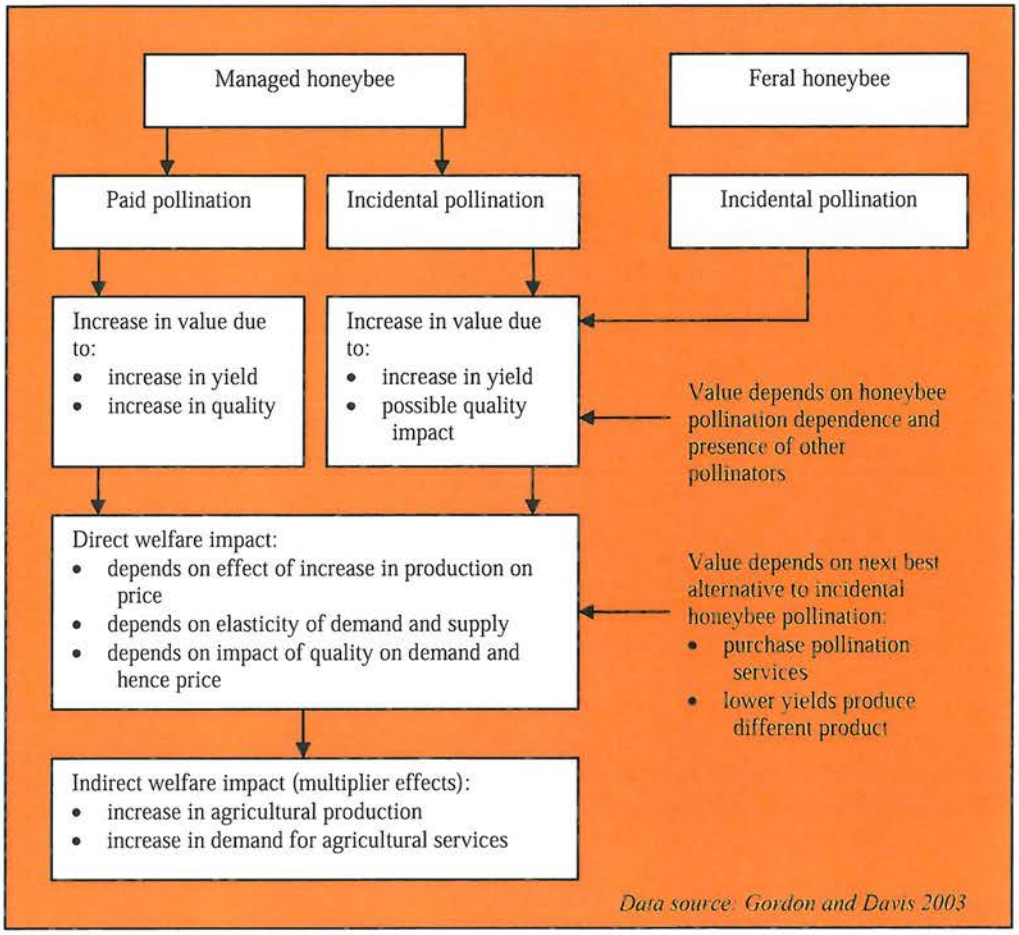

Figure 3 – Economic benefits attributable to honeybee pollination services (Gordon and Davis 2003)

2 METHODOLOGY

2.1 Economic Indicators

Estimates of economic contribution will be presented in terms of the following indicators:

- gross value of production (GVP) for lucerne seed for the period 2002/03 to 2006/07;
- cost of production based on gross margin analysis;
- lucerne seed exports from Australia (quantity and value);
- external factors that influence the economic condition of the lucerne seed industry;
- economic impact of the lucerne seed industry in South East South Australia being the major region for lucerne seed production in Australia;
- contribution to gross state product (GSP) from the lucerne seed industry in South East SA; and
- employment within the lucerne seed industry

2.2 Data Collection

2.2.1 Production Data

Crucial to the analysis was the collection and collation of data showing the value of output and economic contribution of lucerne seed production in Australia. This data was needed to:

- quantify the contribution of the lucerne seed industry to Australian economic activity; and
- validate the information collected from the lucerne seed industry survey.

The relevant data was drawn from the following sources:

- Australian Bureau of Statistics (ABS);
- Australian Seeds Authority Ltd (ASA);
- Primary Industries and Resources South Australia (PIRSA);
- Rural Industries Research & Development Corporation (RIRDC);
- Seed Services Australia; and
- Lucerne Australia (provided gross margin data for lucerne production)

2.2.2 Survey of Lucerne Seed Industry

An outline of the lucerne seed industry survey conducted for this project is provided below. This details the type of information sought, the businesses contacted and the survey response rate.

Questionnaire

To enable the estimation of the impact of the lucerne seed industry in the major production regions, a questionnaire was prepared for completion by lucerne seed service industry firms and other organisations that undertake related activity in those regions. The questions in the survey were designed to capture:

- the nature of the firm's lucerne seed industry activity;
- the firm's employment levels and average wage;
- estimates of employment and the nature of goods and services provided by contractors to the firm;
- the magnitude of other costs incurred by the firm in the course of conducting lucerne seed operations; and
- a breakdown of lucerne seed industry related earnings and market share by broad category.

Respondents were asked to indicate what proportion of their business was allocated to lucerne seed related activity and to apportion, where possible, employment costs and revenue from lucerne seed activity in the region.

A covering letter for the questionnaire was prepared on SA Government letterhead to encourage participation in the survey. The letter outlined the background and objectives, explained why the survey was required and indicated that all survey data would be treated in confidence. A copy of the covering letter and questionnaire is reproduced in Appendix 2.

Service industry firms who received the questionnaire

The contact list of firms and contractors for inclusion in the survey was compiled in consultation with the Executive Committee of Lucerne Australia.

The covering letter and questionnaire were sent by post in mid September 2007. A detailed follow-up was undertaken by telephone and email during September and October 2007. The mail out of questionnaires and subsequent follow-up was completed by Rural Solutions SA.

Responses

The survey aimed to collect data from lucerne seed industry service providers from the relevant growing regions around Australia to allow an analysis of the economic impact of lucerne seed production from a national perspective. However, limited response to the questionnaire prevented the collection of sufficient data to conduct the analysis on a national scale. The difficulty in accessing vital information on the lucerne seed industry restricts the analysis that may be undertaken, therefore the authors were restricted to analysis of the economic impact from the major lucerne seed production region of South East SA from where the most survey responses were received.

A summary of the responses to the lucerne seed industry survey in the major growing region of South East of SA is presented in Table 2. While the rate of responses appears to be low it is important to note that at least 50 per cent of lucerne seed related activity in the region, by value, was recorded by the 16 completed, relevant responses.

Table 2 - Lucerne seed industry survey respondents

Total number of supply chain firms who received the questionnaire	30
Number of firms who reported no lucerne seed activity in the region	2
Net total of supply chain firms from whom data was sought	28
Firms that did not respond	
Cited confidentiality reasons	7
Incorrect contact details	1
No response despite follow up	4
Total non-respondents	12
Number of completed responses	16

Survey limitations

The lack of available data restricted the analysis that could be undertaken. With the intent of this study to develop baseline data and understanding of the industry from which it can develop and grow, this restriction of transparent and relevant data may reduce outside confidence in the lucerne seed industry's potential. Therefore, a priority must be to ensure greater participation in data collection from all players within the industry so that an accurate representation of its current economic status can be made and the industry's successful evolution can continue.

ECONOMIC INDICATORS FOR THE AUSTRALIAN LUCERNE SEED INDUSTRY

2.3 Gross Value of Production

Current published sources of production data for lucerne seed are limited to Australian Seeds Authority certified pasture seed reports and ABS export statistics which have made the estimation of GVP difficult. The amount of uncertified[2] seed produced in Australia is seemingly unknown as the industry does not publish data for this category of seed. Lucerne Australia has provided an estimate on the quantity of uncertified seed which has resulted in the figures shown in Table 3.

In the years 2002/03 and 2003/04 the large quantities of exported lucerne seed could be attributed to carry-over[3] seed from previous years. In 2002/03 the lucerne seed industry suffered from an oversupply on the worldwide market and poor prices, resulting in seed shifting very slowly and payment terms to growers (especially in the pools) being extended out to over two years. As production increased in the following years in line with price and demand, the export / production ratio (around 86%) has realigned.

Industry sensitivity around pricing data has resulted in the value of lucerne seed production for this report to be based on average farmgate prices for total production in each year, regardless of the varietal specification.

Total production of lucerne seed increased during the period 2002/03 to 2005/06 which was a significant result for the industry considering the drought has affected many of the dryland enterprises across Australia. The value of lucerne seed production has also increased significantly over the same period. Production in the period 2002/03 (5652 tonnes) to 2005/06 (8657 tonnes) increased by 53.1 per cent, while the total value grew by a massive 143 percent in from $13.9 million in 2002/03 to $33.9 million in 2005/06.

As with other major agricultural industries in recent years, lucerne seed production is not immune from the effects of drought and in 2006/07 recorded a fall in production from 8657 tonnes in 2005/06 to 7913 tonnes 2006/07 as a result of the extended dry conditions. Although production was down during this period the average price for lucerne seed was at an all time high due to very strong export demand resulting in an increase in total value by 14.7 percent between 2005/06 and 2006/07 from $AUD 33.89 million to $AUD 38.86 million.

Increasing export demand and world prices are primarily driving the increase in value of lucerne seed which looks set to continue in the coming years giving the industry great confidence for the future.

[2] Seed that has been produced but has not undergone quality assurance that is recognised by OECD, AOSCA and domestic seed certification schemes.

[3] Carry-over is seed that has been produced and stored from the year before.

Table 3 – GVP for certified and uncertified lucerne seed in Australia for the period 2002/03 to 2006/07

Australian Production (tonnes)					
Varieties	**2002/03**	**2003/04**	**2004/05**	**2005/06**	**2006/07**
Aurora	373	624	744	793	545
CUF 101	27	29	53	90	15
Hunterfield	218	192	242	100	72
Hunter River	423	547	480	320	347
Sequel	302	324	297	330	215
Siriver	1894	1971	2101	1688	1348
Trifecta	170	150	159	147	45
Proprietary Varieties	1680	2228	3388	4324	4377
Uncertified	565	673	829	865	949
Total Lucerne (t)	**5652**	**6738**	**8293**	**8657**	**7913**
Value ($m)	**13.9**	**18.9**	**26.01**	**33.89**	**38.86**

Source: Australian Seeds Authority Ltd.

Uncertified seed estimates provided by Lucerne Australia

Assumptions

Uncertified seed calculated by Lucerne Australia

Value calculated on average farmgate prices for each year

Table 4 shows the largest increase in GVP during the period was in 2003/04 to 2004/05 where production increased by 23.1 per cent from 6738 tonnes to 8293 tonnes. Production was matched by a significant increase in value from $18.9 million to $26 million (37.6 per cent) as export demand increased, which resulted in a rapid price spike per kilogram that has continued on into 2007/08.

The significant increase in value of total lucerne seed production over the 5 year period 2002/03 to 2006/07 is illustrated in Figure 4.

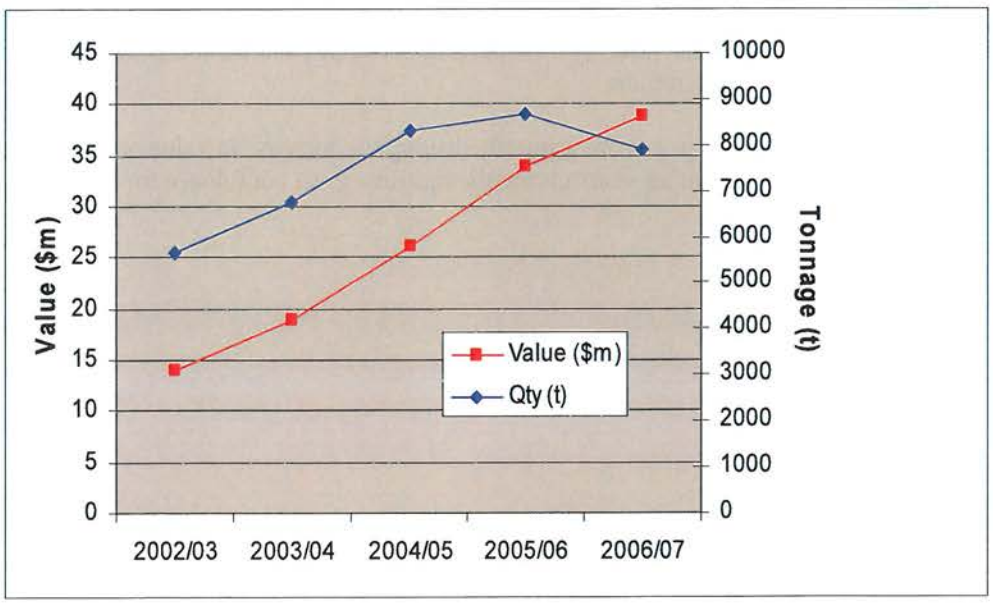

Figure 4 - GVP for lucerne seed for the period 2002/03 to 2006/07

2.4 Lucerne Seed Exports from Australia

Figures 5 and 6 provide a historical breakdown of total lucerne seed exports from Australia, by top 5 countries of destination, quantity and value(Free On Board[4]), for the period of 2002/03 to 2005/06 in the 12 months to 30 September. Over this period the total quantity of lucerne seed exported from Australia increased from 6386 tonnes in 02/03, 7134 tonnes in 03/04 (11.7% increase), 7186 tonnes in 04/05 (0.7% increase), 7459 tonnes in 05/06 (3.8% increase). Overall during this period lucerne seed exports have increased by 16.8 per cent in total quantity and 56 per cent in total value.

Over this period the most significant export destinations were Argentina, USA and Saudi Arabia, accounting on average for 32, 27 and 13 per cent respectively, of the total quantity of lucerne seed exports from Australia. In 2005/06 the most significant export destinations by quantity and value were USA (39 per cent of quantity, 38 per cent of value), Argentina (23 per cent of quantity, 24 per cent of value) and Saudi Arabia (15 percent of quantity, 17 per cent of value). As can be seen, the fall in exports in 2006/07 reflected the fall in overall production as a result of the drought conditions that affected yields in that year but it is important to note that the strong level of demand kept export values high. Table 4 provides a full breakdown of exports by countries of destination.

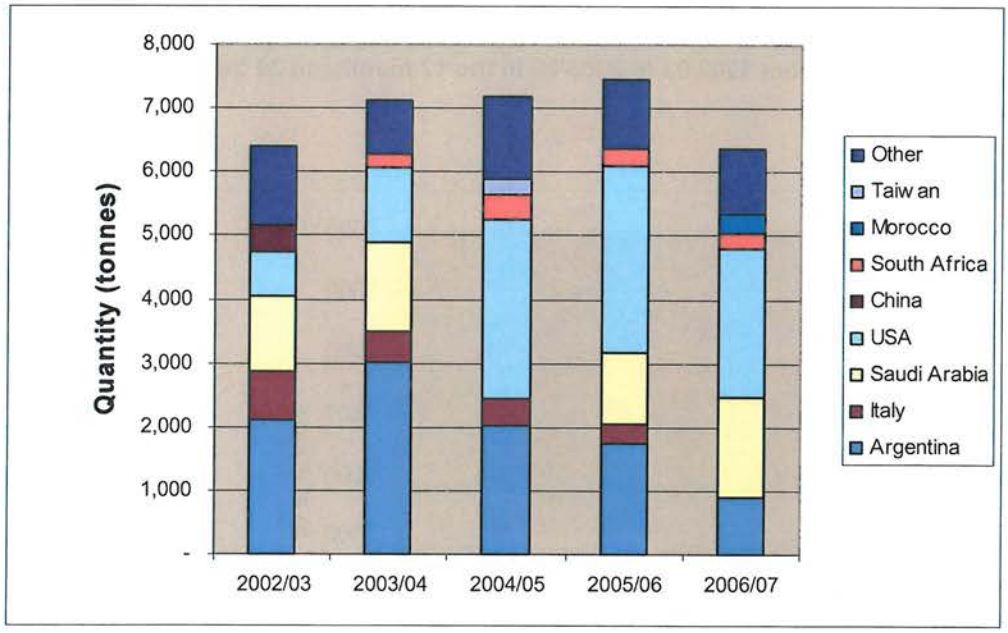

Figure 5 – Lucerne seed exports from Australia, quantity (t) by major countries of destination from 2002/03 to 2005/06 in the 12 months to 30 September

[4] Free On Board is a pricing method in which a producer bears only the costs involved of delivery of goods "free-on-board" to a local carrier's despatch point; at that time, title for the goods passes to the purchaser, who is responsible for the remainder of the freight charge.

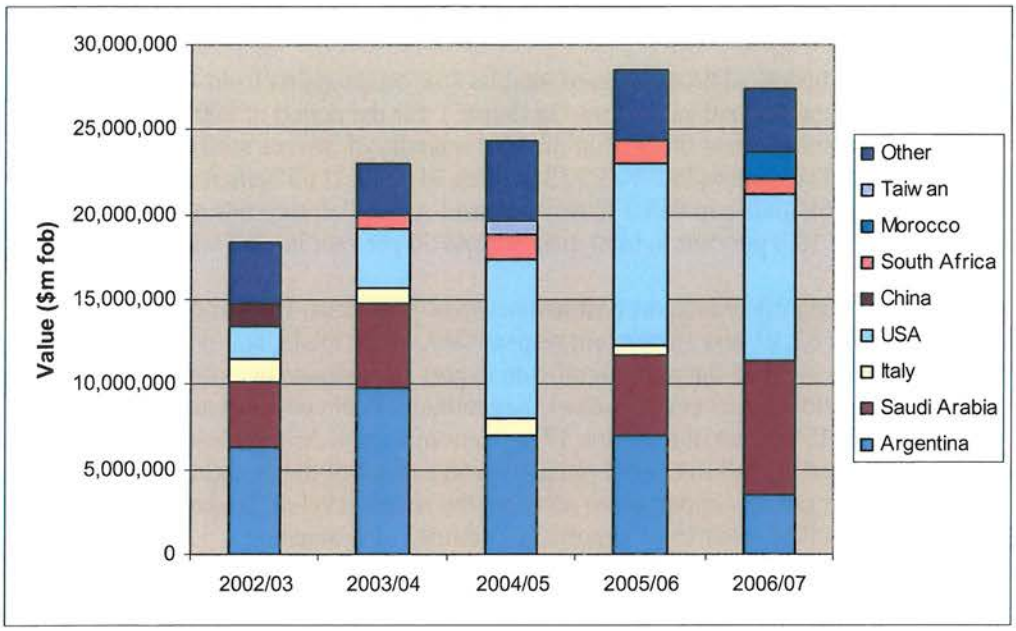

Figure 6 – Lucerne seed exports from Australia, value ($m FOB) by major countries of destination for each year from 2002/03 to 2005/06 in the 12 months to 30 September

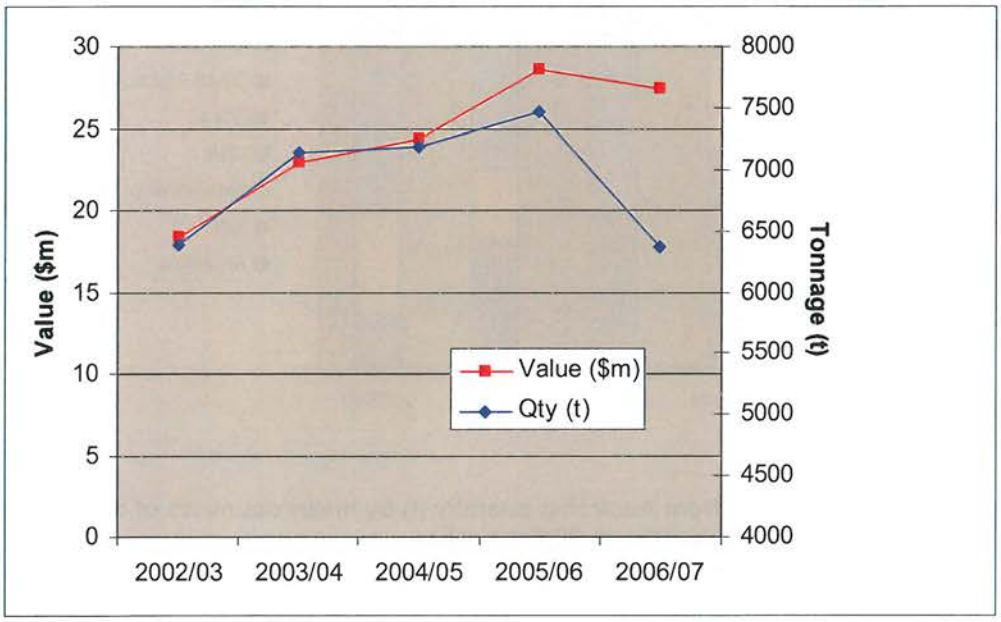

Figure 7 - Lucerne seed exports for the period 2002/03 to 2006/07 in the 12 months to 30 September (Value, Tonnage)

Table 4 - Lucerne seed exports from Australia, quantity (tonnes) and value by country of destination, 2002/03 to 2006/07 in the 12 months to 30 September

YEAR	QUANTITY (t)	VALUE ($'000 FOB)
2002/03		
Argentina	2108	$6,279
Saudi Arabia	1178	$3,819
Italy	756	$1,414
USA	686	$1,900
China	446	$1,325
Other	1212	$3,595
Total	**6386**	**$18,332**
2003/04		
Argentina	3021	$9,830
Saudi Arabia	1402	$4,976
USA	1178	$3,419
Italy	468	$910
South Africa	209	$828
Other	856	$2,989
Total	**7134**	**$22,952**
2004/05		
USA	2828	$9,366
Argentina	2032	$7,008
Italy	400	$992
South Africa	382	$1,455
Taiwan	244	$772
Other	1300	$4,738
Total	**7186**	**$24,331**
2005/06		
USA	2907	$10,752
Argentina	1741	$6,937
Saudi Arabia	1140	$4,829
Italy	298	$532
South Africa	297	$1,286
Other	1076	$4,222
Total	**7459**	**$28,558**
2006/07		
USA	2343	$9,889
Saudi Arabia	1565	$7,874
Argentina	907	$3,463
Morocco	322	$1,542
South Africa	220	$935
Other	1014	$3,744
Total	**6371**	**$27,447**

Source: ABS Export Statistics

In 1999 a glut in the international market was created when the US produced almost 5 times its average seed production which saw prices forced down in the following years. The shifting of excess

stock and reduced production due to drought conditions in Australia in the last 2 years have seen prices double.

In the next decade as populations of the smaller lucerne seed importing nations such as India, China and Africa increase, so will the growth of exports as these rapidly developing countries become major importers. This could increase the export seed trade by around 80%. With recent increases in the Australian dollar against foreign currency, in particular the US dollar, primary producers may be concerned about their commodity's global competitiveness because traditionally they are price takers, and the price they receive for their output will determine their gross margins and profitability.

The Australian lucerne seed industry however contradicts this statement as strong economic growth which is being fuelled by increasing export demand, particularly in the United States, has driven lucerne seed prices to their highest on record and has Australia placed as the major exporter of lucerne seed even with the declining US economy and strengthening Australian dollar.

Economists have pointed out that if you look at export volumes over time and the economic growth rates of our major trading partners, you will see a relationship, whilst there is less correlation with movements in the exchange rate. This is because exchange rates tend to affect export values rather than volumes.

The exchange rate is just one of the factors affecting our agricultural export markets. Recent economic evidence has shown that since the Australian dollar was floated over two decades ago our exporters have certainly been able to manage fluctuations in the exchange rate as part of their overall export strategy.

Of course, strong commodity prices matter as does the overall growth in the world economy. Long term growth in export volumes is mainly determined by global economic demand, so a continuation of above average trend growth in the world economy will be a more important factor affecting exports than an increase in the value of the Australian dollar.

2.5 Cost of Production

When considering the economic impacts of lucerne seed production it is also important to have an understanding of the value of investment at the grower level which considers the level of inputs required to produce good yields in any given season.

Based on an average gross margin (see Appendix 3) for lucerne production provided by Lucerne Australia the value of grower investment has been estimated in real terms[5] for the last 3 years from 2004/05 to 2006/07 presented in Table 5.

Gross margin analysis does not account for overhead/fixed costs (eg. farm machinery, depreciation, insurance, wages, loan repayments) that are factored in when determining the overall financial performance of broadacre cropping enterprises.

[5] Real terms is a measure of the value of money that removes the effect of inflation.

Table 5 - Producer cost of lucerne production, 2004/05 to 2006/07

Year	Area (ha)		Value ($m)		Total Value ($m)
	Irrigated	Dryland	Irrigated	Dryland	
2004/05	16,465	9,669	14.4	3.3	**17.7**
2005/06	17,614	10,345	15.4	3.6	**19.0**
2006/07	15,483	9,093	13.6	3.1	**16.7**

Assumption: Areas have been calculated based on the estimate that South East SA contributes 85% of total production.

The cost of lucerne production as a percentage of GVP was 68 per cent in 2004/05, 56 per cent in 2005/06 and 43 per cent in 2006/07. The rapid price increase and strong demand for lucerne seed in the past 2 years has generated higher gross margin incomes for producers and given them a great deal of confidence in this perennial crop going forward.

2.6 Estimated Economic Impact of the lucerne seed service industry in South East SA

The scenario presented below (Table 6) depicts the economic impact or flow-on effect[6] of the firms servicing the lucerne seed industry in South East South Australia – Table 6 assuming a 2.5% per annum real escalation in expenditure over the 5 year period (to simulate a growing industry) before levelling off. This scenario has been chosen to represent an estimate about the trajectory of expenditure and employment of the firms over the period in question. Tables 7 and 8 contained in Appendix 2 represent the service industry with Table 7 assuming flat expenditure over the 5 year period considered, and Table 8 presenting the 'net difference' to highlight the differences in each of the outputs between the 'real growth' and 'flat expenditure' scenarios.

Table 6 - Estimated Economic Impact – 2.5% real growth p.a.

	Year 1	Year 2	Year 3	Year 4	Year 5	PV 5 yrs^	PV 10 yrs^
Value Added ($m)							
Service Industry – wages	5.74	5.88	6.04	6.18	6.34	24.66	43.20
Service Industry - operating profit	3.80	3.88	3.98	4.08	4.18	16.30	28.52
Direct Suppliers (eg. seed processors, irrigation)	2.94	3.0	3.08	3.16	3.24	12.60	22.06
Indirect (eg. shopkeepers, newsagent)	3.70	3.78	3.88	3.98	4.08	15.86	27.78
Total	*16.16*	*16.56*	*19.98*	*17.40*	*17.84*	*69.40*	*121.56*
Employment (FTEs)							
Lucerne Seed Service Ind. - emp.	216	222	228	234	240		
Direct Suppliers (eg. seed processors, irrigation)	32	34	34	36	36		
Indirect (eg. shopkeepers, newsagent)	44	44	46	46	48		
Total	*292*	*300*	*308*	*316*	*324*		

Notes: Individual items may not tally due to rounding; ^ 7% real discount rate[7]
Data collected has been extrapolated out to represent 100% based on a consistent industry structure

2.5% real growth scenario – summary:

[6] Flow-on effects are the sum of production-induced effects and consumption-induced effects. Production-induced effects are additional output, employment and household income resulting from re-spending by firms (e.g. seed processors) that receive payments from the sale of goods and services to firms undertaking, in this example, lucerne seed production. Consumption-induced effects are additional output, employment and household income resulting from re-spending by households that receive income from employment in direct and indirect activities.

[7] Guidelines for the Evaluation of Public Sector Initiatives, Department of Treasury and Finance, 1997

- Based on the provided inputs, the industry generates an annual stimulus (in real Gross State Product (GSP) value added terms) of around $17.84m per annum – this amount comprised of $6.34m in wages, $4.18m in profit, $3.24m in incomes in supplying industries and $4.08m of value added via broader flow through effects. 5 years of operation would have a cumulative impact on GSP (i.e. value added) of about $69.40m and over 10 years of $121.56m in net present value terms.

- Associated with this industry's existence under the growth assumptions outlined is the generation of employment of a total of 234 Full Time Equivalents(FTE)[8] (by the end of the fifth year) – comprised of 240 direct FTEs within the industry, 36 FTEs in directly supplying industries and around 48 FTEs in broader flow-on effects.

Lucerne Australia open day (photo supplied by Shane Oster)

[8] FTE is the unit of measure which is equal to one filled, full time, annual salaried position.

3 DISCUSSION

The results from this report show the significant contribution being made to Australia's agricultural production by the lucerne seed industry. Increases in GVP and the high demand for lucerne seed internationally has bolstered the key performance indicators and generated confidence amongst growers and seed industry service providers that they are competitive with other grain crops.

The Australian lucerne seed industry and its major players have traditionally been very protective of their market and production data. This has resulted in very limited analysis of the industry's structure and performance being made available. For the lucerne seed industry to continue to grow, the economic indicators such as the ones presented in this report should be updated annually with more accurate data provided on an aggregate basis from willing industry players. The creation of strategies and incentives for extracting this information could form the basis for Lucerne Australia to lobby government and industry to set up or contract an impartial group to collect and analyse lucerne seed production data for the purpose of tracking and presenting the industry's performance into the future.

By their nature all industries/contributions have broad impacts, and this is particularly relevant when analysing the 'social dimensions' of primary industries. Perhaps the best recognised industry development reporting methodology is assessing the inter-relationship between economic measures and social dimensions. In most cases, and certainly with lucerne seed production, direct economic growth contributes to positive employment outcomes. Assessment of the economic impact of lucerne industry service providers in South East SA has shown that:

- Under the real growth scenario there would be a total of 162 FTEs generated, comprising of 120 direct FTEs within the industry, 18 FTEs in directly supplying industries and approximately 24 FTEs through the broader flow-on effects.

- $3.17m in service industry wages would be paid as a result of industry growth.

In the case of the lucerne seed industry it would seem on the basis of this desktop study and without insights gleaned from regional community consultation and interviews, that the economic and social benefit derived from this growing industry, even through this tough time of drought, is contributing significantly to the regional economy in which the lucerne industry operates, and its employees and their families who rely on the industry to provide income.

The continued growth of the lucerne seed industry and high level of foreign demand which has seen rapid price increases in the past 2 years represents an emerging industry that is certainly making a positive contribution to Australian agriculture while also working to service our trade deficit when other exports have declined.

If the lucerne seed industry can continue to grow through adaptive management, research, marketing and support from organisations such as Lucerne Australia, then that growth will lead to more jobs being created and more prosperous regional communities that drive lucerne seed production throughout the country.

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APPENDIX 1 METHODOLOGY FOR THE EVALUATION OF THE ECONOMIC IMPACT OF THE LUCERNE SEED SERVICE INDUSTRY IN SOUTH EAST SA[9]

With approximately 83 per cent of all lucerne seed production concentrated in the South East of South Australia, this section of the report will outline estimates of the economic impact of the lucerne seed industry on the South Australian and regional (South East SA) economies in 2005/06.

Once again it is important to note that the data collated from the survey responses is representative of at least 50 per cent of lucerne seed service industry providers in South East SA, and that data has been extrapolated out to 100 per cent based on the assumption that industry structure is relatively consistent throughout the region.

This section of the report presents an evaluation of the economic impact[10] associated with the existence and operation of the supply-chain service industry surrounding the lucerne seed industry in South East SA.

In this evaluation the concept of economic benefit relates to the creation of income and employment within the regional community, both directly and indirectly from the operation of the firms that together form an industry entity servicing the lucerne seed industry in this State. The impacts of the industry have been estimated using financial and other information provided by Rural Solutions SA (or derivations thereof, by the author), and by applying the SA RISE model developed by EconSearch. That information has been used to generate a gross economic impact estimate.

The evaluation does not include an independent assessment or audit of that information or of the model structure and hence it relies on the accuracy of those inputs and modelling instruments. The evaluation is also limited by the need to assume the accuracy of the survey data which was utilised to provide the inputs into calculating the industry impact. Any margin of error in the survey results will also be reflected in the findings indicated below. The relevant sections contain more detail about the evaluation's methodology and the assumptions adopted.

Assumptions

Due to the nature of the valuation contained in this report (a pre-existing industry), there are no 'investment' expenses as the modelling is focussed on valuing the contribution of an aggregate of firms (the lucerne seed service industry) which are already in existence and therefore the valuation is of the ongoing expenses and ongoing contribution to economic activity. There is also no 'base case' scenario or 'net impact' analysis as the focus is on the gross impact of the industry on the State economy in its present form.

The direct and indirect value added and employment figures generated by these expenditures were estimated using the SA Regional Industry Structure and Employment (RISE) model. The SA RISE model utilises input-output multipliers, based on the structure of the economy in 2002-03, to trace the value added and employment impacts of changes in expenditure. Impacts derived from General Equilibrium models would usually provide a slightly more conservative estimate than the straight application of input-output multipliers because they account for supply-side constraints.

9 Within the ability of the standard Input Output (IO) analysis framework. There may be broader economic impacts that cannot be captured within the standard IO analysis framework that will not be included in this evaluation.

Data on direct Full Time Equivalent's (FTE's), wages and expenditure by category was provided by Rural Solutions SA for the financial year 2005/2006. These expenditures have been utilised as required depending on the scenario adopted in the modelling – Scenario 1 (flat real growth) or Scenario 2 (2.5% annual growth in real expenditures over a five year period).

As the modelling here is attempting to account for the entire value-added contribution of the lucerne seed service industry, the profit margins of the industry are required to be added in. Since actual profits were not available, the calculated profit as entered into the spreadsheets was made by reference to ABS Catalogue 7506.0 Agricultural Industries, Financial Statistics, 1999-2000 (the last year in which they were published) and a document outlining costs and revenues for typical NSW lucerne production produced by the NSW Department of Primary Industries.

From these two documents, an industry and state 'typical' cash operating surplus was calculated (revenue figures were provided by Rural Solutions SA) and then an allowance of 50% was deducted to allow for income tax (~30% of total) and depreciation (~20% of total), which cash operating surplus does not take into account. Generally, Input-Output analysis[11] performed to determine the benefit to the State as a whole does not include the profits of the firms as they are deemed to be a private benefit accruing to the firm/s involved; however, this particular analysis is attempting to value the entire industry's contribution in respect of the SA economy (in value added[12] terms) and so profit has been included in this case.

All the expenditures associated with this proposal were traced through the SA RISE model in order to estimate the benefits in terms of value added and employment. It is assumed for the purposes of the modelling that industry (which is pre-existent) will also continue beyond the period of the analysis, so the analysis is confined to five operating years (plus a cumulative Gross State Product figure in Net Present Value[13] terms for ten years of operation).

Standard economic analysis assumes that benefits and costs matter more if they are experienced now rather than in the future. Consequently, a 7% p.a. discount rate[14] has been used in the net present value calculations in this document.

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[11] Input-Output analysis is an accounting system of inter-industry transactions based on the notion that no industry exists in isolation. (Econsearch, 2005)

[12] Value-added is the market value of the product sold by a firm less the value of the goods purchased and used by the firm to produce the product

[13] Net Present Value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows. NPV compares the value of a dollar today to the value of that same dollar in the future.

[14] Discount rate is the interest rate used to find the present value of an amount to be paid or received in the future

APPENDIX 2 ESTIMATED ECONOMIC IMPACT TABLES

The scenario presented below for the economic impact of the firms servicing the lucerne seed industry in South East South Australia – the first in Table 7 assuming flat (in real terms) expenditure over the 5 year period considered. This scenario has been chosen to represent an estimate about the trajectory of expenditure and employment of the firms over the period in question. Table 8 presents a 'net difference' table to highlight the differences in each of the outputs between the scenario in Table 10 and the real growth scenario presented in Section 3.4 of the report.

Table 7 - Estimated Economic Impact – 0% real growth p.a.

	Year 1	Year 2	Year 3	Year 4	Year 5	PV 5 yrs^	PV 10 yrs^
Value Added ($m)							
Industry - wages	5.60	5.60	5.60	5.60	5.60	22.96	39.34
Industry - operating profit	3.70	3.70	3.70	3.70	3.70	15.18	25.98
Direct Suppliers	2.86	2.86	2.86	2.86	2.86	11.72	20.08
Indirect	3.60	3.60	3.60	3.60	3.60	14.76	25.28
Total	*15.76*	*15.76*	*15.76*	*15.76*	*15.76*	*64.62*	*110.68*
Employment (FTEs)							
Lucerne Seed Ind. - emp.	210	210	210	210	210		
Direct Suppliers	32	32	32	32	32		
Indirect	42	42	42	42	42		
Total	*284*	*284*	*284*	*284*	*284*		

Notes: Individual items may not tally due to rounding; ^ 7% real discount rate[15]
Data collected has been extrapolated out to represent 100% based on a consistent industry structure

0% real growth scenario – summary:

- Based on the inputs provided, the industry generates an annual stimulus (in real GSP) of around $15.76m per annum – this amount comprised $5.6m in wages in the lucerne seed service industry, $3.7m in profit, $2.86m in incomes in supplying industries and $3.6m in value added via broader flow through effects. Five years of operation would have a cumulative impact on Gross State Product (GSP) (i.e. value added) of about $64.62m and over 10 years of $110.7m in net present value terms.

- Associated with this industry's existence in its present form is the generation of a total of 284 Full Time Equivalents (FTE) – comprising of 210 direct FTEs within the industry, 32 FTEs in directly supplying industries and around 42 FTEs in broader flow through effects.

[15] Guidelines for the Evaluation of Public Sector Initiatives, Department of Treasury and Finance, 1997

Table 8 - Estimated Economic Impact – Net Difference Table – Scenario 1 vs Scenario 2

	Year 1	Year 2	Year 3	Year 4	Year 5	PV 5 yrs^	PV 10 yrs^
Value Added ($m)							
Industry - wages	0.14	0.28	0.44	0.58	0.74	1.70	3.86
Industry - operating profit	0.10	0.18	0.28	0.38	0.48	1.12	2.52
Direct Suppliers	0.08	0.14	0.22	0.30	0.38	0.86	1.98
Indirect	0.08	0.18	0.28	0.38	0.48	1.10	2.50
Total	0.40	0.80	1.22	1.64	2.08	4.78	10.86
Employment (FTEs)							
Lucerne Seed Ind. - emp.	6	12	18	24	30		
Direct Suppliers	0	2	2	2	4		
Indirect	2	2	2	2	6		
Total	*8*	*16*	*24*	*32*	*40*		

Notes: Individual items may not tally due to rounding; ^ 7% real discount rate[16]
Data collected has been extrapolated out to represent 100 per cent based on a consistent industry structure

- Comparing the two scenarios (base case of 0% real growth and 2.5% real growth per annum in expenses over five years), the difference (by year 5) in real GSP per annum is around $2.08m – comprising of $0.74m difference in wages paid by the industry, $0.48m in profit, $0.38m in incomes in supplying industries and $0.48 million in value added via broader flow through effects. Over five years of operation, the difference in cumulative GSP is $4.78m and over 10 years is $10.86m in net present value terms.

The difference in industry employment generated between the two scenarios by year 5 is 40 FTEs per annum – comprising 30 direct FTEs within the industry, 4 FTEs in directly supplying industries and around 6 FTEs in broader flow through effects.

[16] Guidelines for the Evaluation of Public Sector Initiatives, Department of Treasury and Finance, 1997

APPENDIX 3 AVERAGE GROSS MARGIN FOR LUCERNE PRODUCTION – 2007/08

	IRRIGATED	DRYLAND
Income ($/ha)		
Hay	525	300
Seed	2500	625
Total Income	**3025**	**925**
Expenses ($/ha)		
Fertiliser	120	45
Liquid fertiliser (foliar sprays)	24	24
Herbicide	87	35
Insecticide	12	12
Spray applications	64	48
Hay operations	110	85
Harvesting	80	35
Freight	5	1.25
Pollination	12.5	2
Agronomy	25	12.5
Certification	10	8
Phytosanitary	6	6
Seed cleaning & packaging	85	25
Pumping costs (electricity or diesel approx. 1:1)	150	0
Pump replacement/maintenance	30	0
Infrastructure upgrade (earthmoving or pivot replacement)	35	0
LA membership	2	0.5
Labour	20	5
Total Expenses	**878**	**344**
Gross Margin ($/ha)	**2148**	**581**

Source: Lucerne Australia (2008)

APPENDIX 4 SURVEY COVERING LETTER AND QUESTIONNAIRE

Date

Title >> First Name >> Surname
Company

Address 1
Town >> Postcode

Dear Title >> Surname

The Economic Impact of the Lucerne Seed Industry in the South East of South Australia

The Executive Committee of Lucerne Australia has commissioned Rural Solutions SA to undertake a study to assess the economic impact of the Australian lucerne seed industry.

As part of the study, Rural Solutions SA is conducting a survey of firms involved in the service industry of lucerne seed production. A short questionnaire is attached. The survey will provide information that is not available from published sources. It will enable Rural Solutions SA to estimate the regional impacts of the lucerne seed industry, both direct and flow-on effects, in terms of a range of indicators (e.g. employment, contribution to regional income, etc.).

In order to maintain confidentiality of data from individual organisations, the final report will present results in aggregated forms only. All completed questionnaires will be held by Rural Solutions SA, treated in confidence and subsequently destroyed. Lucerne Australia will not have access to, nor will they seek to obtain access to, the completed questionnaires.

A representative from Rural Solutions SA (Martin Carter) will contact you by phone shortly to ensure that you have received the questionnaire and to see if you require any assistance in interpreting it. In the meantime if you have any queries regarding the project or questionnaire, please contact me on (08) 8226 0495 or Martin Carter at Rural Solutions SA on (08) 8226 0371.

I would be grateful if you would support this study by completing the attached questionnaire and returning it to Rural Solutions SA in the reply paid envelope by **20 October 2007**. The questionnaire can be provided in electronic form (via email) if preferred.

Yours sincerely

Daniel Casement
Business Manager
Rural Solutions SA

Rural Solutions SA
GPO Box 1671
Adelaide SA 5001
Tel: 08 8226 0371
Fax: 08 8463 3336
Email: carter.martin@saugov.sa.gov.au
Contact: Martin Carter or Daniel Casement

CONFIDENTIAL

LUCERNE SEED INDUSTRY ECONOMIC IMPACT STUDY

Please read this first:

- If exact figures are not available, please provide careful estimates.
- Please report all monetary values in ***thousands of dollars*** ($'000).

1. Company Information

Company Name:_____

Lucerne industry activities (*e.g. processing, marketing, transport, etc.*):

_____
_____
_____

Contact Name:_____

2. Employment

a) Please indicate the number of employees and associated costs incurred by your business: (*average for financial year 2005/06, including working proprietors, managers, directors*):

Employment	
Full Time (no. jobs)	
Part time (no. full time equivalent jobs)	
Total wages and salaries ($'000) (*including super, etc.)*	

b) Please indicate the proportion of employment in:

a. lucerne seed related activity (%)_____

b. seed processing and related activities (%)_____

3. Other Costs

a) Please indicate the magnitude of other costs incurred in the course of conducting your business in 2005/06:

Expenditure ($'000)	
Repairs and maintenance	
Contracted services	
Machinery & Equipment	
Communication Services	
Transport	
Insurance	
Fuel	
Other	

b) Please indicate the proportion of these costs incurred in:

a. lucerne seed related activity (%)_____

b. seed processing and related activities (%)_____

4. Earnings

Please break down your lucerne seed industry related earnings by broad category and estimate market share[17] for each.

Category	Revenue 2005/06 ($'000)	Market share (%)
Other (please specify)		
TOTAL		

Thank you for your time and cooperation. Please return the questionnaire by **20 October 2007** in the reply paid envelope **OR** Fax: (08) 8463 3336.
If you have any queries don't hesitate to contact Martin Carter on (08) 8226 0371 or email: carter.martin@saugov.sa.gov.au

[17] Market share relates to your impact on the Australian lucerne seed industry. Best guess response will be sufficient.

GLOSSARY

Gross Value of Production (GVP) is an indicator of economic prosperity. It measures the contribution to the economy of each individual producer, industry or sector.

GVP is the difference between gross output and intermediate inputs. Gross outputs of a production unit during a given period is equal to the gross value of the goods and services produced during the period and recorded at the moment they are produced. Intermediate inputs refer to the value of goods and services used in the production process during the accounting period.

Gross Domestic Product (GDP) Gross domestic product of Australia is the total market value of all goods and services produced within Australia in a given period of time.

GDP does not allow for the depreciation of plant and equipment which is why the measure is called 'gross' domestic product. Also, GDP does not differentiate between who produces the goods and services, i.e. residents or non-residents, this is left to the gross national income (GNI) measure—formely called gross national product (GNP)—which attributes production to residents irrespective of where the production occurs.

Gross State Product (GSP) is the value of output less the cost of goods and services (including imports) used in producing the output. It represents payments to the primary inputs of production (labour, capital and land). Contribution to GSP is consistent with standard measures of economic activity and provides an assessment of the net contribution to regional economic growth of a particular enterprise or activity. (Econsearch, 2005)

Employment is a measure of the number of working proprietors, managers, directors and other employees, in terms of the number of full-time and part-time jobs.

Input-output analysis is an accounting system of inter-industry transactions based on the notion that no industry exists in isolation. (Econsearch, 2005)

Direct impacts are the initial round of output, employment and household income generated by an economic activity, in this case lucerne seed production.

Flow-on (or indirect) impacts are the sum of production-induced effects and consumption-induced effects. Production-induced effects are additional output, employment and household income resulting from re-spending by firms (e.g. seed processors) that receive payments from the sale of goods and services to firms undertaking, in this example, lucerne seed production. Consumption-induced effects are additional output, employment and household income resulting from re-spending by households that receive income from employment in direct and indirect activities.

Freight On Board (FOB) is the export value of production without incurring the costs of loading the commodity on-board the ship.

Full Time Equivalent (FTE) is the unit of measure which is equal to one filled, full time, annual salaried position.

Net Present Value (NPV) is the difference between the present value of cash inflows and the present value of cash outflows. NPV compares the value of a dollar today to the value of that same dollar in the future.

Economic Analysis of the Australian Lucerne Seed Industry

RIRDC Publication No. 08/103

Australia produces pasture seeds ranging from temperate to subtropical species for domestic use and for export markets. The export value of certified pasture seeds exceeds $36 million. Lucerne and clover are the major leviable seed crops. Total production of leviable temperate legume seed currently exceeds 10,000 tonnes. Lucerne and clover seed exports to the world in 2004 were valued at over $25 million. In the three calendar years from 2002-04, the export value of lucerne seed exports rose by 55% and the export value of clover seed rose by 32%.

Perennial grasses are grown for seed in all States with Victoria having the greatest production. Perennial grass seed production is not yet levied for R&D. The main subtropical grasses grown for seed in north-eastern New South Wales, Queensland and the Northern Territory are Rhodes Grass, Setaria, Panicum, Carpet Grass and Paspalum.

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RIRDC Innovation for rural Australia

INTRODUCTION

Trevor Monson from Monsons Honey & Pollination, with wide experience in beekeeping and pollination. Specializing in pollination services to practically all crops that need honey bees. Travelled extensively to the USA researching CCD and other pollination problems, recently visiting the Chinese Beekeeping Industry via ACACA and beekeeping in Laos, Thailand, the UK and Burma, with a big focus on varroa.

I've read the submissions with great interest. Most appear to centre around 6 main topics, with 1 exception. That is the unique opportunity for Tasmania to test the management and use of bumble bees.

1. Labeling Needs to be Honest

The need for improved labeling of Australian products is very clear.

Our present laws enable products to be legally marketed as a Product of Australia, because the container is Australian and worth more than the product inside.

2. Chemicals

Chemical users, farmers and beekeepers have to know what they are doing, so instructions need to be:

1. Clear, explicit and easy to read.
2. Giving quantities for small batches as well as large
3. Strict time of application
4. Warnings: Fines could apply for off-label use

Government legislation must ensure that all chemicals are regularly tested for toxicity on bees and beneficial insects at whatever stage of life, not just on adult bees

Eg Fungicides often not labeled as toxic to bees or detrimental to fruit set
(I have documentation to support this)

Chemical companies need to take greater responsibility for off-label use and state the risks of combining chemicals with other chemicals, and should encourage users to adopt integrated pest management

3. Employment Opportunities to Meet the Needs of the Industry

I have spent 50 years studying bee behavior. I'm a pollination specialist – not for money but because I have a passion for nature and how it works.

I have a concern that my knowledge may not be passed on.
I have three sons:
1 is a specialist superbike technician
1 is a aeronautical engineer, specializing in instruments and radio
1 is a diesel technician, working on mining equipment

All earning far more than the beekeeping industry can afford.

Many beekeepers say they can't find workers that are skilled in areas such as royal jelly production, queen rearing, propolis production and bee breeding techniques.

It would be an advantage to have 3-6 month visas, so that workers were available for short work assignments, from places like China or Canada.

The move by Government to increase the level of English required could further disadvantage and restrict the availability of workers.

4. Importation of Queen Bees

It's extremely important that the beekeeping industry has access to bee stock from overseas, to strengthen existing breeding stock and to develop strengths to resist pests and diseases, such as varroa.

Quarantine policy needs reviewing:

1. It would be best of the quarantine facility stays in the Sydney area.
2. Need to employ staff that has the necessary beekeeping skills to care for and manage bees
3. To release queens as soon as they've been declared free from disease and pests, which is not the current policy

5. Biosecurity top priority and continue support

I would like to take this opportunity to applaud the way in which Horticulture Australia, Plant Health, the Beekeeping Industry and Rural Industries are working together to develop improved surveillance methods, including sentinel hives.

Government would save billions of dollars by continuing to fund biosecurity.

6. We desperately need DPI staff, but unless they engage in being there to help beekeepers with mentoring and training, I see no need for their existence.

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Stigma Development and Receptivity in Almond (*Prunus dulcis*)

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• *Background and Aims* Fertilization is essential in almond production, and pollination can be limiting in production areas. This study investigated stigma receptivity under defined developmental stages to clarify the relationship between stigma morphology, pollen germination, tube growth and fruit set.
• *Methods* Light and scanning electron microscopy were employed to examine stigma development at seven stages of flower development ranging from buds that were swollen to flowers in which petals were abscising. Flowers at different stages were hand pollinated and pollen germination and tube growth assessed. Artificial pollinations in the field were conducted to determine the effect of flower age on fruit set.
• *Key Results* Later stages of flower development exhibited greater stigma receptivity, i.e. higher percentages of pollen germination and more extensive tube growth occurred in older (those opened to the flat petal stage or exhibiting petal fall) than younger flowers. Enhanced stigma receptivity was associated with elongation of stigmatic papillae and increased amounts of stigmatic exudate that inundated papillae at later developmental stages. Field pollinations indicated that the stigma was still receptive and nut set was maintained in older flowers.
• *Conclusions* Stigma receptivity in almond does not become optimal until flowers are past the fully open stage. The stigma is still receptive and fruit set is maintained in flowers even at the stage when petals are abscising. Strategies to enhance pollination and crop yield, including the timing and placement of honey bees, should consider the effectiveness of developmentally advanced flowers.

Key words: Almond, effective pollination period, *Prunus dulcis*, stigma receptivity, stigmatic exudate.

INTRODUCTION

Fertilization is essential for almond (*Prunus dulcis*) production (Cousin and El Maataoui, 1998). The crop is mainly self-incompatible and requires cross-pollination (Pimienta *et al.*, 1983; Socias i Company *et al.*, 2002). Pollination can be limiting in certain production areas, and it has been reported that the percentage of fruit set in commercial orchards is commonly only 30 % (Gary *et al.*, 1976). Optimum pollination is critical for maximum crop production, and crop thinning is never practised (Connell, 2000).

The effective pollination period (EPP), first introduced by Williams in 1966, is one of the most important factors determining successful fertilization. EPP is determined by the longevity of the ovule minus the time lag between pollination and fertilization, providing that this value does not exceed the length of stigmatic receptivity. As reviewed by Sanzol and Herrero (2001), the EPP is limited by three main events during the reproductive process: stigma receptivity, pollen tube kinetics and ovule longevity.

Stigma receptivity refers to the ability of the stigma to support germination of viable, compatible pollen. It has been implicated as a factor limiting the EPP and fruit set in kiwifruit (Gonzalez *et al.*, 1995*b*), apricot (Egea and Burgos, 1992), pear (Sanzol *et al.*, 2003*b*) and cherry (Guerrero-Prieto *et al.*, 1985; Furukawa and Bukovac, 1989). A short life span of ovules is limiting to EPP in sweet and sour cherries (Postweiler *et al.*, 1985; Cerovic and Ruzic, 1992) and apricot (Burgos and Egea, 1993). Abnormalities of the ovule or embryo sac development limit EPP in olive (Rallo *et al.*, 1981), avocado (Tomer *et al.*, 1976) and almond (Pimienta and Polito, 1982). Unlike other *Prunus* species where well-developed embryo sacs are present at anthesis, almond ovules are in the megaspore-mother-cell stage at flower opening, and complete embryo sac maturation 7–8 d after anthesis (Pimienta and Polito, 1983). Since embryo sac development is stimulated by the presence of compatible pollen tubes in the style and final elongation growth of the embryo sac is promoted by cross-pollination (Pimienta and Polito, 1983), ovule longevity in almond may be less limiting to EPP than in species attaining a mature embryo sac at anthesis.

Details of stigma receptivity have been studied in only a limited number of species (Shivanna, 2003). Optimal receptivity is variable and can be from a few hours after flower opening as in teak (Tangmitcharoen and Owens, 1997), to a few days after anthesis as in oak (Kalinganire *et al.*, 2000) and *Silene alba* (Young and Gravitz, 2002). Although there are a few histological studies of ovule development in almond (Sterling, 1964; Pimienta and Polito, 1983), evaluations of stigma development and its relationship to stigma receptivity are lacking. The timing of pollination for adequate fruit set has been evaluated in almond to some extent, but solely on a time/day basis which precludes direct comparisons due to differences in flower maturation that occur with environment and location. Furthermore, the contribution of stigma receptivity to support pollen germination and tube growth is unknown. The objectives of this study were to investigate stigma receptivity under defined developmental

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stages and to clarify the relationship between stigma morphology, pollen germination and tube growth. Such information would allow a greater understanding of how factors affect the EPP in almond, and thereby provide information providing strategies to optimize pollination and increase fruit set.

MATERIALS AND METHODS

Plant material

Almond [*P. dulcis* (Mill.) D.A. Webb] budwood from 'Nonpareil' and 'Padre' cultivars was collected from a commercial orchard (Paramount Farming Co., Bakersfield, CA, USA), packed in coolers, and shipped by next-day mail to the laboratory in Georgia. Upon delivery, shoots were recut under water, placed with their bases in water, and held in a dark cold room at 7 °C for up to 7 d. Buds were forced as needed under light conditions at room temperature, and collected for histological evaluations. Flowers were also used in pollination studies to assess stigma receptivity, in which case flowers were emasculated before anther dehiscence. Pollen collected from 'Sonora' and 'Fritz' trees was used to pollinate 'Nonpareil' and 'Padre' flowers, respectively. *In vitro* germination tests (Yi *et al.*, 2003*b*) were conducted to verify pollen viability. Pollen was inoculated into germination wells containing 12 % sucrose (w/v), 0·062 % $CaNO_3$ (w/v) and 0·024 % boric acid (w/v). Germination percentages were 51 and 41 % for these two cultivars, respectively.

Flower stage descriptions

Buds and flowers were classified into seven developmental stages (Fig. 1): stage 1, bud swollen, no pink visible; stage 2, pink visible, petal tightly closed; stage 3, petals extended, but corolla still tubular with opening at tip of petals; stage 4, petals unfurling, individual petals cup-shaped and curved; stage 5, fully open stage, little or no curvature in petals, individual petals are predominantly planar; stage 6, flattened stage, petals are attached to the floral axis at 0 ° angle or reflexed; stage 7, petal fall stage, all or most petals abscised, stigma has not darkened in colour.

Light microscopy

'Nonpareil' flowers from stages 1–7 were prepared for microscopic evaluations. Pistils were dissected and fixed in 2 % glutaraldehyde in cacodylate buffer pH 7·2, dehydrated in a series of methyl cellosolve (ethylene glycol monomethyl ether), ethanol, propanol and *n*-butanol, then infiltrated and embedded in Historesin (Leica Instruments, Heidelberg, Germany). Sections were cut using a HM350 rotary microtome (Microm, Heidelberg, Germany). For general histological observations, sections were stained with 0·05 % toluidine blue O, and examined using a Zeiss Standard microscope (Carl Zeiss, Oberkochen, Germany). Cuticles were localized using 0·01 % auramine O in Tris–HCl buffer (pH 7·2) under fluorescence illumination (Heslop-Harrison, 1977).

Scanning electron microscopy (SEM)

'Nonpareil' flowers at each stage were selected to observe as fresh, unfixed samples. Pistils were dissected from flowers/buds, and stigmas with attached styles were mounted on aluminium stubs using carbon paste. Each sample was observed immediately using a JSM-5800 scanning electron microscope (JEOL, Tokyo, Japan) at 5 kV. Images were captured digitally.

Pollination and tube growth assessment

Accurately counted numbers of pollen grains were applied onto the stigmas of flowers at selected developmental stages to assess pollen germination and tube growth. Direct counting of pollen numbers on the stigma was not possible because pollen is obscured by stigmatic exudate, thus pollen numbers were determined indirectly. Pollen grains were applied to the transparent covers of 12-well tissue culture plates (Costar Tissue Culture Clusters 12; Costar, Cambridge, MA, USA), and grain numbers were counted using an inverted microscope (Nikon, Garden City, NY, USA). Detached flowers were pollinated by gently touching the stigma to the pre-counted pollen grains. The number of pollen grains adhering to the stigma was determined by subtracting the number of remaining grains on the plate from the number of originally counted grains. In general, from 100 to 200 pollen grains were applied to each stigma. Flowers were transferred into the wells containing tap water and kept under light conditions at 24 °C.

At 24 h after pollination, flowers were dissected to remove pistils, then stigmas and styles were fixed in ethanol : acetic acid 3 : 1 (v/v). Tissues were softened and cleared by autoclaving at 120 °C for 20 min in 1 % sodium sulfite solution (w/v), stained using aniline blue (0·01 % aniline blue in 0·1 M K_3PO_4) for at least 4 h, then examined using a Zeiss Standard microscope (Carl Zeiss, Oberkochen, Germany) under fluorescent light (G365, LP420). The numbers of pollen tubes and the extent of their growth through the length of the style were assessed.

Four developmental stages (4, 5, 6 and 7) for each cultivar were assessed in the pollination and tube growth studies. The entire experiment was repeated three times at 2 d intervals with five flower replicates each time, using a completely randomized block design: four developmental stages × three blocks (days when the experiment was conducted) × five flower replications. Statistical analysis was conducted by GLM followed by Duncan's multiple range test at P=0·05 (SAS Institute, 1989).

Fruit set field studies

Fruit set of flowers hand pollinated at different developmental stages was assessed under commercial orchard conditions in Bakersfield, CA, USA in 2003. Investigations were carried out on 7-year-old 'Butte' and 'Padre' trees. To prevent insect pollination, individual branches within the middle third of the canopy were randomly selected and enclosed within fibreglass screen (1·6 mm opening) bags prior to flower opening. As branches came into bloom, they were assessed for uniformity and assigned a flower

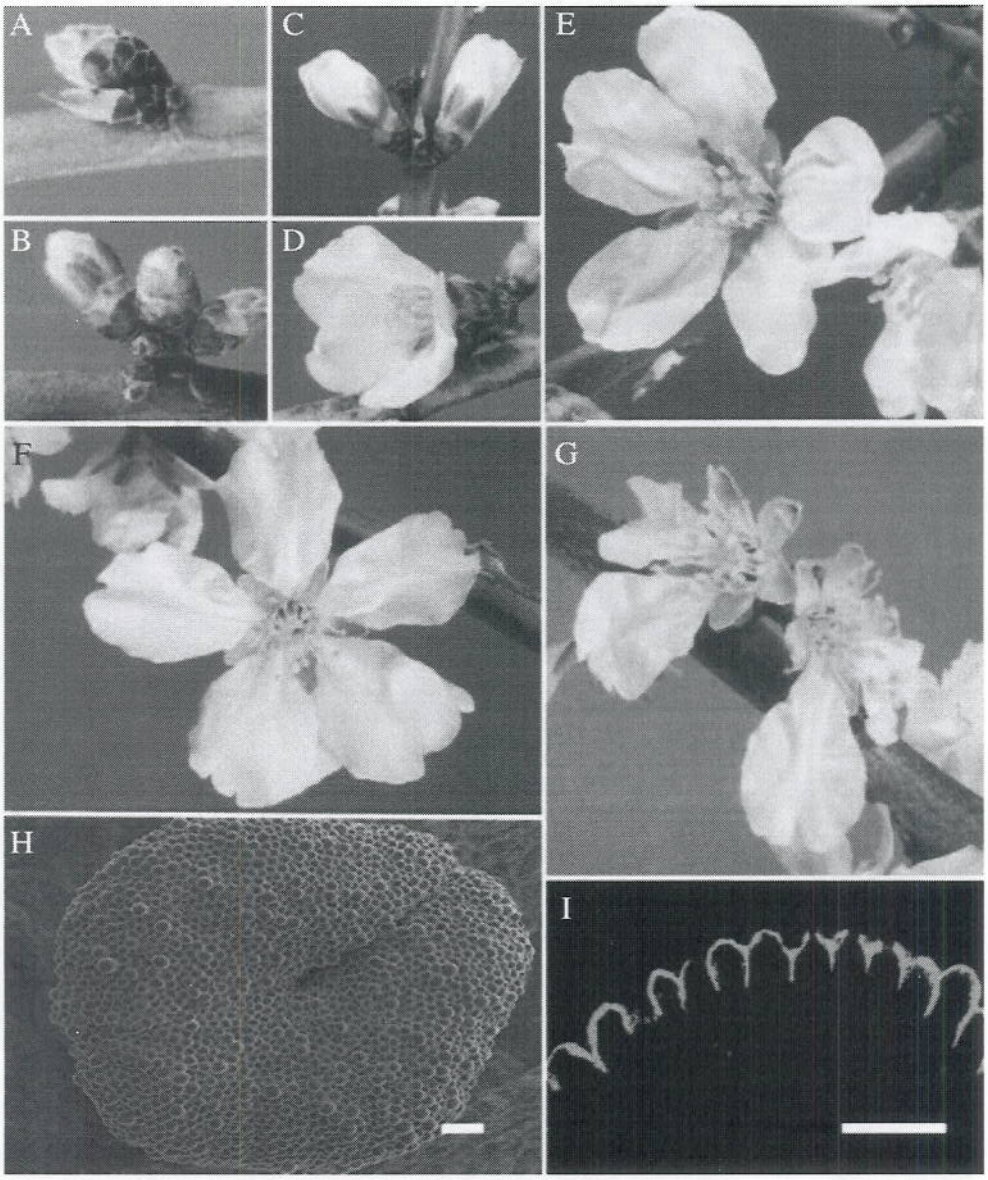

FIG. 1. (A) Stage 1, swollen bud. (B) Stage 2, pink bud. (C) Stage 3, extended petals. (D) Stage 4, unfurling petals. (E) Stage 5, fully open. (F) Stage 6, flattened petals. (G) Stage 7, abscised petals. (H) SEM view of a stigmatic surface at stage 1. Scale bar = 80 μm. (I) Section through the surface of a stage 1 stigma stained with auramine O under fluorescence microscopy showing a cuticle layer on the surface. Scale bar = 40 μm.

stage (stage 4, 5, 6 or 7) closest to the majority of their blooms. Flowers that were younger and older than the assigned stage were manually removed from branches at the time pollinations were made. Branches were successively pollinated throughout the bloom period of February 19 to March 7. Data from March 7 were excluded from the analysis, because all flowers pollinated on that date were infertile and did not set fruit.

The pollen used for hand pollinations was obtained from 'Neplus' trees and applied using a small paintbrush. The numbers of flowers on each branch were counted and bags were replaced until stigmas were desiccated shortly after petal fall. Young fruits were counted on May 5, and the percentage fruit set was calculated as the (number of fruit set)/(number of flowers pollinated) × 100 %. On August 7, nuts were harvested and dissected to assess the percentage of full nuts that were set as calculated by the (number of full nuts)/(number of flowers pollinated) × 100 %.

Thus, the experiment was blocked by pollination date with almond variety and flowering stage nested in a split plot design. A type 4 analysis of variance (ANOVA; SPSS, Inc.) was conducted since not all flowering stages were represented in each pollination date. Sample size was 40 after excluding one outlier (2·4 % of the data) as determined by Cooks Distance criterion.

RESULTS

Stigma development

Pistil morphology in almond is characterized by a single circular bilobed stigmatic surface (Fig. 1H) that expands

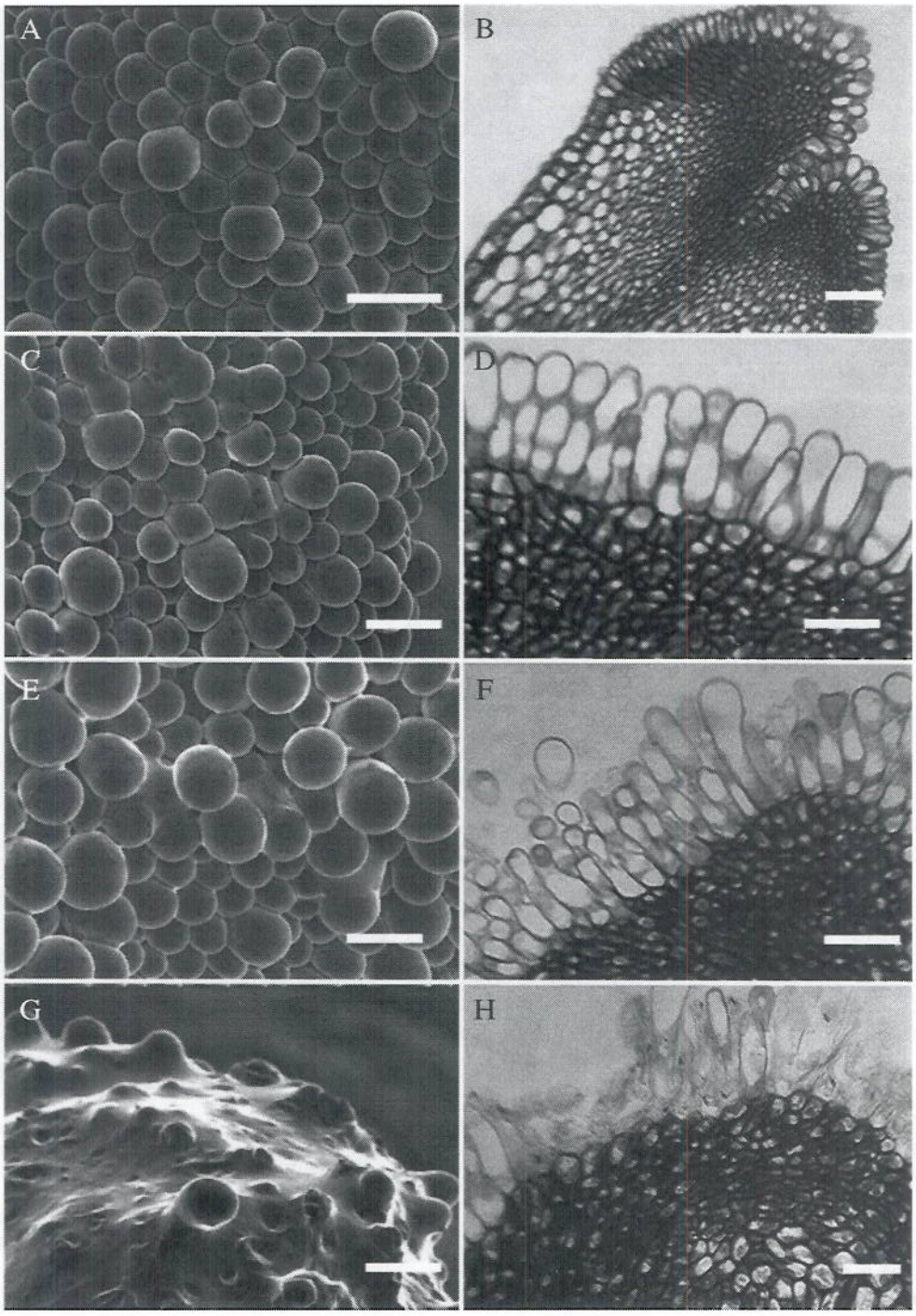

FIG. 2. (A) Portion of a stage 1 stigmatic surface showing short papillae. Scale bar = 50 μm. (B) Longitudinal section through the stigma of a stage 1 flower. Scale bar = 75 μm. (C) Surface papillae from a stage 4 flower showing localized areas with exudate. Scale bar = 45 μm. (D) Light micrograph of a longitudinal section through a stage 4 stigma. Papillae are elongate with large vacuolar content. Scale bar = 50 μm. (E) Stage 6 stigma with some shorter papillae immersed in exudate. Scale bar = 40 μm. (F) Section through stage 6 stigma. Papillae have elongated differentially so that stigmatic cells are of different heights. Scale bar = 45 μm. (G) Surface view of a stage 7 stigma. Only a few elongated papillae are visible over the exudate. Scale bar = 40 μm. (H) Cross-section of a stage 7 stigma. Collapse of some papillae is evident. Scale bar = 41 μm.

slightly in a fan-like manner beyond an elongated and cylindrical style (Yi *et al.*, 2003*a*). Stigmatic surface cells at stage 1 were composed of raised unicellular papillae (Fig. 2A and B). Sub-papillar regions were composed of small, densely staining cells (Fig. 2B). The short papillae were closely packed and had little visible exudate accumulation (Fig. 2A). A cuticle–pellicle layer on external surfaces of papillae was visualized with auramine O staining under fluorescence microscopy (Fig. 1I). At stages 2, 3 and 4, papillae were more elongated, and accumulated stigmatic

TABLE 1. *Pollen germination and tube growth in 'Nonpareil' and 'Padre' almond flowers, 24 h after pollination of flowers at different developmental stages with 'Sonora' and 'Fritz' pollen, respectively*

Flower stage	Germination percentage*		Tube length (%)†	
	'Nonpareil'	'Padre'	'Nonpareil'	'Padre'
Stage 4	0·1[a‡]	3·9[a]	3[a]	31[ab]
Stage 5	0·4[a]	2·4[a]	9[ab]	22[a]
Stage 6	3·0[b]	14·5[b]	19[b]	42[bc]
Stage 7	4·5[b]	20·1[b]	50[c]	60[c]

* Germination percentage was calculated as (germinated pollen)/(viable pollen) × 100 %.

† Length of longest pollen tubes as a percentage of the total length of the style.

‡ Means within the same column followed by the same letters are not significantly different at $P = 0{\cdot}05$ using Duncan's multiple range test.

exudate appeared at some interstitial regions at the base of adjacent papillae (Fig. 2C). In stages 2 and 3, stigmatic exudate accumulations were limited to the central region of stigmas, while in stage 4, exudate was observed in both central and peripheral areas. An intact cuticle was absent at these and subsequent stages. Elongated papillae were tightly packed, of uniform height and appeared turgid (Fig. 2D). With further elongation in stage 4, papillae had prominent vacuolar spaces.

Fully open flowers (stage 5) exhibited localized regions where exudate accumulated and could reach the tips of some papillae; minor collapse of some stigmatic cells occurred. Increasing amounts of exudate were observed as flowers developed further, as shown in stage 6 flowers where shorter papillae were partially inundated (Fig. 2E). Papillae elongated differentially so that stigmatic cells of variable heights were observed, with taller cells exhibiting enhanced protruding apical regions (Fig. 2F). Cells had more extensive vacuolar spaces which occupied most of the cell volume. In stage 7 flowers, which were initiated at the onset of petal fall, substantial and copious exudate submerged the entire stigmatic surface so that only a few elongated papillae were visible (Fig. 2G). Further collapse of papillae was observed (Fig. 2H).

Pollination studies

Flower stage had a significant and similar effect on pollen germination in both 'Nonpareil' and 'Padre' (Table 1). The percentage pollen germination was significantly higher in more developed flowers at stages 6 (flat petal) and 7 (petal fall) compared with younger flowers at stages 4 (petals unfurling) and 5 (fully open). The two cultivars differed in germination percentage, with 'Padre' flowers exhibiting up to approx. 15–20 % germination compared with 'Nonpareil' which had approx. 3–5 % germination. Younger staged 'Nonpareil' flowers failed to support pollen germination, i.e. germination was <0·4 %.

Pollen tube growth was also impacted by flower developmental stage when the lengths of the longest pollen tubes were expressed as the percentage of the total style length that tubes penetrated (Table 1). In 'Nonpareil', the longest tube lengths were observed in flowers at stage 7, where at 24 h after pollination, tubes extended to 50 % of the style length. Maximum pollen tube length was significantly shorter in younger flowers after the same duration, where pollen extension at the two earliest stages was only 6–18 % of that obtained in the oldest stage flowers. In 'Padre', flower development had a less marked effect on tube extension. Although stage 7 flowers exhibited more extension tube growth than flowers at stages 4 or 5, maximum tube extension was over 30 % of the style length at even the youngest stage pollinated.

TABLE 2. *Fruit and nut set of 'Butte' and 'Padre' almond flowers after hand pollination at different developmental stages*

Flower stage	Fruit set (%)*		Full nut set (%)†	
	'Butte'	'Padre'	'Butte'	'Padre'
Stage 4	27·3[a‡]	78·9[a]	27·3[a]	74·7[a]
Stage 5	30·5[a]	74·7[a]	30·5[a]	74·7[a]
Stage 6	45·1[a]	70·9[a]	44·2[a]	67·8[a]
Stage 7	32·9[a]	49·0[a]	29·6[a]	47·5[a]

* Fruit set percentage was calculated as: (number of fruit set)/(number of flowers pollinated) × 100 %.

† Full nut percentage was calculated as: (number of full nut set)/(number of flowers pollinated) × 100 %.

‡ Means within the same column followed by the same letters are not significantly different at $P = 0{\cdot}05$ using Duncan's multiple range test.

Fruit and nut set studies

Flowers hand pollinated at different developmental stages exhibited no significant differences in percentage fruit set among the four developmental stages (Table 2). Appreciable levels of fruit set were observed in flowers of all developmental stages for both 'Butte' (from 27 to 45 %) and 'Padre' (from 49 to 79 %). Similar results were observed in the percentage of full nuts (Table 2), with similar nut set observed in all stages. 'Butte' exhibited lower fruitfulness than 'Padre', obtaining levels of fruit and full nut set of only 35–70 % of that observed in 'Padre'.

DISCUSSION

The stigma is reported to be receptive at the time of anthesis in many tree crops such as peach, apricot, sweet cherry, apple and kiwi (Sanzol and Herrero, 2001). However, the receptive period can vary with species or cultivar, and requires delayed maturation of the stigma post-anthesis. Herrero (1983) reported that pear stigmas were not receptive at anthesis and pollen germination increased with time for 4 d. Likewise, stigmas in apricot were not mature at the balloon stage, but attained higher receptivity 2 and 4 d after flower opening (Egea *et al.*, 1991). Williams *et al.* (1984) concluded that in apple, recently opened flowers were not yet fully receptive to pollination.

In the current study, stigma receptivity in 'Nonpareil' and 'Padre' almond flowers was delayed, with higher

percentages of pollen germination and more extensive tube extension observed in older (flat petal or petal fall) than younger flowers (petals unfurling or fully open flowers). Previous studies to determine the optimal timing of stigma maturation in almond have resulted in variable responses depending on cultivar and environment. Ortega *et al.* (2004) pollinated almond flowers at 0, 2, 4 and 6 d after emasculation, and evaluated the number of pollen tubes in the style. Stigma receptivity varied with cultivar, and in some cases was optimal in youngest flowers and declined after 2 d; some cultivars were not receptive until 6 d after emasculation. Since flower stages at pollination were not defined, it is unclear if cultivars varied in flower development on their respective days after emasculation. Environmental conditions such as temperature at time of blooming may have impacted flower development and stigma receptivity.

Appreciable levels of fruit and nut set were observed in flowers pollinated at both younger (stage 4 and 5) and older (stage 6 and 7) stages, with no statistical differences observed. This is in contrast to our data on pollen tube numbers in the style, which indicate that younger flowers do not support pollen tube growth as well as older flowers. Almond flowering can progress rapidly under field conditions. We have observed flowers maturing from our stage 3 to stage 5 within a single day in California when temperatures are warm. Pollen grains can maintain their viability under room temperature conditions for a few days (data not shown). Therefore, pollen grains attached to young stigmas could germinate and fertilize flowers after undeveloped stigmas reach a sufficient maturity for pollen hydration, germination and tube growth to occur. This could explain the fruit set we obtained with young staged flowers that had low stigma receptivity. Although loss of ovule viability can impair fruit set if pollination occurs when flowers are too old, our data show that even flowers that exhibit petal abscission (stage 7) are capable of setting fruit at levels comparable with earlier staged flowers. At stage 7, the stigma has not darkened, and pollen readily germinates and grows within the style. Whether ovule degeneration is a factor in these and even further advanced flowers is work for further evaluation.

In almond, there have been conflicting reports regarding the effects of flower age and fruit set. Vezvaei and Jackson (1995) achieved the highest fruit set in newly opened flowers. In contrast, Griggs and Iwakiri (1964) indicated that older staged flowers were effective at setting fruit; flowers pollinated 3 d after emasculation had higher fruit set than those pollinated at 0 or 1 d, and fruit set remained high for 7 d. Ortega *et al.* (2004) obtained acceptable fruit set following pollination from day 0 to day 4 after emasculation. In these studies, morphological descriptions of floral development were not given. Environment can play an important role in the rate of flower development, emphasizing the advantage of expressing receptivity on a developmental rather than a calendar basis. In the current study, we further correlated stigma receptivity under different developmental stages with histological evaluations of almond pistils.

Papillae degeneration and the production of exudate have been associated with the beginning of stigma receptivity in tree crops such as sweet cherry and peach (Uwate and Lin, 1981; Herrero and Arbeloa, 1989). Rupture of cuticle layers during development of wet stigmas is associated with exudate production originating from epidermal and subjacent cell layers, that accumulates in the intercellular spaces of the stigmatic tissue and below the cuticle–pellicle layer of epidermal cells. The cuticle–pellicle layer is torn away with continued secretion of exudates (Konar and Linskens, 1966; Dumas *et al.*, 1978). In sweet cherry, the primary pollen-receptive area was associated with cuticle exfoliation and papillae degeneration (Uwate and Lin, 1981). Our observations concur in that an intact cuticle layer was only observed in early stage flowers, characterized as having minimal amounts of stigmatic secretion. Degeneration of stigmatic surface cells accompanied the profuse accumulation of surface exudate in older flowers. Copious stigmatic secretions could enhance pollen hydration, germination and tube growth.

In pear, immature stigmas can support adhesion of pollen on their surface, but cannot provide a proper substrate for pollen hydration (Sanzol *et al.*, 2003*a*). This could explain why almond stigmas younger than stage 6 supported very little pollen germination. Before flowers reached stage 6, insufficient exudates were produced, and little secretion occurred, suggesting that the transition of the stigma from an immature to a mature stage occurs with the acquisition of competence to support pollen hydration and germination.

More severe forms of stigma degeneration may have inhibitory consequences and result in loss of receptivity. Cessation of stigma receptivity in kiwi occurred simultaneously with papillae rupture. Pollen germination stopped when papillae degeneration and loss of cellular integrity occurred (Gonzalez *et al.*, 1995*a*). However, in some cases, degeneration can be severe, yet have no apparent negative effects. The stigmatic tissue can become necrotic when the flowers are still receptive. By the later stages of flower development, the exudates can be secreted through holocrine secretion following degeneration of the protoplasts of the secretory cells (Herrero and Dickinson, 1979; Kristen *et al.*, 1979). In the current study, no abnormal tip growth or swelling was observed for the pollen tubes growing in stage 7 flowers.

Our studies indicate that in almond, stigma receptivity is not optimal until flowers are beyond the fully open stage and exhibit flattened petals. Flowers at younger stages failed to support pollen germination, indicating that further maturation is required. Morphological evaluations confirm that stigmatic papillae elongate and exudate is produced in more mature flowers that exhibit higher percentages of pollen germination and more extensive tube growth in the style. Sufficient amounts of exudate may be prerequisite for adequate pollen function. Thus, efforts to improve fertilization for improved yield should include methods to enhance pollination in both younger and older flowers. The current results show that the stigma is still receptive, and fruit and nut set are maintained even in flowers at the stage when petals are abscising. This information is especially valuable to growers when they need to decide the time period for effective honeybee pollination.

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Fungicide Sprays Can Injure the Stigmatic Surface During Receptivity in Almond Flowers

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Fungicides can be detrimental to flower development, pollen function and fruit set in a number of crops. Almond is a self-incompatible nut crop that has a fruit set of only approx. 30 % of the total number of flowers. Thus, interference of pollination and fertilization by fungicide sprays is of concern, and identification of chemicals having the least detrimental effects would be desirable. The objective of this study was to evaluate the effect of fungicide sprays on stigma morphology in almond using a laboratory spray apparatus that simulated field applications. Four fungicides (azoxystrobin, myclobutanil, iprodione and cyprodinil) were applied, and fresh, unfixed stigmatic surfaces were observed using a scanning electron microscope at 4 and 24 h after spraying. Increased exudate accumulation was induced by azoxystrobin at both time periods, and localized damage and collapse of stigmatic cells were observed after 24 h. Damaged stigmatic papillae exhibited wrinkling, surface distortion or collapse. Likewise, myclobutanil caused significant damage to and collapse of papillae; these were more extensive at later observations. Iprodione had no effect on exudate accumulation but caused marked and severe collapse of stigmatic papillae which was pronounced at 24 h. Cyprodinil promoted a copious increase in exudate secretion and caused the most severe collapse of stigmatic cells of all the fungicides evaluated. Damage was somewhat localized at 4 h but more global at 24 h. This study has verified that certain fungicide sprays have direct detrimental effects on stigma morphology and enhance exudate production in almond flowers.

Key words: Almond, collapse, exudate, fungicide, pesticide, *Prunus dulcis*, scanning electron microscopy, stigmatic papillae.

INTRODUCTION

Adequate pollination and fertilization are critical in agricultural crops where fruit or seed is the final product, and have been identified as factors limiting yield and crop quality (e.g. fruit size, shape, sugar content and storage ability) in numerous economically important crops including apple (*Malus* × *domestica* Bokh.), kiwifruit [*Actinidia deliciosa* (A. Chev.) C.F. Liang et A.R. Ferguson], cacao (*Theobroma cacao* L.) and melon (*Cucumis melon* L.) (Costa *et al.*, 1993; Dag and Eisikowitch, 1995; Falque *et al.*, 1995; Volz *et al.*, 1996; Gonzalez *et al.*, 1998). Critical events associated with pollination in higher plants include the development of receptive stigmas and functional pollen, pollen transfer and attachment, pollen hydration and activation, pollen germination and tube growth (Johri, 1984; Raghavan, 1997). These events are necessary for fruit set to proceed.

Almond [*Prunus dulcis* (Mill.) D. A. Webb] is an important nut crop that blooms relatively early in the spring (February in California, USA). The crop is self-incompatible and requires cross-pollination. Pollination can be limiting in certain production areas owing, in part, to cool, damp weather conditions during the blooming period which may limit insect activity. It has been reported that the percentage of fruit set in commercial orchards is commonly only 30 % (Gary *et al.*, 1976). Almond is heavily sprayed during the bloom period for blossom blight caused by *Monilinia fructicola* and/or *M. laxa*. Interference with pollen germination and function by fungicide sprays during the pollination period would be of particular concern in almond production.

The stigma is the receptive surface for pollen. It can provide nutrients to the pollen and direct pollen tube growth. The stigmatic surface must have the correct physiological condition for the pollen, i.e. a balanced osmolarity and sufficient water supply (Johri, 1984). Any damage to the stigmatic surface by fungicide sprays may potentially cause the pollination process to fail. A number of studies have reported detrimental effects of fungicide sprays on fruit set and/or yield in crops such as apple (Hutcheon *et al.*, 1986), cranberry (*Vaccinium macrocarpon* Ait.) (Shawa *et al.*, 1966; Bristow and Shawa, 1981; Ozgen and Palta, 2001), raspberry (*Rubus idaeus* L.) (Redalen, 1980), strawberry (*Fragaria* × *ananassa* Duch.) (Eaton and Chen, 1969; Kovach *et al.*, 2000) and pecan (*Carya illinoensis* Wangenh C. Koch) (Wetzstein, 1990; He and Wetzstein, 1994). However, studies specifically evaluating the effects of fungicides on stigma morphology are extremely limited for fruit crops and absent in almond.

The objective of this study was to evaluate the effect of fungicide sprays on stigma morphology in almond at the ultrastructural level. Fungicide sprays were applied in the

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TABLE 1. *Fungicides applied to almond flowers and rates of application*

Active ingredient	Formulated product name	Class	Field rate per acre	Laboratory equivalent
Azoxystrobin	Abound	Strobilurin	12·8 oz	1 ml l^{-1}
Myclobutanil	Rally	Conazole	6·0 oz	0·45 g l^{-1}
Iprodione	Rovral	Iprodione	1·0 lb	1·2 g l^{-1}
Cyprodinil	Vangard	Pyrimidine	5 oz	0·37 g l^{-1}

Spray solutions were calculated based on spray application volumes of 100 gallon per acre (935 l ha^{-1}).

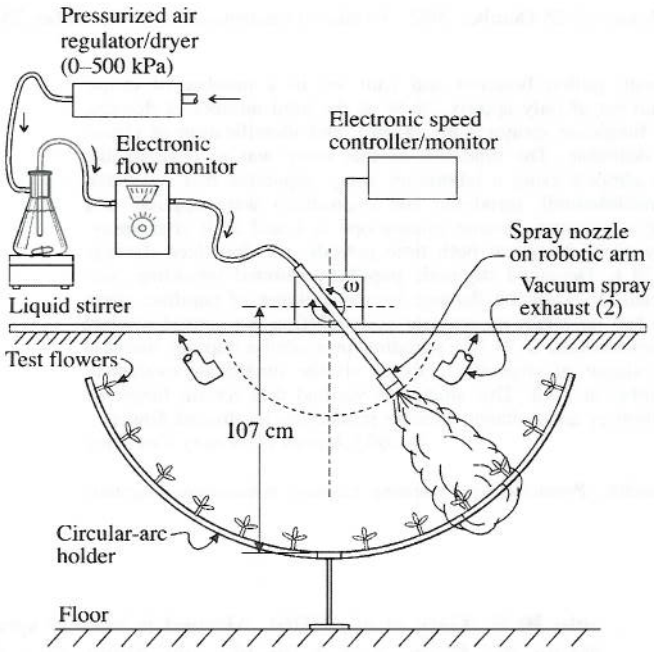

FIG. 1. Laboratory apparatus used to simulate field fungicide applications. A conventional hydraulic-atomizing nozzle at operational pressure commonly used for fungicide applications provided the appropriate droplet-size spectrum, volumetric flow rate and active ingredient concentration for each fungicide. An electronically controlled robotic arm swept the spray nozzle at controlled speed past test flowers positioned around a circular-arc holder.

laboratory to detached flowers using a mechanized spray apparatus to simulate field application conditions. Stigmatic surfaces were observed in a fresh, living state to avoid loss of stigmatic exudate associated with fixation and critical point drying.

MATERIALS AND METHODS

Plant material

Almond (*Prunus dulcis* 'Nonpareil') budwood was collected from a commercial almond orchard (Paramount Farming Co., Bakersfield, CA, USA), packed in coolers, and air-shipped for next-day delivery. Upon delivery, shoots were recut and stored with their bases in water in a cold room at 7 °C. Buds were forced as needed and flowers were emasculated before anther dehiscence to remove sources of pollen contamination. Just prior to spraying, individual flowers were selected and removed with approx. 1 cm of the shoot still attached, then transferred into wells of tissue culture plates (Costar Tissue Culture Clusters 12; Costar, Cambridge, MA, USA) containing tap water. Flowers that showed normal stigma development and similar stigma orientations and style lengths were chosen with the aid of a dissecting microscope. Flowers were carefully selected so that they were all at the open petal stage of development within a day after anthesis.

Chemicals and spray application

Four fungicides that are widely applied during the bloom season to prevent blossom blight were tested: (1) azoxystrobin (Zeneca Agric. Products, Wilmington, DL, USA); (2) myclobutanil (Rohm and Haas Co., Philadelphia, PA, USA); (3) iprodione (Aventis CS, Research Triangle Park, NC, USA); and (4) cyprodinil (Novartis Crop Protection, Inc., Greensboro, NC, USA). The formulated product name and classification of each fungicide are shown in Table 1. A water spray served as control. Just prior to spraying, eight flowers were attached (via a spring-clip to their woody stem) to a circular-arc holder with stigmas oriented towards the oncoming spray. Fungicide or water was then applied using a laboratory spray apparatus designed to simulate field application conditions (Fig. 1). The spray apparatus was set to provide application conditions equivalent to a spray volume of 100 US gal $acre^{-1}$ (935 l ha^{-1}), 2 mph (3·2 km h^{-1}) tractor ground speed, tree spacing of 24 ft (7·3 m) between rows, and an application rate of 0·263 gal min^{-1} (16·6 ml s^{-1}) per nozzle (using TeeJet 8003; Spraying Systems Co., Wheaton, IL, USA) at 40 p.s.i. (276 kPa) for dual-pass by targets. Immediately after spraying, flowers were transferred back into the culture plates and kept under light conditions at 24 °C. In a separate experiment, Rhodamine B stain solution (0·1 % w/v) was applied using the same conditions to evaluate the spray patterns.

Experimental design

A factorial design was used, evaluating different spray compounds and time periods after spraying. The design was: two time periods × five spray compounds (including water control) × eight flowers. Five stigmas were used in observations of fresh flowers without fixation; three stigmas were fixed, coated and observed as described below.

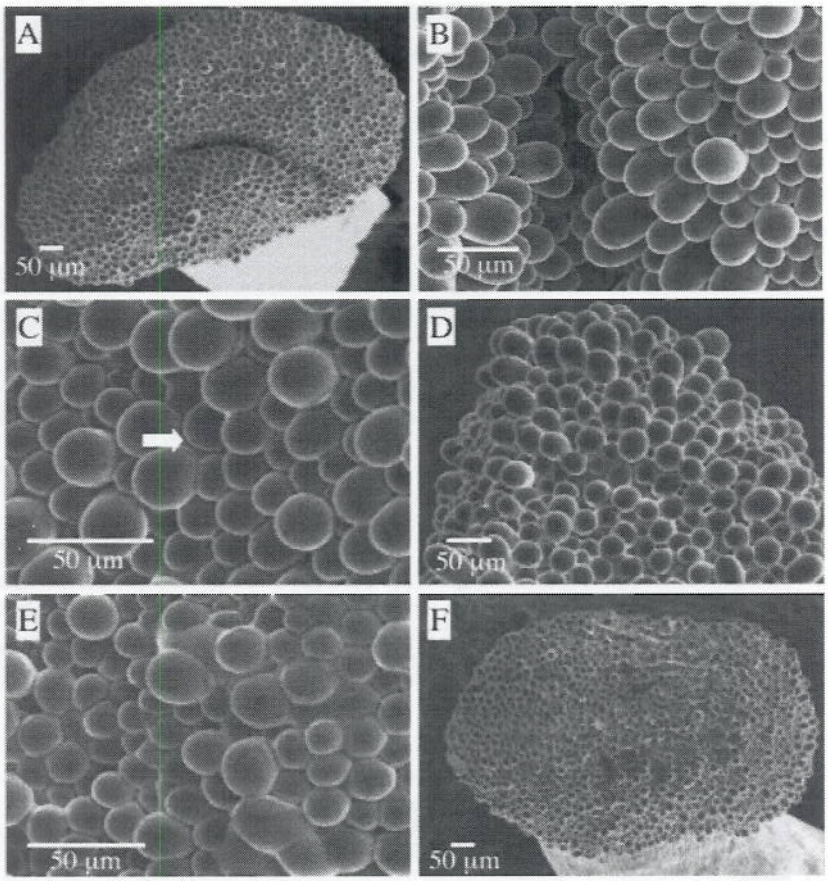

FIG. 2. Stigma morphology of almond flowers 4 (A–C) or 24 h (D–F) after spraying with water. A, Pistil morphology in almond is characterized by a circular, bilobed stigmatic surface that expands slightly in a fan-like manner beyond an elongated and cylindrical style. B, Stigmatic surface cells are composed of raised papillae. C, Slight exudate secretions accumulated in interstices at the base of papillae; arrow indicates exudate accumulation. D–F, Showing variable exudate production. D, Slight accumulation, similar to that at 4 h. E and F, More extensive exudate accumulation.

SEM observations

Flowers were sampled 4 or 24 h after spraying. Spray treatments were scheduled and staggered to allow adequate sampling and observation time. Five pistils were dissected from flowers and the stigmas and styles were mounted on aluminium stubs using carbon paste. Each sample was observed immediately using a JSM-5800 scanning electron microscope (JEOL, Tokyo, Japan) at 5 kV, and images captured digitally. Three other flowers from each treatment were dissected and fixed with 2 % glutaldehyde in 0·1 M cacodylate buffer, pH 7·2. The tissues were dehydrated in a graded ethanol series, then critical-point dried using a Samdri 780-A Critical Point Drier. The tissue was mounted in carbon paste on an aluminium stub and coated with gold using an SPI module sputter coater. Observations were conducted at 20 kV.

RESULTS

Fixed and critical point dried tissue samples failed to preserve stigmatic structure effectively as compared with observations of fresh, living samples. Considerable amounts of stigmatic exudate were retained, but losses during fixation and/or critical point drying were evident when fresh and fixed tissues were compared. Surface secretions in critical point dried tissues appeared as dried residues that were often irregular, plate-like or granular. This was in contrast to the fluid-like secretions observed in fresh tissue samples. Observations of fresh tissues were deemed more informative and accurate. Thus, the data summarized in Table 2 are based on fresh tissue observations.

Morphology of control stigmas

Pistil morphology in almond is characterized by a circular, bilobed stigmatic surface that expands slightly in a fan-like manner beyond an elongated and cylindrical style (Fig. 2A). Stigmatic surface cells are composed of raised papillae (Fig. 2A and B). In flowers observed 4 h after spraying with water (Table 2), papilla cells were bulbous, elevated and intact. Electron-dense, raised regions were evident, and visualized as mottled stigmatic exudate. In most cases exudate was uniformly dispersed. However, some flowers exhibited regions on the stigma where slight fluid secretions accumulated in interstices at the base of

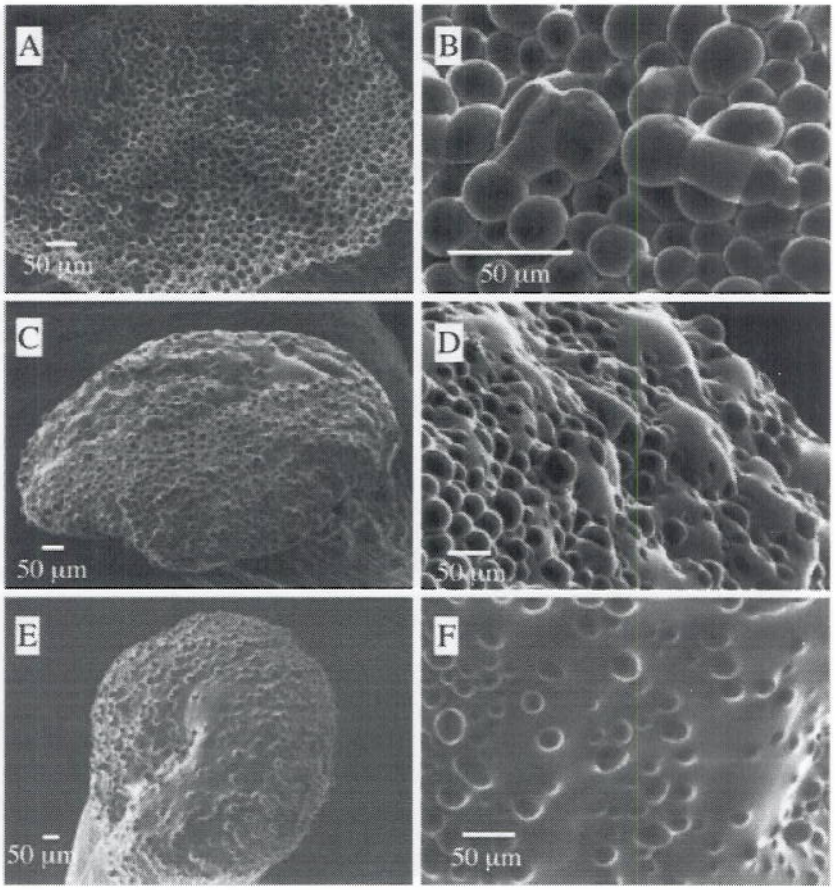

FIG. 3. Increased exudate accumulation induced by some fungicide spray materials. A, Fungicide-induced accumulation occurred in any region of the stigmatic surface and was not necessarily limited to the depression between lobes. Image taken 4 h after spraying with azoxystrobin. B, Exudate production could be very localized with an accumulation observed between as few as four adjacent cells; neighbouring cells exhibited no or little accumulation. Image taken 4 h after spraying with azoxystrobin. C, Considerable exudate accumulation occurred in any region of the stigmatic surface. Image taken 4 h after spraying with azoxystrobin. D, Accumulation of fluid was observed bridging between cells. Image taken 4 h after spraying with azoxystrobin. E, Substantial and copious secretions inundated the whole stigmatic surface. Image taken 24 h after spraying with cyprodinil. F, Stigmatic papillae completely submerged or only apical regions exposed. Image taken 24 h after spraying with cyprodinil.

papillae (Fig. 2C). Stigmas of control flowers observed 24 h after spraying exhibited a range of exudate accumulation from minor (Fig. 2D) to more abundant (Fig. 2E and F). Exudate accumulation (Fig. 2F) occurred particularly at the central region of the stigma.

Spray-induced responses

Some of the fungicide spray treatments induced similar morphological responses. Thus, the types of general cytological reactions will be described first (Figs 3 and 4), followed by a characterization of the specific responses observed for each of the fungicide treatments (Table 2).

Increased exudate accumulation was induced by some fungicide sprays and varied in extent (Fig. 3A–F). Exudate production could be very localized (Fig. 3B) with an accumulation between as few as four adjacent cells; neighbouring cells could exhibit no or little accumulation. Unlike controls where the greatest accumulation of stigmatic secretions occurred in the depression between lobes, fungicide-induced accumulation occurred in all regions of the stigmatic surface (Fig. 3A, C and E). Accumulation of fluid was observed between cells (Fig. 3D). Some fungicide sprays induced substantial and copious secretions which inundated the whole stigmatic surface in some cases (Fig. 3E). Stigmatic papillae could be completely submerged or have only apical regions exposed (Fig. 3F).

Damage and collapse of stigmatic cells were also observed following application of some fungicide sprays (Fig. 4A–D). Damaged areas could be localized (Fig. 4A), where severely collapsed papillae occurred adjacent to normal, undamaged areas. Damage could also be extensive, with collapsed areas encompassing one-third or more of the stigmatic surface (Fig. 4C). Damaged areas ranged from papillae cells exhibiting wrinkling and distortion of cell surfaces (Fig. 4B), to those that were concave or totally flattened (Fig. 4C). In addition to cases where enhanced stigmatic exudate and cell damage were observed independently, some fungicides induced a simultaneous occur-

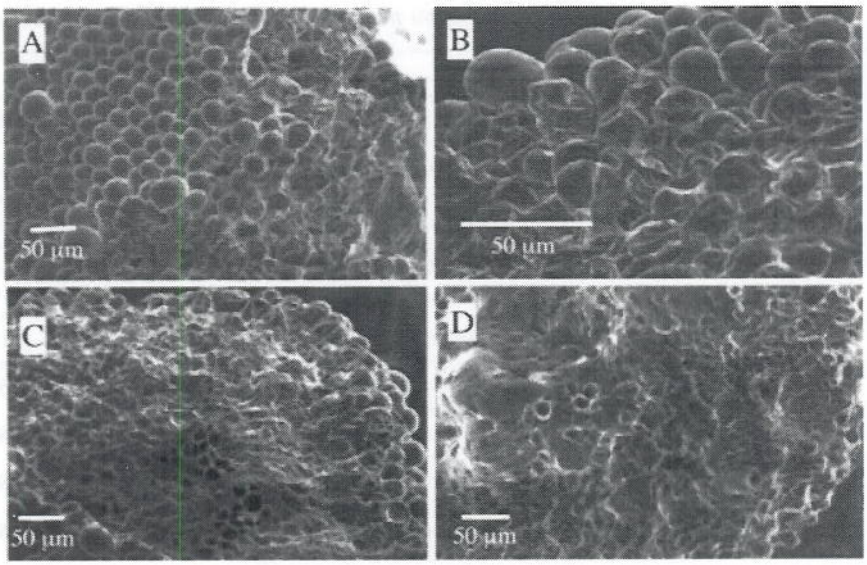

FIG. 4. Fungicide spray causes stigmatic papillae collapse. A, Localized fungicide-spray damage to stigmatic papillae, with severely collapsed papillae occurring adjacent to normal, undamaged areas. Image taken 4 h after spraying with myclobutanil. B, Damaged papillae cells exhibit wrinkling and distortion of cell surfaces. Image taken 4 h after spraying with cyprodinil. C, Extensive damage with collapsed areas encompassing one-third or more of the stigmatic surface. Papillae concave or totally flattened. Image taken 24 h after spraying with cyprodinil. D, Enhanced stigmatic exudate and cell damage can occur simultaneously. Image taken 24 h after spraying with iprodione.

rence (Fig. 4D): copious exudate production was associated with collapse and/or inversion of exposed papilla tips.

The specific effects of sprays on almond stigmas are summarized in Table 2. Increased exudate accumulation was induced by azoxystrobin at both 4 and 24 h after spraying. Exudate production ranged from that occurring at very localized regions to very expansive regions that could inundate the entire stigmatic surface. Exudate accumulation was more extensive and copious 24 h after spraying compared with that 4 h after spraying.

Although stigmatic papillae were generally intact 4 h after spraying with azoxystrobin, damage and collapse were observed 24 h after fungicide application. Damaged areas were generally localized, with severely collapsed papillae occurring adjacent to undamaged areas. Damage included wrinkling, distortion of cell surfaces or concave stigmatic papillae. Some stigmas showed both damage and exudate accumulation.

Myclobutanil caused significant damage to and collapse of stigmatic papillae. Damaged areas exhibited wrinkling, distortion of cell surfaces or concave stigmatic papillae as in the case of azoxystrobin. Damaged regions varied in area and location, and ranged from localized to extensive, with collapsed papillae sometimes encompassing one-third or more of the stigmatic surface. In some samples, exudate production was associated with collapse and/or inversion of exposed papilla tips. More extensive collapse was observed at 24 h *vs.* 4 h. Compared with controls, a slight increase in exudate accumulation was noted 4 h after spraying. Exudate accumulation at 24 h was similar to that of controls at the same time.

Iprodione did not affect exudate accumulation, but caused marked and severe collapse of stigmatic papillae. As with other fungicides, damaged areas ranged from localized to extensive and varied in severity. More severe injury occurred at 24 h. Stigmatic cell collapse was observed with and without exudate accumulation.

Cyprodinil promoted a copious increase in exudate secretion that was evident after 24 h. Commonly, stigmatic papillae were totally submerged or had only apical regions exposed. Cyprodinil also caused severe collapse of stigmatic cells. Of all the fungicides evaluated, cyprodinil caused the most severe damage. Damage was somewhat localized at 4 h, but was more global at 24 h, often covering extensive regions.

Spraying with Rhodamine B dye

Spray applications of Rhodamine B verified that all stigmas received sprays. Stigmatic areas exhibited some variation in dye deposition.

DISCUSSION

This study has verified that fungicide sprays applied to flowers during anthesis can have a direct effect on stigma morphology and exudate production. All of the fungicides evaluated induced changes in stigmatic surfaces. Common responses were collapse of surface cells and enhanced production of exudate. The current study was conducted under controlled laboratory conditions using an apparatus that closely simulates field spray conditions. Sprays were directly targeted onto stigmatic surfaces of flowers at the same developmental stage. An additional feature of this study was that SEM observations directly assessed spray effects on the stigmatic surface, i.e. ultrastructural examin-

TABLE 2. *Effects of spray treatments on the morphology of almond stigmatic surfaces*

Fungicide	Time after spraying (h)	Characteristic features*	
		Stigma papillae	Exudate production
Water control	4	No damage, cells raised and intact	None-to-slight accumulation
	24	No damage, cells raised and intact	Slight-to-extensive accumulation
Azoxystrobin	4	No damage	Enhanced production, intermediate-to-extensive accumulation
	24	Collapsed cells in localized areas	Enhanced production, extensive copious accumulation
Myclobutanil	4	Collapsed cells, damage varying in area and location	Slight increase in exudate
	24	Collapsed cells, damage more extensive than at 4 h	Same as control
Iprodione	4	Collapsed cells, damage varying in area and location	Same as control
	24	Severe collapse and flattening of cells, damage varying in area and location	Same as control
Cyprodinil	4	Severe collapse of cells, damage varying in area and location	Same as control
	24	Severe collapse of cells over extensive regions of the stigma	Enhanced production, copious exudate engulfing papillae

* Based on observations of five flowers per treatment. Times of observation were 4 and 24 h after spraying. All flowers within a treatment exhibited the features listed and, when specified, all five flowers had damage or enhanced exudate production greater than that of the controls.

ations were of living tissues, eliminating artefacts induced by fixation and critical point drying.

A marked collapse of stigmatic papillae was observed following application of some fungicides. This loss of cellular integrity could degrade the function of stigmatic cells and cause a loss of surface available to support pollen capture, hydration and germination. Deposition of large numbers of pollen grains on the stigma can be beneficial to fruit set in crops. Dennis (1979) found that a minimum of 50 pollen grains per flower is required for consistent fruit set in 'Delicious' apple even though fruits generally contain only ten ovules. Deposition of fewer pollen grains resulted in poorer germination and slower tube growth. In the current study, the collapse of stigmatic papillae might result in smaller numbers of pollen grains germinating. Therefore, although certain undamaged areas might still be receptive to pollen germination, fruit set could be detrimentally impacted.

Pollen activation and hydration is mediated by the uptake of water by colloidal imbibition and endosmosis. This hydrodynamical process strongly depends on the condition of the cytoplasm of the vegetative cell and the thickness of the intine because of its imbibition capacity (Johri, 1984). Wetzstein (1990) evaluated the effects of pesticidal sprays on the stigma in pecan and found that some fungicides were detrimental to pollen function. Benomyl applied in combination with triphenyltin hydroxide caused severe inhibition of pollen–stigma interactions, with pollen grains failing to hydrate. Although pollination was not performed in the current study, fungicides may hinder pollen hydration, especially in the collapsed areas without exudate, thereby reducing pollen germination on the stigma.

The stigmatic surface is a critical component in post-pollination responses and plays a crucial role in pollen capture, adherence and germination. Any damage to the stigmatic surface by fungicide sprays could potentially affect stigma receptivity, decrease the effective pollination period (EPP), and thereby detrimentally impact fertilization. The EPP, i.e. the period when the embryo sac remains functional for fertilization minus the time required for pollen to reach the egg apparatus (Williams, 1969), is a very important factor for successful fertilization. It can be limited by the time period in which the stigma remains receptive. In kiwifruit, stigma receptivity was the main factor responsible for a short EPP (Gonzalez *et al.*, 1995). In apricot (*Prunus armeniaca* L.), a close relative of almond, the short duration of stigma receptivity was the factor limiting EPP (Egea and Burgos, 1992). Stigma receptivity is considered by many as fundamental in explaining fruit yield differences (Egea *et al.*, 1991). In almond, the highest fruit set was obtained in pollinations of newly opened flowers and it decreased significantly at progressively later stages (Vezvaei and Jackson, 1995).

Enhancement of exudate production was particularly marked in flowers sprayed with azoxystrobin and to a lesser extent with cyprodinil. Increased exudate production is commonly associated with flower development. Control flowers in the current study exhibited some increases in exudate accumulation at later observation times. However, fungicide-induced increases were clearly greater than those induced by spraying with water. Copious exudate formation is characteristic of receptive flowers in some species; this is not the case in almond. In association with flower development studies with almond, we have evaluated stigmatic

surface changes at different stages. Stigmatic papillae were intact with minimal exudate production at anthesis when petals were fully open (data not shown). Cell collapse and copious exudate did not appear until petal fall and flower senescence. This indicates that the exudate formation caused by fungicide sprays may be the signature of senescence. Further studies are required to determine whether fungicide-induced exudates inhibit, or even prompt, pollen germination and tube growth. It is also possible that this is a senescence or stress response which may decrease the period of stigma receptivity or EPP, and thereby detrimentally impact fertilization.

Spray deposition patterns of Rhodamine B showed dye deposition was variable among stigmas. This could explain why damage observed after spraying varied in area and location. Given that under orchard conditions flowers are oriented in many directions whereas the sprays were targeted directly to stigmas in the current study, further field study is warranted. In addition, this study found that extraction of stigmatic exudate occurred during fixation and/or critical point drying, as evidenced by comparison with fresh tissue (data not shown). The dried surface secretions in fixed and critical point dried tissues sharply contrasted with the fluid-like secretions observed in fresh tissue samples. Likewise, Cresti *et al.* (1982) observed that part of the stigmatic exudate in citrus (*Citrus limon* L.) stigmas was removed as a result of fixation and critical point drying. This emphasizes the need to consider sample preparation methods carefully and be aware of the potential introduction of artefacts in ultrastructural studies.

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Fungicides can reduce, hinder pollination potential of honey bees

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Fungicide recommendations suggest that fungicides should not be applied to fruit and nut trees when honey bees or blue orchard bees are flying or when pollen is being shed.

However, some fungicides alter the foraging behavior of bees and can be toxic to adults or larvae. Fungicides can interfere with pollen tube germination and damage the stigmas of flowers. This can result in fewer cross-pollinated flowers and reduced yields.

During the 2008 almond bloom, scientists at the USDA-ARS Carl Hayden Bee Research Center, Tucson, Ariz., studied the effects of supplemental protein feeding on honey bee colonies during almond pollination in the Bakersfield, Calif., area.

Just past full bloom one grower sprayed Propiconazole, a broad spectrum fungicide, on every other row during daylight hours. Applications were repeated for several days since the fungicide was not applied prior to bud break due to poor weather.

The bees stopped foraging along the sprayed rows. The week after the spraying, given the weather conditions and number of open blossoms, only about half of the honey bees that should have been foraging on the almond blossoms were actually on the blossoms. In addition, dead bees were found outside of several colonies which suggested the sprays were toxic to the bees.

Other studies have reported adult bee toxicity from fungicide applications. Scientists working with the blue orchard bee in a commercial cherry orchard in California's Central Valley reported decreased foraging after applications of fungicides, surfactants, and foliar fertilizers. This prompted investigations on the toxicity of several fungicides on honey bees and blue orchard bees.

The scientists found that Propiconazole use was toxic and reduced the survivorship of adult bees in both species. However, recommended field application rates of Propiconazole are considered too low to kill a

substantial number of bees, but when mixed with surfactants, fertilizers, or residual amounts of insecticides left in tank sprayers, the solutions could be more toxic to bees than each compound alone.

One study found that Propiconazole mixed with a pyrethroid insecticide was 16.2 times more toxic to bees than the insecticide alone. Similarly, research has shown that feeding larval honey bees pollen contaminated with fungicides can lead to increased mortality. Exposure to pollen containing captan, ziram, or iprodione led to 100 percent mortality of larvae.

One possible reason is when honey bees collect pollen contaminated with fungicides the levels of the compounds become higher in the stored pollen than in the pollen brought back to the hive by the foragers.

High levels of fungicides in stored pollen might also inhibit the growth of certain strains of fungus that are necessary to convert pollen into bee bread. The loss of the beneficial fungus could reduce the nutritional value of the pollen to bees.

Aside from potentially harming and deterring bees from visiting blossoms, fungicides can also reduce fruit or nut set even though pollination has occurred. For the blossom to set, pollen deposited on the stigma must germinate and grow a tube down the length of the style to the ovary where ovule fertilization occurs.

In laboratory experiments, most almond pollen exposed to fungicides failed to germinate. When germination occurred, the pollen tubes frequently didn't reach the ovary for fertilization. A fungicide application to the stigma can further prevent fertilization due to stigmatic surface damage. This reduces the pollen reaching the stigma and germination.

Other experiments suggest that negative fungicide effects on pollen germination and pollen tube growth varies by the crop and only last while the fungicide is wet. This can reduce pollination success on the day of the compound application.

Brown rot and other diseases can significantly harm a crop, but the recommended cure can reduce pollination potential and may harm the bees.

So what should growers do? First, make sure the tank sprayer is clean and free of insecticide residue. Apply fungicides at the end of bloom. If this is not possible, apply several days before the honey bees are brought to the orchard.

In almonds and apples, cross-pollination and nut set cannot occur until the pollen is available from at least two compatible cultivars so there is no need to bring in the bees early. This provides more time to safely spray before the bees arrive; reducing the likelihood of exposing bees and open flowers to fungicides. Applying fungicides in the evening or at night after the blossom has shed its pollen might reduce the harmful

effects on bees. However, even nighttime applications might keep bees from foraging on trees for several days. Nighttime applications might still be potentially damaging to the stigmas in open blossoms.

Not every commercial fungicide has been tested for its impact on bees, pollen, or stigmas. Of those tested, not all are equally harmful.

It's best to assume however, that all fungicides might present some potential hazards and care should be taken in product use.

Protecting Honey Bees from Chemical Pesticides

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Honey bees are vulnerable to many of the insecticides used to control damaging pest species by fruit, vegetable, nut, and seed growers. Growers dependent on honey bees for the pollination of their crop(s) must constantly maintain a delicate balance between protecting their crops from pests and pathogens, and protecting the insects that are necessary to pollinate these crops.

The recent dramatic die-off of tens-of-thousands of honey bee colonies has left many beekeepers devastated and possibly many growers without the quantity and quality of bees needed to pollinate crops this spring and summer. A research group; the Colony Collapse Disorder Working group (see MAAREC.org) is trying to determine what factors are responsible for these unprecedented colony losses. Chemical contamination is one of the possible contributing factors that is being investigated. These include chemicals being used within the hive for mite and disease control as well as chemicals pesticides used on crops that may inadvertently find their way into hives. Until we have more documented information, it is advisable to use pesticides with care, erring on the precautionary side.

The neonicotinioids are a relatively new class of insecticides that impact the central nervous system of insects. They act either as contact insecticides or applied to plants, they are translocated throughout the plant tissue, making all parts of the plant toxic to pests that ingest them. While imidacloprid registered in 1992, is the best-known insecticide in this class, there have been a number of new neonicotinoids introduced since then (clothianidin, acetamiprid, thiamethoxam, etc.). Their use has increased dramatically over the past few years and they are now the most widely used group of insecticides in the US. Their many uses include: seed treatments for corn, cotton, canola and sunflowers; foliar sprays of fruit, nut and coffee crops; granular, and liquid drench applications in turf, ornamentals, fruit crops and in forests; and in California the number one use of imidacloprid is for the control of structural pests.

There is conflicting information about the affects of neonicotinoids on honey bees, and different chemicals in this class are known to vary in their toxicity to bees, however the EPA identifies both imidacloprid and colthianidin as highly toxic to honey bees. For example: "Clothianidin is highly toxic to honey bees on an acute basis (LD50>0.0439 mg/bee). It has the potential for toxic chronic exposure to honey bees, as well as other non-target pollinators through the translocation of clothianidin resides in nectar and pollen. In honey bees, the affects of this toxic chronic exposure may include lethal and/or sub-lethal effects in the larvae and reproductive effects on the queen". [EPA Fact Sheet on Clothianidin]. Documented sub-lethal affects of neonicotinoids include physiological affects that impact enzyme activity leading to impairment of olfaction memory. Behavioral affects are reported on motor activity that impact navigation and orientation and feeding behavior. Additional research has found that imidacloprid impairs the memory and brain metabolism of bees, particularly the area of the brain that is used for making new memories. Decourtye et al. (2004). Recent research done on imidacloprid looked at crops where imidacloprid was used as a seed treatment. The chemical was present, by systemic uptake, in corn and sunflowers in levels high enough to pose a threat to honey bees. Bonmatin et al. (2003 and 2005). In 2002 a broad survey for pesticide residues in pollen was conducted across France.

Imidacloprid was the most frequently found insecticide and was found in 49% of the 81 samples. Chauzat et al. (2006).

In addition, there is concern about the practice of combining certain insecticides and fungicides. A North Carolina University study found that some neonictinoids in combination with certain fungicides, synergized to increase the toxicity of the neonicotinoid to honey bees over 1,000 fold in lab studies. Iwasa et al. (2004). Both the neonicotinoids and the fungicides (Terraguard and Procure) are widely used. This synergistic effect needs to be looked at more carefully.

Below is a summary of the chemical and brand names of the commonly used neonicotinoids and their toxicities to honey bees. ***We are asking growers who are using these materials and who are dependent on honey bees for pollination, to use caution when selecting and applying these materials.*** Below are more specific recommendations for growers.

Neonicotinoids' Toxicity to honey bees

Chemical	**Brand name**	**Acute Contact**	**Acute Oral**
thiamethoxam	Actara, Platinum, Helix, Cruiser, Adage, Meridian, Centric, Flagship	Highly toxic	Highly toxic
clothianidin	Poncho, Titan, Clutch, Belay, Arena	Highly toxic	Highly toxic
imidacloprid	Confidor, Merit, Admire, Ledgend, Pravado, Encore, Goucho, Premise	Highly Toxic	Highly toxic
acetamiprid	Assail, Intruder, Adjust	Toxic	Toxic
thiacloprid	Calypso	Toxic	Toxic
dinotefuran	Venom	Highly Toxic	Highly Toxic

Recommendations for Growers

• Know the pesticides you are using and their toxicity to bees (do not depend on third party to provide this information).

• READ the LABEL AND FOLLOW THE LABEL DIRECTIONS

• **Never** use a neonicotinoid pesticide on a blooming crop or on blooming weeds if honey bees are present.

• The use of a neonicotinoid pesticide pre-bloom, just before bees are brought onto a crop **is not recommended**. If one of these materials MUST be used pre-bloom (for example at pink in apples), select a material that has a lower toxicity to bees (acetamiprid or thiacloprid) and apply only when bees are not foraging, preferably late evening.

• Do not apply these materials post bloom (example petal fall) until after the bees have been removed from the crop.

• Blooming time varies depending on varieties. Bees pollinating one variety or crop may be at risk while another post-bloom crop or variety is being treated. Also while crops may have completed blooming, bees may be visiting blooming weeds in an around crops. Be aware of these situations and avoid the application of pesticides on a non-blooming crop if there is risk of drift onto blooming crops and weeds if bees are present. If a spray must be applied, use the least toxic material and apply when bees are not foraging.

• Protect water sources from contamination by pesticides. If necessary, provide a clean source of water close to colony locations prior to their arrival in the orchard or crop.

For more information on CCD visit the Mid-Atlantic Apiculture Research and Extension Consortium website: MAAREC.org

For more information on pesticide toxicity and protecting bees from pesticides, please visit the online publication, *How to Reduce Bee Poisoning from Pesticides*.
(http://extension.oregonstate.edu/catalog/pdf/pnw/pnw591.pdf)

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