



Case studies of research, development and extension in NSW:

1. Ultrasound pregnancy diagnosis in ewes
2. Integrated pest management in greenhouse horticulture

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Title: Ultrasound pregnancy diagnosis in ewes and integrated pest management in greenhouse horticulture – A technical report on the research, extension and the adoption of the practices in NSW

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Disclaimer

The information contained in this publication is based on knowledge and understanding at the time of writing (July 2012). However, because of advances in knowledge, users are reminded of the need to ensure that information on which they rely is up to date and to check the currency of the information with the appropriate officer of the NSW Department of Primary Industries or the user's independent advisor.

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Summary

The following report outlines two diverse industries that involve adoption of a practice that will provide an economic benefit for the producer providing they (the producer) utilise the technology sufficiently. The technologies reviewed for the report were pregnancy diagnosis of ewes and integrated pest management in greenhouse horticulture. The review for each industry includes a brief history, departmental involvement and the level of adoption of the specific technology.

It is clear that the recording of sufficient data, reporting and evaluation by Agriculture NSW for these two technologies is of an inadequate standard to determine the adoption of a technology and the contribution of Agriculture NSW to change and the adoption of the technology. As a result of this the major recommendations are:

- Improve the recording and documentation of baseline (data) and developments
- Develop methods to determine the contribution of Agriculture NSW to industry growth
- Record a baseline level of data to help in the monitoring, evaluation, reporting and improvement/innovation
- Capture the feedback from (workshop/field day) attendees better
- Ensure the activities presented to the producers are presented at critical production time points (i.e. 1 month prior to joining or at the time of planting)
- Know the cultural aspects of the industry (i.e. English may not be the first language for many farmers of horticulture farmers)

Case Study 1:

Pregnancy Diagnosis in Ewes

Introduction

Research, Development and Extension (RD&E) programs have been utilised in NSW with an aim to improve the productivity of the sheep industry. This paper reviews the linkage between research, extension and adoption of pregnancy diagnosis of ewes via ultrasound. This review could be used as a model that could potentially lead to an evaluation of a broader range of productivity based industry programs.

Curnow et al. (2011) stated that “*sheep management is particularly challenging due to the complex nature of the grazing system and many research and adoption programs aimed at increasing productivity and profitability for sheep producers have failed to result in significant change in farming practices*”. This indicates the complexity of the issue and hence the difficulty of encouraging sheep producers to alter their production system.

Industry Goals

The industry has identified the following points that need require investigation;

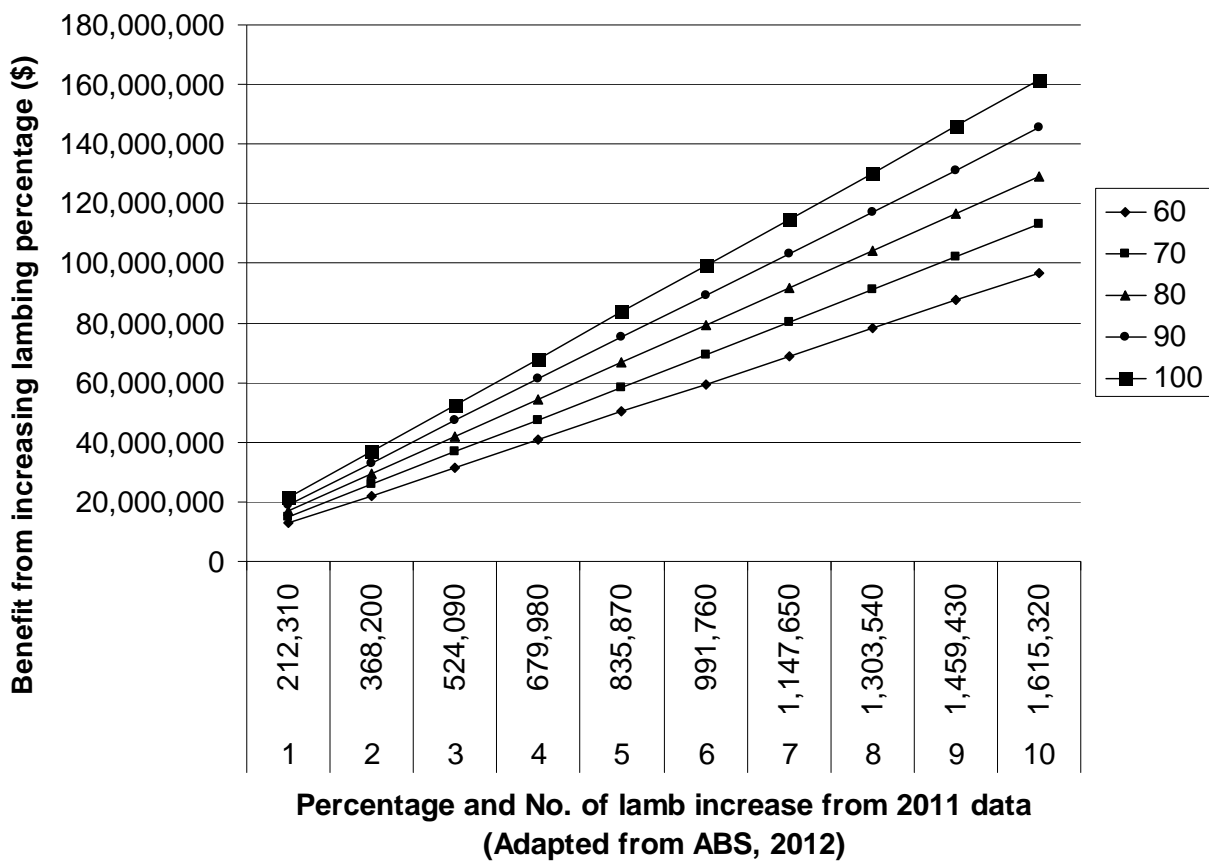
1. Improved management systems to increase reproductive efficiency as part of the National Wool RD&E Strategy 2011-2030 (Primary Industries Standing Committee 2011)
2. Increasing natural resource use efficiency
3. Increasing cost efficiency and productivity as part of the National Sheepmeat Production RD&E Strategy (Primary Industries Standing Committee 2010).

Industry Background

The farm gate value of the NSW sheep meat and wool production industry is a major contributor to the states' economy, with \$1.5 billion (ABS 2011). The number of lambs produced in NSW in

2011 was 12.1 million (ABS, 2012). These lambs were produced from 15.5 million breeding ewes for an estimated lambing percent of 78%. The lambing percentage was 75 and 79% in 2010 and 2009, respectively. Figure 1 outlines potential increases in NSW lambing percentages using 2011 data as the baseline and an estimate of the economic value of a given increase for a given value of the lamb. For example, an increase in the NSW lambing percent from the 2011 figure of 78 to 83% would result in an additional 835,780 lambs. Assuming the value of the lambs was \$80; this would lead to nearly a \$67million increase in overall farm revenue in NSW.

Figure One: The economic benefit of increasing the lambing percentage in NSW with 2011 lambing percentage and breeding ewes as the baseline when the value of the lamb is estimated at \$60, \$70, \$80, \$90 or \$100.



One approach to improved efficiency in the industry is using pregnancy diagnosis to improve breeding ewe management during pregnancy. The development of a cost effective method for

pregnancy diagnosing ewe in the extensive sheep industry was developed in the early 1980s in NSW (Fowler and Wilkins, 1984).

In relation to the key areas for the NSW government, the main area related to pregnancy diagnosis is for the improvement in the productivity of the sheep industry leading to growth of the NSW agriculture and the economy. When this is broken down, the issues that are addressed include improved animal welfare, reduction in greenhouse gas emissions (through increased efficiency), increased farm revenue, improved land use, reduced erosion and improved resource management.

Nationally, this technique is mostly used to identify pregnant and dry ewes approximately 40-70 days after ram removal. However, there are additional productivity benefits.

These include:

- ❑ Potential to increase farm productivity (increased farm revenue). Shands (2009) reported that as a result of an improved management system within the Lifetime Wool program, there was an increase of \$7800. Sixty percent of this improvement in farm revenue was achieved through differential management of dry ewes and 40% through improved management of twin-bearing ewes. The return per dry ewe was \$8.15 and the return for the twin-bearing ewes was \$1.95 (Young 2008).
- ❑ Removal of dry ewes from the flock (improved animal welfare, improved land use/pasture utilisation and ground cover and improved resource management). This can aid in the management of the stock due to the dry ewes' requirement for nutrients is much lower than a pregnant ewe and do not need to be allocated a similar level of nutrition. It can also provide information for culling in the future. These dry ewes could be re-joined to potentially provide more lambs or sold to provide income to the farm. However, this can have complications with flock structure and cash flow.

- ❑ Preferential feeding to twin-bearing ewes (improved farm revenue, improved animal welfare, improved land use/pasture utilisation and improved resource management). Twin-bearing ewes have a greater nutrient requirement during pregnancy, primarily in the last trimester (Edwards et al. 2011). In addition, allowing an increased level of nutrition from pregnancy diagnosis to twin-bearing ewes can improve the birth weight of twin born lambs (leading to improved survival and faster growth rates and increased weaning weights). The nutrition of the single-bearing ewes can be better managed to ensure lambs are not exposed to the “large offspring syndrome” (Young et al. 1998) that can lead to an increase in the incidence of dystocia and reduced lamb survival.
- ❑ Potential to change the structure of the flock (improved farm revenue). Selling dry ewes after scanning means that to maintain ewe flock numbers there needs to a greater number of younger ewes in the flock. If this system is maintained, the lambing percentage would be expected to be higher. Also, the younger ewes will be of higher genetic merit. Therefore, the rate of genetic gain of the whole flock would be expected to increase.
- ❑ Increased level of on-farm monitoring leading to improved planning (improved animal welfare, increased farm revenue, improved land use, reduced erosion and improved resource management). Utilising pregnancy scanning can provide the farmer with information about potential lambing percentages and performance indexes (such as Scanning Index (scanning percentage/live weight at mating)). These can give an indication of the reproductive performance of the ewe flock, eliminating any genetic factor and primarily concentrating on management practices and the physiological status of the ewe. It can also provide information that can be used for the preparation of lambing paddocks, particularly if the farmer has identified single- and twin-bearing ewes. The farmer can then allocate the paddocks with pasture of higher quality and shelter to the twin-bearing ewes to give the lambs the best chance of survival and growth. In addition, the farmer can have a greater knowledge of where losses occur and manage their flock accordingly. Just having lamb marking data without any information on the potential lambing percentage, there can be no confidence in making conclusions about lamb losses. Utilising the pregnancy diagnosis data,

the farmer can calculate the lamb losses from pregnancy scanning until lamb marking and weaning and can alter management to optimise potential lamb survival and production.

The benefits outlined above clearly indicate that there can be huge benefits from farmers utilising pregnancy diagnosis. However, the concerns of the cost (both of increased labour and of the scanning) and timing (of when it can be done) can be mitigated to a degree when the pregnancy diagnosis is compatible with other farm practices.

This report outlines the pregnancy scanning research conducted; the extension activities conducted attempting to change the mindset of sheep farmers and what level of adoption of pregnancy diagnosis has occurred in NSW.

Where were we and where are we now?

To create a base line for evaluation of the adoption of pregnancy diagnosis by NSW sheep farmers is difficult due to the absence of reporting of this practice. There are reports that 30% of NSW farmers are utilising this tool. Compare this to 71% of New Zealand sheep farmers utilising this tool (BeefandlambNZ, 2012) and separating single-, twin- and triplet-bearing ewes and managing them accordingly.

Resources, programs and activities

Early reports and/or investigation into the development of pregnancy diagnosis via ultrasonography have suggested the benefit of pregnancy diagnosis via ultrasound (Fowler and Wilkins, 1984 and Kilgour, 1992). However, in recent years the project has focused on those farmers that have already utilised the practice.

The following outlines the workshops conducted in the past 18 months to two years including location, presenter/trainer and number of attendees where appropriate:

Managing Scanned Ewes (workshop):

- ❑ Sixty-four producers and pregnancy scanning contractors attended the workshops
- ❑ These workshops have involved primarily 5 Department of Primary Industries staff (Jane Kelly, Chris Shands, Geoff Casburn, Geoff Duddy and Ed Joshua). In addition, Shands (2011) reported that up to 47 of these workshops have been presented overall. The workshops have typically been run for 3-4 hours (e.g. 9am-1pm). However, the dataset attained does not include these attendees.
- ❑ The workshops were conducted in Bathurst, Boorowa, Burrumbuttock, Coonabarabran, Coonamble, Cumnock, Dubbo, Dunedoo, Grenfell, Harden, Hay, Hillston, Lockhart, Mossgiel, Narromine, Nyngan, Peak Hill, Stanthorpe, Taralga, Trangie, Wongarbron and two in Yass.
- ❑ Chris Shands, the national co-ordinator for the Managing Scanned Ewes workshops provided by the Sheep CRC, stated that the workshops provides information about pregnancy diagnosis (<http://www.sheepcrc.org.au/management/reproduction/pregnancy-scanning.php>) and outlines the benefits from pregnancy scanning and how the practice can be utilised to improve the management of the flock through preferential feeding of twin-bearing ewes and removal of the dries.

Ewe Management (workshop):

- ❑ Twenty-five sheep producers attended the workshops.
- ❑ The workshop was presented by Phil Graham. A technical specialist in Livestock Grazing Systems from Agriculture NSW.
- ❑ The workshops were conducted in Crookwell and Gunning.

Managing Breeding Ewes (workshop):

- Fifty-five producers and a member from the LHPA from the Tablelands attended the workshop.
- The workshop was presented by Phil Graham.
- The workshops were conducted in Boorowa, Harden, and Yass.

Managing Seasonal Issues (workshop):

- Eleven producers attended the workshop.
- The workshop was presented by Phil Graham.
- The workshop was conducted in Canberra but the producers recorded were from NSW.

Sheep Connect (workshop):

- Thirty-eight producers attended the workshop.
- The workshop was presented by numerous DPI staff.
- The workshop was conducted at Trangie Agriculture Research Centre.
- The workshop reported on the activities of Sheep Connect.

Wean More Lambs (workshop):

- Twenty-five producers attended the workshop.
- The workshop was presented by Megan Rogers, a District Livestock Officer, Agriculture NSW.
- The workshop was conducted at Grenfell and Peak Hill.

Making More from Sheep (workshop):

- ❑ Six producers attended the workshop.
- ❑ The workshop was presented by Phil Graham.
- ❑ The workshop was conducted at Yass.

Figures 2 and 3 are examples of the resources provided by the Sheep CRC that farmers can utilise to make decisions about whether or not to pregnancy diagnose their ewes. The figures outline profitability and combine differences in quality of the season (pasture growth) and scanning for dries and/or multiples.

Figure Two: The impact on profit per ewe when flock structure changes are accounted for.

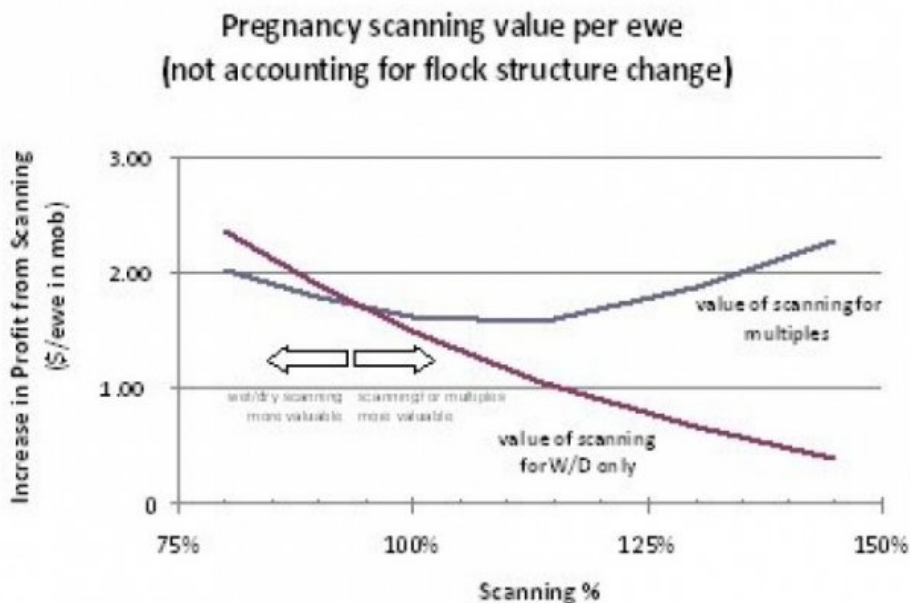
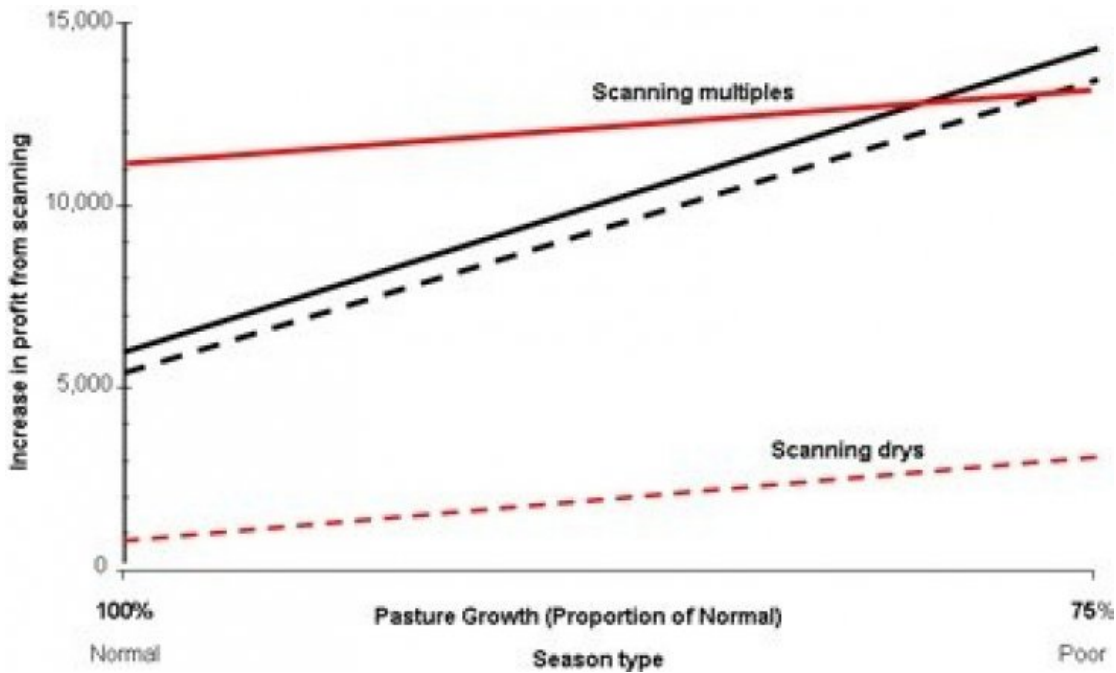


Figure Three: The relative value of scanning wet/dry or multiples in a normal season compared to a poor season



Agriculture NSW staff members (Chris Shands, Trudie Atkinson and Ed Curran) are also involved in presenting the “Improving Sheep Reproduction” workshop which is conducted for approximately 6-7 hours. Within this workshop, presenters discuss how to manage scanned ewes. Although, being specifically targeted to producers who have pregnancy diagnosed their ewes it is more than likely producers that do not pregnancy diagnose their ewes will be present at the workshops.

Additional Information about the Agriculture NSW workshops

The “Bred well, fed well” workshops include aspects of ewe nutritional management for the reproductive performance and flock profitability. However, utilising of pregnancy scanning to allow for manipulation of the nutrient intake of dry, single and twin ewes is not mentioned in the flyer. The benefits or utilisation of pregnancy scanning may well be discussed at the workshop. For this workshop to be useful for producers, an understanding of the nutritional requirement

during pregnancy of ewes and knowledge of the pregnancy status is required due to different nutritional requirements. In addition, there is also “High performance lamb systems field days”, “It’s ewe time” and “Pasture for lambing ewes” field days or workshops that should have a strong influence from pregnancy scanning as a management practice.

Feedback of participants to program

Public comment on the adoption of pregnancy scanning as a management practice appears to be minimal. However, John and Shirley Green from “Kalinda” in *The Land* reportedly said:

“Pregnancy scanning was also paying dividends, as they achieved an overall lambing percentage at weaning of 110pc last year. Mr Green said that figure included every sheep but some mobs were closer to 150pc, due to favourable seasonal conditions and scanning out twins and singles and running them accordingly. “We are just starting to see a genetic advantage from scanning for so long and we are breeding twins more consistently,” he said. Those scanned dry were re-joined and if they were young ewes, Mr Green said they generally conceived the second time”.

George Kidman said of the Lifetime Ewe Management workshops:

“The great thing about LTEM is that the delivery method is like a discussion rather than a classroom environment. It’s good having the opportunity to get feedback from the other farmers in the group especially those using other breeds of sheep. Going to other peoples farms was really interesting as everybody’s enterprise is different. The principles of the program are outstanding and we’ve been applying them with great results, in particularly weaning, scanning and condition scoring. I couldn’t recommend the program more highly; it has been extremely beneficial for us”.

Analysis of the “Managing Scanned Ewes” workshops has found that of those producers attending the workshop:

Major Outcomes

- ❑ Just 49% of the producers scanned for litter size prior to attending the workshops, however, this increased to 79% after they had attended the workshop.
- ❑ 63% of the producers manage the mobs according to nutritional and management needs.
- ❑ Approximately 20% of the producers reported an increase in the lambing percentage since attending the workshop.

Other Outcomes

- ❑ Over 51% of the producers said it had a major or moderate impact on the reproduction rate of their ewes.

In a request for a statement that best describes their pregnancy scanning practice, it was found that only 5% of the producers did not pregnancy scan whilst, 80% of them either scanned for pregnancy (17%) or scanned for litter size and managed the mob separately (63%).

A survey conducted in Victoria of farmers involved in the “Lifetime Ewe Management” workshops, which were also conducted in NSW, revealed that as a result of the attending the workshop, the proportion that were scanning for multiples and separated them increased from 0.18 to 0.71 (Trompf et al. 2011). Trompf et al. (2011) found that the lamb marking percentage increased by 11-13% depending on the enterprise. This increase in the adoption of pregnancy scanning for multiples would have aided in this increase, therefore, increasing farm revenue.

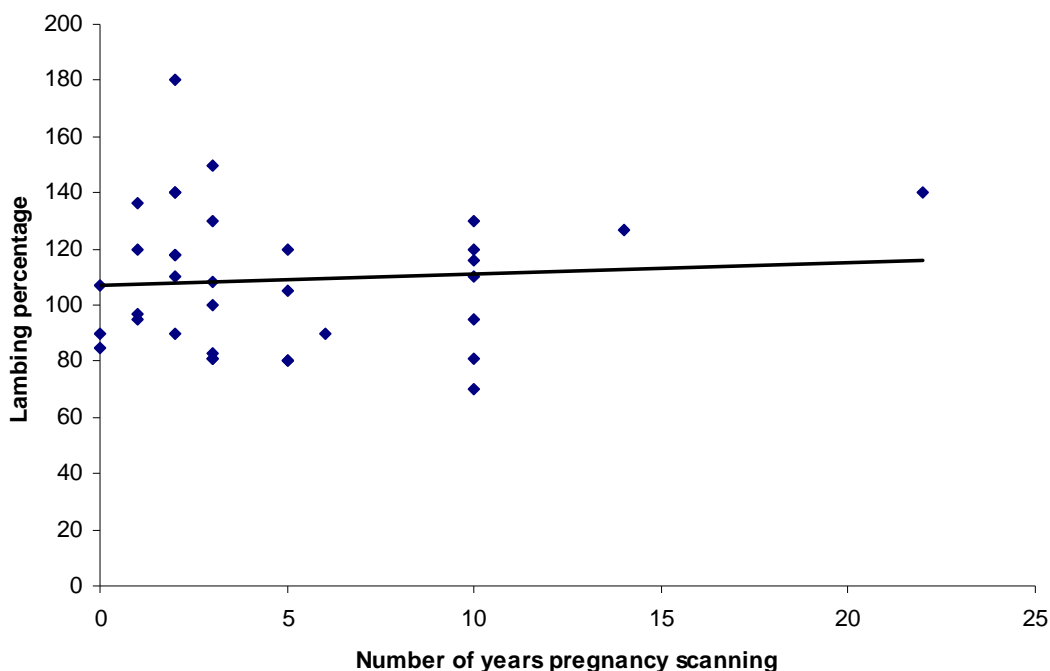
Direct feedback from Agriculture NSW workshops

“Managing Scanned Ewes” is the primary workshop that relates to promoting pregnancy scanning and encouraging producers to fully utilise the practice. The evaluation forms completed at the end of the workshop indicated that, in relation to pregnancy scanning, 32% (31 out of 97

attendees) stated that their first change was to manage the twin-bearing ewes differently to single-bearing ewes. Whilst, 42% or 41 out of 97 attendees stated that their second planned change was to manage the twin-bearing ewes differently to single-bearing ewes.

Interestingly, just over a quarter (25 out of 97) of the attendees did not mention anything in relation to pregnancy scanning, however 6 of these mentioned that they already scanned for twinning. As a result of this, 19 or 20% of the attendees did not mention anything in relation to pregnancy scanning. From this information, we can assume that 80% of the attendees are not only utilising pregnancy scanning but plan to utilise the information from pregnancy scanning and manage the twin-bearing ewes differently to single-bearing ewes. In addition, some producers estimated that they had just pregnancy diagnosis for 1 year whilst, one producer stated that they had been pregnancy scanning for 22 years. The lack of a relationship ($R^2=0.0058$) between lambing percentage and the number of year's pregnancy scanning may indicate that the producers could improve the utilisation of scanning data (Fig 4).

Figure Four: A demonstration of the poor utilisation of pregnancy diagnosis from information provided at the “Managing Scanned Ewes” workshop in 2010 and 2011.



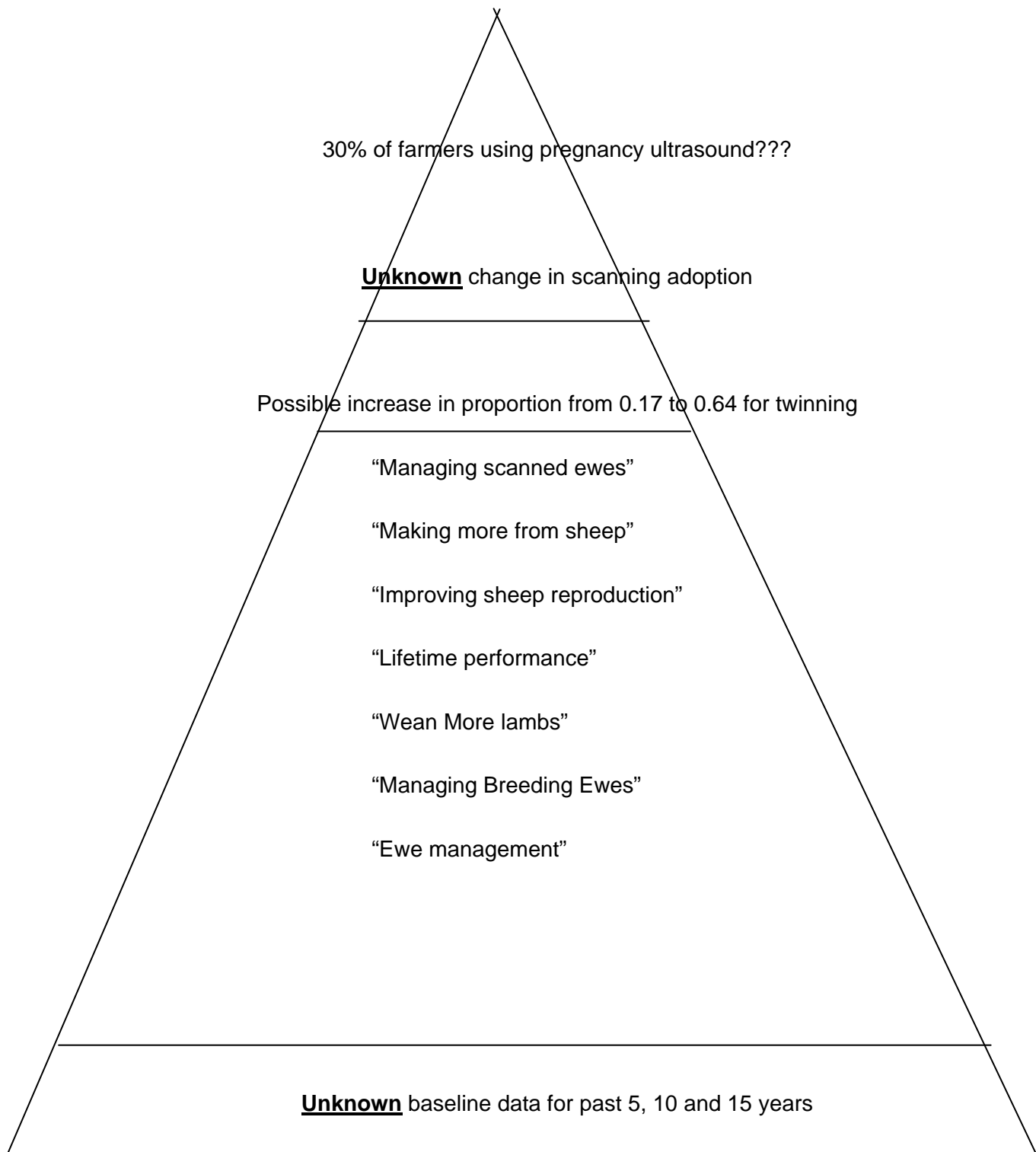
However, many of the producers that attended the workshop stated that they were looking at improving the utilisation of the data via separating dries, single- and twin-bearing ewes to allow for better utilisation of pasture during the pregnancy period. In addition, Agriculture NSW is currently developing the “sheep fertility application” that will provide similar information that can be used to improve monitoring of the NSW breeding ewe flock. The “sheep fertility application” will be detailed later in this report.

Discussion

There have been anecdotal reports that 30% of NSW farmers are currently utilising pregnancy diagnosis. However, there are no reports of what percentage of farmers having adopted the practice 5, 10 or 15 years ago. There is currently work by the department to set up a database to assist industry to manage the data, however it requires the scanners to input the data. Providing that the numbers are correct for the number of farmers utilising pregnancy diagnosis, the increase since pregnancy diagnosis the 1980s, it is only an uptake of approximately 0.75% per year.

Rogers (1983) provided a model for the uptake or adoption of a practice with 4 stages or types of people (innovators, early adopters, early-majority and late-majority). Using this model and relating it to the adoption of pregnancy diagnosis, it can be postulated that the vast majority of NSW farmers are in the “late-majority” phase. For rapid adoption of a practice to occur, the majority of the adopters would need to be “innovators” or “early-adopters” and very few “late-majority”. At the commencement of the development of pregnancy diagnosis via ultrasound, it would have been expected that the farmers that adopted the practice early were the “innovators” and the industry are currently at the “late-majority” stage.

Figure Five: Baseline data, activities to encourage change in management, adoption, change in proportion utilising pregnancy scanning.



It is clear that the workshops that have been conducted have concentrated on “post-pregnancy diagnosis” practices (i.e. managing scanned ewes). It may be of benefit to encourage farmers to pregnancy scan through explaining the advantages of pregnancy diagnosis around the time of ram joining as they can plan ahead and select a suitable time (i.e. days after ram introduction). However, in saying this, there is a large spread in the timing of ram introduction in NSW and therefore, a huge spread in the timing of pregnancy diagnosis. Therefore, providing suitable timing of the workshops is made difficult and the timing of these workshops could be more defined to the region of production. The lack of any clear-cut baseline information in reference to the proportion of farmers utilising pregnancy scanning (Fig 5) is a huge limitation to providing the extent of the adoption of pregnancy. However, recent developments of the “sheep fertility application” by a Senior Research Scientist with the assistance from staff (IT) within Agriculture NSWIT may impact on the adoption of pregnancy scanning practices. A limitation to this application is that the target audience is those producers already utilising the practice. Anecdotal evidence suggests 70% of producers are not utilising the practice. As a result of this, it would take additional work from the application to encourage further adoption of pregnancy scanning.

The “sheep fertility application” is primarily a database that the pregnancy scanning technicians can input the scanning results from a given client into the database that can be accessed by the industry. The producer can compare their data with other producers for benchmarking their flock’s reproductive performance. This system would allow for an increase in the monitoring of the proportion of producers and/or number of ewes pregnancy diagnosed and the use of the information provided in the database (proportion pregnant/dry, twinning, plan to separate dries, singles, dry and pregnancy scanning performance that can be utilised for forecasting).

The pregnancy scanning technicians will also be trained to provide information to producers such as identifying aspects of the scanning performance, the condition of the ewes and

increasing their technical skill level (i.e. increasing twinning identification, identifying dead fetuses, age and an overall increase in accuracy). The project will be promoted through the workshops discussed above. Not only will this project collect scanning performance, it will also aim to collect marking percentage information. This will provide additional information for producers and for scientists to investigate the losses that occur from scanning until marking and design research projects as a result, utilising the database as a bench marking tool.

The project is funded by NSW DPI (52.3%), MLA (23.8%) and AWI (23.8%) and is budgeted over a 5 year period with the commencement date being the 2012/2013 financial year). It is aimed for a peak adoption period to occur by August 2015.

Recommendations

- ❑ Identify what proportion of farmers that are currently utilising pregnancy diagnosis and why farmers are not currently utilising the practices. This will provide a baseline to determine whether the extensive work being conducted is effective or does there need to be a change in the method. The “sheep fertility application” may provide the majority of this information. There is potential for a biannual survey to monitor the management change in utilising the information provided in the database.
- ❑ There is an opportunity to better capture feedback from the workshops, so that it can be used for promotion and monitor the effectiveness of the program.
- ❑ Improve the way the numerous workshops are currently conducted and encourage farmers to adopt pregnancy scanning through describing the benefits (e.g. difference in the nutrient requirement to produce optimal birth weight for optimal lamb survival and reduced lambing difficulties).
- ❑ Develop a small pilot study (survey) of those who attended a workshop and what impact the workshop has made on their management. This will allow for the determination of whether the workshop led to a change in utilising pregnancy scanning.

Major Limitation

Recording of data and documentation: There is lack of quality baseline data and recording of developments (e.g. feedback, numbers of farmers scanning and twin scanning) that can be utilised to determine the adoption of the practice to the adoption. This will potentially be addressed with the development of the “sheep fertility application”.

Case study 2:

Integrated pest management (IPM) for pest control in greenhouse horticulture

Introduction

The vegetable production in the Greater Sydney region is valued at over \$220 million. The major crops include hydroponic lettuce (\$21.5 million), greenhouse cucumbers (\$38.5 million), greenhouse tomatoes (\$53 million) and Asian vegetables (\$33 million). The director of the Gosford Horticultural Institute Centre of Excellence for Market Access and Greenhouse Horticulture (Doug Hocking), stated in 2004 that:

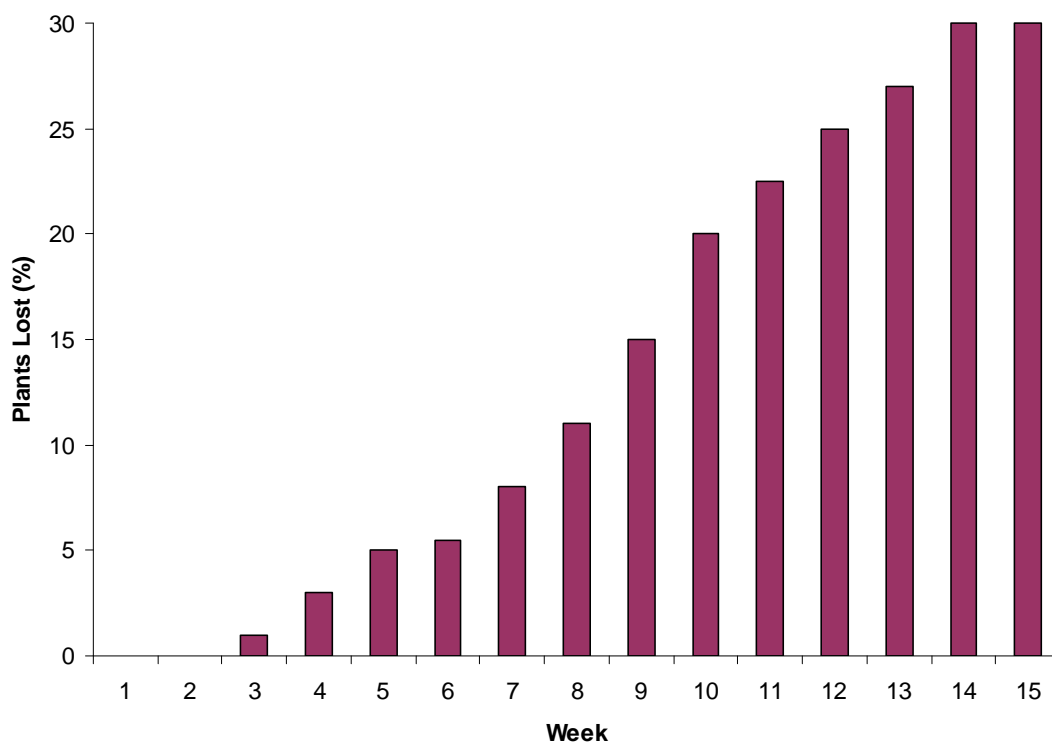
“There is no doubt that horticulture is one of the fastest growing agricultural sectors in Australia and Gosford is, in terms of its research and development areas, well placed to be part of this. Assisting in developing sustainable greenhouse horticulture production and industry to maintain existing markets and gain access to new export markets are key goals for our Program”

A major constraint to the growth and development of the industry is the impact of significant problems with “insect vectors” such as thrips and aphids. These insects cause damage to produce and potentially spread viruses. The main produce that is affected by these pests includes lettuce, capsicum, cucumber, zucchini and eggplant. The value of cucumber and lettuce combine to make up approximately a quarter of the total value of the vegetable industry in the Greater Sydney region. The main issues arising from the impact of the pests is the loss of production, residues from increased levels of insecticides and the resulting reduction in the profitability of the farm.

The Australian horticulture industry has increased the use of insecticides by, on average, \$10,959,000 per annum since 1975 (ABARE, 2010). This indicates a huge impact of insect pests have on this sector and increase of cost of control. Badgery-Parker (*pers comm*) reported that “a

typical real cost of growing greenhouse mini cucumbers is estimated to be between \$0.55 (high technology system) and \$0.70 (low technology system) per kilogram of fruit, assuming a potential yield of 10kg per plant. Using a simple disease impact model (Fig 1), which assumes loss increases over the cropping period to a maximum loss of 30% of the crop, the actual loss equates to 2.2kg (\$1.21 - \$1.54) per plant lost by the end of the cropping period. The corresponding opportunity cost of the disease is approximately \$4.95 per plant. Therefore the total loss to a low technology grower is around \$6.49 per plant lost, or almost \$90,000 per hectare per year. With some 260 hectares cropped to greenhouse cucumbers each year, it is estimated that the industry is potentially losing up to \$23 million annually due to pest and disease.”

Figure One: Disease impact model: Cumulative percentage of plants lost over time.



Therefore, any low cost and efficient combination of insect pest control techniques that can be investigated, promoted and adopted by the producer that can be integrate into their management of their crop that will lead to an increase in the profitability of business.

IPM is a technique of pest control based on ecological approaches to horticulture pest control that integrates pesticides/herbicides into a management system incorporating a range of practices for economic control of a pest.

This paper reviews the linkage between research, extension and adoption of the use of integrated pest management procedure in greenhouse horticulture.

The development of IPM-a historical view

Smith and Smith (1949), both entomologists, developed the concept termed “supervised insect control” in California. In addition, around the same time in the Cotton Belt region of South Carolina and Georgia entomologists were developing their own similar approach. This system of insect control was managed by qualified entomologists who supervised insecticide applications based on conclusions reached from constant monitoring of pest and natural enemy populations. This was utilised as an alternative approach to calendar based insecticide programs. The “supervised” control system formed much of the conceptual framework for the “integrated” control that University of California entomologists developed in the 1950s. This new system sought to identify the best combination of chemical and biological controls. The chemical insecticides were to be used in a manner least disruptive to biological control and were applied only after regular monitoring indicated that a pest population had reached the “economic threshold” that required treatment. Later the IPM system would be adapted to include pesticides but they had to be compatible with control tactics for all classes of pests. Other tactics have also been incorporated into IPM; these include host-plant resistance and cultural manipulations.

The IPM technique now includes 6 basic principle components. These are:

1. Acceptable pest levels
2. Preventative cultural practices
3. Monitoring

4. Mechanical controls
5. Biological controls
6. Responsible pesticide use

Historically, the main focus of IPM programmes was on agricultural pests. However, the IPM programmes have been further developed to address diseases, weeds and other pests that interfere with the management objectives for a given site.

An example of the development of an IPM system is for the control for Western Flower Thrip (WFT). Hydroponic lettuce growers have a limited selection of control methods for WFT due to the rapid development of pesticide resistance. Therefore, the reliance of producers on a single focus for control (e.g. pesticide) has to be reduced. An IPM strategy involving effective, commercially available biological control agents is needed by this specific industry.

Common Insect Pests

Western Flower Thrip (WFT)

The primary insect pest that is discussed in this report is Western Flower Thrip (WFT) (*Frankliniella occidentalis*) that acts as a vector for disease tomato spotted wilt virus (TSWV). Since the initial detection of WFT in 1993, it has become a key pest of hydroponic lettuce in Australia. The insect causes damage due to feeding and laying eggs in plant tissues and is a major vector of disease. Also, the WFT can rapidly develop pesticide resistance (Colomer et al. 2011), resulting in lettuce growers having limited options for management of this pest. The following section outlines research that outlines different techniques for IPM for WFT.

The first major strategy in managing WFT is to maintain good hygiene practices. This means removing weeds or at least controlling the weed population; that crop debris is destroyed; that

seedlings are purchased from a reliable supplier; avoid the introduction of new plant material during the crop season; and attempt to achieve control early in the lifecycle of the pest.

Greenhouse and Silverleaf Whitefly

Greenhouse whitefly (*Trialeuroles vaporariorum*) and Silverleaf whitefly (*Bemisia argentifolii*) are potentially major pests in greenhouse crops in the summer months or during dry and warm conditions. These conditions are ideal for the breeding cycle of the whitefly. In contrast, biological control agents primarily are most efficient under more mild conditions and their efficacy will be reduced in the hotter conditions when the pest flourishes. Whiteflies suck the sap from plants leading to wilting, yellowing, and shedding of leaves. This ultimately leads to a reduction in growth and production. The reduction in plant growth can also be caused by the production of honeydew that encourages sooty and mould growth. This restricts photosynthesis and leads to reduced plant vigour. In addition, whiteflies can also be vectors for plant viruses, tomato yellow leaf curl virus, beet tomato pseudo yellows virus and tomato torrado virus.

Two-spotted mite (TSM)

The two-spotted mite (TSM) spends all life stages feeding the under the leaf. The feeding creates white or greyish spots on the leaf, rendering the affected green crop unmarketable and reduces the overall health of other crops. The mite is usually an “introduced” or “secondary” pest. Like the WFT, this mite can rapidly develop pesticide resistance making the mite an ideal biological control candidate. The primary predator of this mite is ladybird beetles. However, these beneficial insects are killed by insecticide application and can lead to a TSM outbreak.

Research projects and key results

The key results from this project were:

Reduced risk pesticides

- ❑ The new pesticide HGW86 was found to be effective against WFT adults and larvae. However, it had little effect on the predatory mite *T. montdorensis*. Combining applications of this pesticide with releases of *T. montdorensis* provided a high level of control of WFT in the greenhouse.
- ❑ Two other reduced risk pesticides - Agri50NF and Biocover - were tested for compatibility with *T. montdorensis* and found to have minimal effects. These pesticides, if made commercially available and registered for use in these crops, could also be used as part of an IPM strategy.
- ❑ The knowledge regarding the entomopathogen, DPI9, was increased to a level where commercial uptake is highly likely. The effects of application rates, UV light and humidity were all examined to provide a greater framework for the successful commercialization of this reduced-risk pesticide.
- ❑ Several reduced-risk pesticides were shown to be highly effective against pests such as western flower thrips, greenhouse whitefly and green peach aphid. By quantifying the efficacy of these pesticides it is hoped that the manufacturers of each product will actively seek registration for use in the vegetable greenhouse industry.

Biological control agents

- ❑ The predatory mite *G. aculeifer* was assessed for its ability to control WFT when released in onto the ground below hydroponic lettuce plants. The mite greatly reduced the number of WFT pupae, but had less effect on adults on the leaves.
- ❑ The predatory mite *T. montdorensis* was assessed for its ability to control WFT in an open field situation. Best results were achieved with 10 mites per plant. Releasing mites onto one lettuce plant in seven was adequate distribution.

- ❑ Combining *G. aculeifer* and *T. montdorensis* provided excellent control of WFT in the greenhouse. It was not necessary to release *G. aculeifer* separately on the ground; the mites could be released together on the lettuce plant without reducing their efficiency.
- ❑ Control of WFT by predatory mites on a commercial lettuce farm was compared to conventional chemical control. *T. montdorensis* alone or with *G. aculeifer* reduced WFT populations similar to, or better than normal commercial practice.
- ❑ The feeding rates and competitive characteristics of three biological control agents were investigated. The knowledge obtained on these organisms will allow the expansion of their use or lead to new uses of the organisms.
- ❑ The expansion of the use of these biological control agents will allow growers to move away from conventional pesticide use. An understanding of their limitations and where they perform well will assist in the development of any management strategies.

Cultural practices

- ❑ It was shown that leaving a few plants infected with two-spotted wilt virus (TSWV) in a greenhouse could lead to rapid spread of the disease. It has been observed that symptoms of 66 TSWV spread as their insect vector moved through the crop and after 23 days, 56% of lettuces were infected with the virus.
- ❑ A survey of weeds growing on Sydney Basin hydroponic lettuce farms found that, on average, five alternate weed hosts of WFT or TSWV were present, with two of these weeds being hosts to both pests.
- ❑ Although most growers understand that they should remove diseased plants, knowledge of the best way to do this is patchy, while others do not understand the infective role of specific weed species around the farm. Effectively controlling weeds and removing diseased plants could greatly reduce pest and disease pressure.
- ❑ WFT was demonstrated to be more attracted to yellow than blue. Yellow sticky tape placed in potentially high insect traffic areas can be used to intercept WFT before it reaches a crop.

- ❑ Many growers use tractor driven blowers to apply pesticides. Coverage by the blower was compared to a boom spray, knapsack and ute-pack. The blower was far less effective than any other method (average coverage 20-50%). The ute-pack was the best method, averaging 90-100% coverage. Incomplete coverage may not control the pest and increases development of insecticide resistance.

Greenhouse modifications

- ❑ Some cost effective and simple modifications to existing low-technology greenhouses will enhance pest management and vegetable production. This can be achieved through the use of information in this project that looks at improving temperature and humidity controls and enhancing pest exclusion. Through the implementation of the modifications and integrated pest management strategies, growers can reduce their reliance on conventional pesticides.

This clearly outlines that there has been extensive research conducted by the department to develop and improve the IPM practices in greenhouse horticulture. There is a risk of the research being rendered redundant if the results are not successfully extended and utilised by the commercial grower.

The following sections outline how the department has delivered these outcomes; the development of best management practices; and the effectiveness of the delivery.

Staff resources involved in the project

The project has involved staff members of Agriculture NSW based at the National Centre for Greenhouse Horticulture at Gosford, the Yanco Agriculture Institute and the Elizabeth Macarthur Agricultural Institute. The staff involved in the project is Leigh Pilkington, Tony Wellham, Wei Lang, Fah Eagleton, Sylvia Jelinek, Stacey Azzopardi, Steven Goodwin, Len Tesoriero, Marilyn

Steiner, Sandra McDougall and Lorraine Spohr. The project work was jointly funded by Ausveg, HAL and NSW DPI.

Technology Transfer

A key aspect to the projects is the development of useful management techniques to be adopted by producers. Indicative of the project outputs is the list of publications (Goodwin and Pilkington 2006, Pilkington 2007; 2008a, b, Pilkington et al. 2007; 2008 and Kent and Pilkington 2008) from the research being summarised and the development of information. It highlights the effort from the DPI staff to transfer the technology to producers and industry.

Various fact sheets and newsletters were also produced under the auspices of VG03098. This project (VG03098) aimed to deliver the findings of several projects and these publications are reported fully within that final report. The outcomes of this project were also communicated at several grower workshops across the Sydney Basin.

There are additional workshops that the IPM project officer conducted with the key operators participating in the demonstration farms and their grower networks.

Methods of getting the information to the growers

The following are the main categories of extension activities from the project. It includes examples of issues that arose and how they were overcome.

Demonstration farms

Five demonstration farms were set up in key areas and vegetable crop types. They were:

1. Leppington – seedling propagator
2. Camden, Shanes park, Richmond, Freemans Reach – field vegetables

3. Glenorie – hydroponic lettuce
4. Rossmore – low technology greenhouse
5. Rossmore – high technology greenhouse

Once the farms had been selected, initial benchmarking of the pest populations and current management practices were conducted. Each farm was visited weekly to monitor pests and provide IPM recommendations. For further detail of the monitoring process and advice given for each farm see final report VGO3098. In addition, there were also farm walks that could be attended by farmers to observe the developing IPM strategies. An example is of the low technology farm in Rossmore where over 25 producers attended the farm walk with 5 growers showing strong interest in developing IPM programs. In fact, in follow up visits to farms, 2 producers had started to develop an IPM program by improving crop hygiene and cultural controls and reducing chemical inputs. There was also an incidence of incorrect diagnoses that led to the reduction in the growth of plants from inappropriate control methods by producers. This indicates the importance of correctly diagnosing the issue and dealing with it accordingly. Also, the importance of staff advice and accurate diagnoses is critical.

The research conducted of on-farm IPM strategies was presented at a series of demonstration farm workshops, field days/farm walks and grower meetings. The report stated:

“By taking growers through the process in farming examples they would relate to they were able to understand the benefits they could capture for their businesses. Demonstration also had the benefit of showing the benefits before growers took part in what they perceived to be a risky management system.”

Some key benefits that the growers mentioned included; a reduction in chemical use, chemical costs and a reduction in the costs associated with production losses or crop failure.

Surveys

Surveys were conducted in pest identification, for current pests and new pests on plants and weeds. This focussed on zucchini varieties that demonstrate viral resistance to anti-transpirant substances.

The following paragraph provides an example of issues that arose from the survey and how they were investigated.

The most common pest of the aphid-borne mosaic potyviruses was the watermelon mosaic virus (WMV2). The most common variety of zucchini is Congo, which is selected by growers for its apparent virus tolerance. The seed trial crops included in the survey identified that more extensive testing of the seed is needed for virus tolerance. From the information collected through the surveys and published papers, it was concluded that mosaic virus in zucchinis appears best managed by selecting virus tolerant varieties. The identification of problem pests showed a similar pattern over multiple farms in that WMV2 and zucchini yellows mosaic virus (ZMYV) are prevalent early in the growing season. Identification of wilt virus occurred and it was suggested this was due to the failure to control rogue diseased plants and also a lack of weed control.

They concluded that the best management practice is a IPM strategy combining good farm hygiene, the use of resistant varieties, the introduction of beneficial insects as well as “soft chemistry” insecticides.

New pests that were identified were papaya ring spot virus, currant lettuce aphid, psyllids and impatiens necrotic spot virus. IPM strategies were then developed to control these pests and diseases.

Field/hydroponic trials

Trials were carried to evaluate foliar treatments in hydroponic lettuce. On a commercial hydroponic farm, the grower had identified that treatment for the control of tomato spotted wilt virus (TSWV) was not effective even though the TSWV population was much lower than in adjacent grower beds.

Two possible factors were investigated:

1. Removal of 25% of the plants once 25% of leaves showed symptoms of TSWV – Improved hygiene
2. Wet sprays might have impacted on WFT establishment - Cultural practices

Only trial 1 is described here.

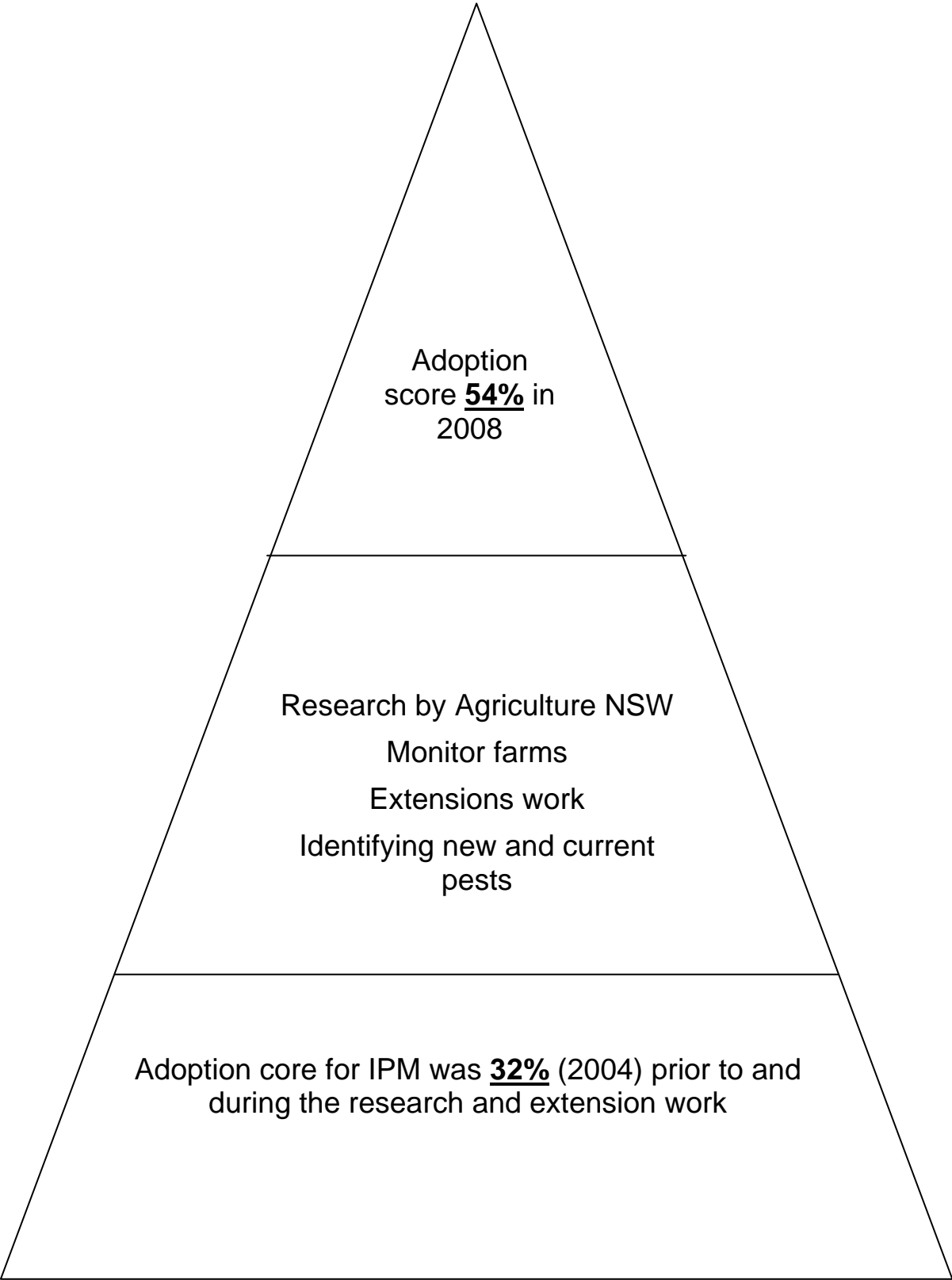
Trial 1 consisted of:

1. No treatment
2. 0.1% Silwet® L-77 as a surfactant applied twice weekly
3. 0.5% Eco-Oil® applied weekly
4. DPI 9 (*Beauveria bassiana* Gosford-collected strain) at 22g spores plus 500mL oil and surfactant/100L, applied weekly

The leaf damage in all treatments was minor. The mean head weight of lettuce in treatment 2 was lower than in treatments 1, 3 and 4. This indicates that “Silwet” caused a phytotoxic effect, therefore, reducing leaf growth. There was a marked reduction on the percentage of thrips in early developmental stages corresponding to reduced adult populations. In addition, there were

also a high percentage of thrips pupated on the lettuce and did not fall to the ground to pupate. The report stated “The substantial reduction in WFT populations by application of water plus Silwet® is very encouraging, but the influence of Silwet® needs to be separated from water alone and the experiment repeated with lower rates of Silwet® or an alternative wetter. However, this study has not been conducted to investigate the impact of just Silwet®

Figure Two: Baseline data, activities to encourage change in management, adoption, change in proportion utilising IPM in their greenhouse horticulture system.



Discussion

There are clear indications that there has been an increase in the number of greenhouse horticulture growers adopting IPM in the Greater Sydney region of NSW (Figure 2) from ~30% to ~55%. The adoption rate varied due to: location (regions), using a consultant and ethnical background.

The adoption rate is not solely the proportion of the growers that adopt the IPM strategy but a higher level of adoption indicates an increase in the diversity of tools utilised by growers.

Increasing the diversity involves: improving greenhouse hygiene (e.g. removal of pest infested plants or the removal of weeds), overall farm hygiene (removal of potential pest/disease areas (e.g. overgrown lawn and vegetation mess), reduced use of high risk pesticides, greenhouse modifications (e.g. sides of greenhouses changed to provide ventilation), and cultural practices.

The adoption rate is lower for the hydroponic lettuce growers due to a reduced number of biological control agents. To increase the adoption rate of this grower group, the registration of additional biological controls tools are required to provide more options.

Although, the industry has a small number of growers, it could be assumed that the level of adoption is not as high as hoped for. The proportion of growers with English as their second language provides an immediate barrier. In an attempt to overcome this problem, a bilingual officer was used to deliver surveys to a smaller proportion of the Asian growers. The investment in up-skilling primarily English speaking officers in the cultural diversities and languages of the non-English speaking growers would lead to increased effectiveness of communication and increase the likelihood of adoption.

Increasing the knowledge of the growers is important to the development, sustainability and growth of an industry. As outlined in the report VG03098, there were misdiagnosis of pests and

diseases by producers that led to extensive production losses. Unfortunately, there is reluctance by growers to include a consultant in the development of their business enterprise and this can be a barrier to IPM adoption. The adoption level for growers with a consultant was 65.7% whilst the adoption level of growers without a consultant was 41.1%. This is market opportunity for Agriculture NSW and the private sector to promote consultancy services on a cost recovery basis to improve the level of adoption of IPM practices and reduces the incidence of misdiagnoses of pests and disease.

A fundamental issue that impacts on adoption of IPM is the low levels of recording that is correctly occurring in the industries. Further, it has been stated that:

“The shortfall in the use of monitoring was the reported lack of record keeping when it came to pest and beneficial arthropods in their crop. Without the extended and highly contextual records that should be collected for each farm, the use of monitoring effectiveness is reduced. Future projects have a need to focus on the development, training and use of monitoring tools that make the process easy and provide a tool for growers to collect this information easily. The identification of trends and management procedures that succeeded, or failed, needs to be worked into all growers’ management practices”

The issue of poor record keeping is not isolated to this industry; it is a wider problem across many industries. Poor records means that management decisions can be flawed and industry bench marks cannot be established.

The department has recently been funded to provide benchmarking and monitoring work for the industry. This will assist in determining key production information and parameters, also providing the advice could. For example, in the IPM strategy report, the key production

parameters could be time of planting, mid-season, and harvest and bed preparation. At these times the greenhouse hygiene, overall farm hygiene, reduced risk pesticides, greenhouse modifications (e.g. sides of greenhouses changed to provide ventilation), and cultural practices could be scored and monitored and related to product yield. There could also be the assessment of pest. The value of the crop should not be the only measure in the monitoring system as crop values change from year to year. Productivity measures and monitoring of practices will prove to be more beneficial.

It is acknowledged that this will take additional labour but would lead to an increase in the ability to assess the impact of the work by the department and the contribution to industry growth. It could provide an opportunity for the department to assess the level of change in the industry and the adoption of IPM practices.

Recommendations

- ❑ Increased knowledge of cultural diversity and languages of the Asian growers to increase communication that may result in an increase in the adoption of IPM. This will improve the relevance and value of Agriculture NSW to this industry sector.
- ❑ Develop additional biological tools that can be used to increase IPM management options, leading to an improved the level of adoption.
- ❑ Encourage an increased level of on-farm recording within the industry including grower feedback from the extension activities.

Major Limitation

A major limitation to this review is the inability to determine the impact and contribution to the industry of the department. Improved levels of monitoring and evaluation processes need to be developed and implemented.

Concluding Discussion

The two activities selected to investigate in this report provide contrasting levels of industry development. The greenhouse horticulture is a rapidly growing industry and has a desire to reduce its' dependence on harsh insecticides and to develop alternative pest control measures. In contrast, the sheep industry has stalled with a lack of increase in the lambing percent in the past 30 years even with a substantial reduction in the national sheep flock (170 million in 1905 to 72 million today).

The following discussion will refer to both the greenhouse horticulture industry with reference to IPM adoption and the sheep industry with reference to the adoption of pregnancy diagnosis via ultrasound.

It is important to monitor the effect that Agriculture NSW has on the industry development and growth. The impact of Agriculture NSW is difficult to say due to poor industry information and low levels of agency monitoring of effort and investment. In the "Corporate Plan 2012-2015" it is stated within the "key measure of success" for "key result area 1": "Competitive primary industries operating in a positive business environment" was "value of primary industries production by sector benchmarked and compared over time" and "% increase in gross value and volume of agricultural production by hectare" is difficult to determine under the current methods. It is accepted that the system of collecting data within the larger industries could be difficult. Determining a baseline for the ewe lambing percentage and farm management practices is

currently being undertaken, this will include a follow up survey that will assess Agriculture NSW involvement and provide data on the agencies contribution to growth.

When the adoption of both practices are analysed, it appears that the IPM within the greenhouse horticulture has a superior monitoring method (adoption score) when compared to pregnancy scanning adoption monitoring. However, one weakness in the “adoption score” system is that it is highly subjective and could create bias. It also has the flaw of not having a system protocol readily available. If this system’s protocol was published, it could be adapted to other industries. Adoption of a practice does not instantly lead to an increase in the bottom line and industry growth; it is how the farmers adapt the information and practice that leads to industry growth. Therefore, monitoring how the farmer is utilising data (for the example of pregnancy diagnosis, questions referring to farm production details, twinning, age of foetus, fat scoring practices and paddock selection for after scanning and at lambing) are included in the “determining the baseline” project as discussed above.

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