Irrigating for white clover seed production

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Evaluating centre pivot drop tube and sprinkler irrigation delivery for white clover seed production

by James De Barro

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Foreword

Key recommendations from *Life Among the Clover* (RIRDC publication no. 10/005) were addressed in this project, particularly to assist white clover seed producers to improve their irrigation practices and their $ return per ML applied. Even though during this research the White Clover Growers Association disbanded, the individual seed producers and engaged allied industries remained focussed on the outcomes of the research. Drop tube centre pivot irrigation has had a significantly positive impact on the lucerne seed industry, emanating from the RIRDC funded research, *An Alternative to Border Check Irrigation* (RIRDC publication no. 08/014). The research in this project was to determine if a similar benefit could be achieved in white clover seed production.

The research identified that there was no significant difference in white clover seed yield whether centre pivot irrigation was applied by either drop tube or regulated and unregulated spray technology. The research highlighted that there was ample scope for irrigators to positively use soil moisture monitoring to reduce gross irrigation output, with no predictable reduction in seed yield production.

The research also highlighted the opportunity for white clover seed producers to positively modify their current irrigation management programs. With reductions in irrigation licence volumes for many producers, the research findings provide confidence to reduce irrigation volumes, yet maintain or improve seed yield. The research findings give confidence to irrigators that investing in drop tube application which benefits other irrigated crops in their rotations will not be counterproductive to their white clover seed production enterprise.

This project is funded by Alpha Group Consulting, South East Natural Resources Management Board, White Clover Growers Association, Water Dynamics, Irrigation Components Australia and industry revenue which is matched by funds provided by the Australian Government.

This report is an addition to RIRDC’s diverse range of over 2000 research publications and it forms part of our Pasture Seeds R&D sub-program, which aims to facilitate the growth of a profitable and sustainable pasture seeds industry based on a reputation for the reliable supply, domestically and internationally, of a range of pasture species.

Most of RIRDC’s publications are available for viewing, free downloading or purchasing online at [www.rirdc.gov.au](http://www.rirdc.gov.au). Purchases can also be made by phoning 1300 634 313.

Craig Burns  
Managing Director  
Rural Industries Research and Development Corporation
Acknowledgments

The author wishes to acknowledge Tallageira Pastoral Company for providing the research site and supporting the project since conception.

Water Dynamics (Mt Gambier) and Irrigation Components Australia are acknowledged for their generous contribution of the supply and fitting of the irrigation sprinkler systems utilised in the research.

The author also wishes to acknowledge the involvement of SARDI (Struan), DPI Victoria (Horsham), Jock Virgo (Binnum Baling) and the assistance of Chris Dyson (SARDI/PIRSA) in research design and data analysis.

About the Author

James De Barro is Managing Director of Alpha Group Consulting. James has an honours degree in Agricultural Science, a Graduate Diploma of Business and was awarded a Churchill Fellowship in 1999. James resides in Keith in South Australia and specialises in consulting to pasture seed producers and industry regarding all facets of seed production in dryland and irrigated systems. In addition James consults to a range of irrigated production industries across Australia in the field of soil moisture monitoring and irrigation scheduling.
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Executive Summary

What the report is about

Scope exists for irrigated white clover seed producers to improve their irrigation practices and their $ return per ML applied. The research identified benefits of continual soil moisture monitoring for irrigation scheduling. Drop tube centre pivot irrigation has had a significantly positive impact on the lucerne seed industry, emanating from the RIRDC funded research, *An Alternative to Border Check Irrigation* (RIRDC publication no. 08/014). This research assisted in determining if similar benefits could be achieved in white clover seed production.

Who is the report targeted at?

The report is targeted at irrigated white clover seed producers and their agronomic service providers. The research is aimed to support centre pivot sales staff in the provision of irrigation application equipment.

Where are the relevant industries located in Australia?

The hub of irrigated white clover seed production in Australia is in the Frances region on the border of South Australia and Victoria. Since 2009 the industry has declined in favour of lucerne seed production with significant crossover of producers of both pasture species. The research aimed to assist producers with information about irrigation strategies and technology utilised in white clover seed production.

Background

This research was undertaken to focus on key recommendations of *Life Among the Clover* (RIRDC publication no. 10/005). The specific focus was on evaluating drop tube sprinkler suitability for white clover seed production and assessing continual logging soil moisture technology in maximising the $ return/ML applied.

Objective

The aim is to improve the knowledge base of white clover irrigators and assist in encouraging an increased professionalism to irrigation management. Specifically it aims to focus on the delivery and volumes of irrigation to increase efficiency in timing and potentially the $ net return/ML applied.

The project will serve as a good case study for the use of improved irrigation delivery for centre pivots for all pasture seeds as well as focus on the importance of continual soil moisture monitoring and the advantages it presents.

Methodology

The research site was established within seedling Haifa white clover in 2009. The site was located within an 80 ha irrigated centre pivot fitted with an unregulated rotator spray package. The pivot was located Frances/Neuarpurr region of western Victoria.

Two spans of the seven span pivot were used for the project with one span fitted with new regulated Senninger LDN drop tubes and another with new regulated Senninger X I-Wob sprinklers. Within each of these spans half of the sprinklers applied 100% of the irrigation with the balance applying 80% of the volume. The comparative control was the unregulated rotators fitted to the remaining 5 spans.

Sentek Enviroscan probes were modified for subsurface installation, with a probe being installed under the 100% output for both the drop tube and sprinkler application. The Enviroscan probe continuously
recorded soil moisture at depths 10, 20, 30, 40, 60 and 80 cm below the soil surface. The irrigation regime was assessed on the basis of the collected data.

Seed was harvested from replicated windrowed plots from within the treatments and control using a small plot harvester. Seed was cleaned and weighed and the results statistically analysed.

**Key findings**

The research determined that no significant difference existed between the impact overhead sprinklers and drop tubes had on white clover seed yield. In addition the findings determined that a 25-30% reduction in irrigation volume per irrigation event had no detriment on seed yield but increased the $ return/ML by 35-100% over the three assessed seasons. The research should provide confidence to irrigated white clover seed producers that in conjunction with continual soil moisture technology, there is considerable scope to improve irrigation efficiency.

**Implications**

The research determined that reduced irrigation volumes can be applied to white clover seed crops with no reduction in seed yield or quality. The findings support and encourage promotion by the pasture seed industry, natural resource managers and state based Departments of Water of soil moisture monitoring, the concept of irrigation scheduling and drop tube irrigation application.

**Recommendations**

Recommendations are targeted at the irrigated seed producer and all supporting industries including agronomic advisers and irrigation equipment retailers and manufacturers.
Introduction

White Clover

White clover (Trifolium repens L) is a perennial pasture legume that is grown for seed production in southern Australia and is widely used as a constituent in mixed grazing pastures. The clover is grown for seed in the period between September and February predominantly under overhead irrigation. Ideally it grows in cool moist environments (Carlson, et al. 1985) but for seed production in Australia it is done in mild to warm and dry weather typical of a temperate climate.

White clover seed is produced in the Frances/Nara coorte region of South Australia and Neuarpurr/Minimay area in western Victoria. It is almost exclusively grown on heavy clay soils that favour the production of seed due to a combination of quality ground water for irrigation and soil conditions that limit clover biomass production. (Miller, et al., 1951).

Life Among the Clover

RIRDC publication, Life Among the Clover, (publication no. 10/005) provides relevant background reading pertinent to this research. This research recommended key areas for further research including utilisation of continuous soil moisture monitoring to permit accurate irrigation scheduling. The research also promoted the need to trial the use of drop tube sprinklers as a means of improving irrigation application.

White Clover Growers Association

The White Clover Growers Association (WCGA) disbanded during the course of this research project. The group reformed as the Mackillop Irrigation Management Group (MIMG) remaining as a subcommittee of the Mackillop Farm Management Group. Whilst the WCGA wound up the MIMG provided a suitable forum in which to extend the results.

Background

Production Factors

Conventional overhead spray irrigation of white clover can flatten the crop and influence the ability to harvest all the produced herbage. Application of overhead irrigation can negatively influence seed quality of early ripe seeds by causing soft, ripe seeds to germinate and dry out which causes them to turn brown. Typically these seeds fall out prior to or at the point of harvest or are cleaned out of the final seed sample which reduces the total clean seed yield. These losses often go unnoticed and can vary depending on seasonal conditions.

The majority of white clover produced in Australia is done under spray centre pivot irrigation. This research will determine if drop tube irrigation is an acceptable and effective application method for white clover seed production.

Anecdotal evidence shows that drop tube irrigation of lucerne for seed creates improved pollination conditions and increased seed yield per ML water applied compared to other forms of spray irrigation. The reduction in applied spray irrigation to lucerne seed crops has been reported to assist in maintaining flower quality and ability to be pollinated. This may also be the case for white clover seed crops although the method of flower pollination between the species is significantly different. Overhead spray irrigation of white clover seed may have a negative influence on pollination by honey bees. Both the temperature of the applied water and the physiological impact of irrigation on white clover plants may have a negative impact on the crop’s ability to be pollinated. Pollination is a key to maximising white clover seed yield and irrigation practices that mitigate the time that flowers are not
conducive to pollination is seen as an advantage. Drop tube irrigation does not completely wet the flowers and foliage when delivering the irrigation and when compared to sprinkler irrigation, pollination opportunities for the flowers irrigated by drop tubes are likely to be longer. It is not proposed to specifically quantify irrigation impact on pollination in this research but, similar to lucerne seed production, anecdotal evidence may be accrued.

‘Life Among the Clover’ research highlighted that the frequency of irrigation negates the opportunity for the crop to extract soil moisture from the full depth of its root zone. This is anticipated to impact negatively on seed yield and result in irrigation applications above what is actually required. This project cited research undertaken in North America that determined an increase in white clover seed yield when applied irrigation was reduced compared to ‘normal applications’. The white clover was forced to use water deeper from its soil profile and whilst there was a decline in vegetative matter the seed yield increase significantly. This response is also observed in lucerne seed production.

Objectives

Purpose of research

The objective of the project is to improve the knowledge base of white clover irrigators and assist in encouraging an increased professionalism to irrigation management. Specifically it aims to focus on the delivery and volumes of irrigation to increase efficiency in timing and potentially the $\text{net return/ML applied}$.

This research aimed to assess if drop tube irrigation is an acceptable and effective application method for white clover.

The project will serve as a good case study for the use of improved irrigation delivery for centre pivots for all pasture seeds as well as focus on the importance of continual soil moisture monitoring and the advantages it presents.
Methodology

Overview

The initial trial design proposed for this project was installed in September 2009. It involved two sites within the centre pivot which were positioned under the pivot spans being monitored. The intention was to have one site monitor the owner’s standard irrigation practice with the other using the soil moisture data to schedule irrigation events.

The 2009/10 irrigation season was to be a data recording year, with the entire crop to be irrigated according to the owner’s own plans. The data from this year was to be used in development of an irrigation program for the subsequent season.

In the 2010/11 season ¼ of the pivot was to be irrigated according to the owner’s own plans. The soil moisture monitoring equipment will record the impacts of irrigation (and rainfall) and the crop water use patterns. The remaining ¼ was to have its own soil moisture monitoring site and the irrigations of this quarter was to be scheduled according to the soil moisture data and the stage of the crop. Due to the size of the pivot and time required to irrigate the complete area it soon became impractical to adhere to this original intention. A range of factors, including inability to find a suitable alternative site, resulted in the research focus being adjusted to monitor and critique the overall irrigation practice applied.

The original project design had irrigation outputs that were more compatible with the initial research intention. After the first year it was decided to alter the output regime to be more compatible with the adjusted research focus. Modifications of the trial design involved incorporating a control which was the standard rotator sprinkler configuration (Photo 1) on the pivot as well as a statistically analysable replicated layout to suit the modifications.

Site Location

The research site was established by seeding white clover var. Haifa in 2009. The site was irrigated by centre pivot with an unregulated rotator spray package. The pivot was located Frances/Neuarpurr region of western Victoria, 36° 41’27.26”S; 140° 59’17.56”E.

Site Management

The research site was managed as part of the entire production system implemented for the seed crop by the owner. The only specific differences were the irrigation application and the harvest process.

Irrigation Delivery

2009/10 Season

Two spans of the seven span pivot were used for the project with one span equipped with new regulated Senninger LDN drop tubes (Photos 2-3) and the other with new regulated Senninger X I-Wob sprinklers (Photo 4). Within each span there were different irrigation outputs. The span with the sprinklers had half the sprinklers applying 100% of the recommended application and the other half of the span applied 125% of the recommended application. The span with the drop tubes had half the drop tubes applying 100% of the recommended application and the other half of the span applied 75% of the recommended application.
Photo 1  Unregulated rotator sprinklers on centre pivot

Photo 2  Regulated drop tube sprinklers on centre pivot
Photo 3  Drop tubes in sprinkler mode

Photo 4  Regulated IWOB sprinklers on centre pivot
2010/11 and 2011/12 Seasons

After the 2010 harvest the drop tubes applying 75% were rejetted to apply 80% of the irrigation output. The sprinklers applying 125% were also rejetted to apply 80% of the irrigation output.

Soil Moisture Monitoring

Sentek Enviroscan probes were modified for subsurface installation, with a probe being installed under the 100% output for both the drop tube and sprinkler application. The Enviroscan probe continuously monitored soil moisture at depths 10, 20, 30, 40, 60 and 80 cm below the soil surface (Photo 5). Probe data was sent to a server via Next G modem where it was downloaded into IrriMax software for viewing. Two sets of monitoring sites were installed, with one site being the primary recording site and the second, due to alterations in the research’s focus, becoming a backup site.

Harvest

2009/10 Harvest

The initial harvest plan was for SARDI to conduct replicated small plot harvesting for each treatment. An issue arose at harvest (17/2/10) due to the inability of the SARDI harvester to harvest low enough. The design of the header led to approximately half of a replicate remaining ‘unharvested’ after being harvested. It was decided to windrow the trial plots due to a windrower being capable of cutting at ground level (Photo 6). The small plot harvester subsequently harvested the windrow. Eight replicates were harvested per treatment with the total area harvested per treatment varying due to positioning within the pivot and the main harvest operations of the owner. Harvested seed from each replicate was retained and cleaned to determine clean seed produced (Photo 7).
Photo 6  Clover windrow.

Photo 7  SARDI clover seed cleaning apparatus.
2010/11 Harvest

The 2010/11 white clover seed production season was hampered by significant rainfall. This challenged the irrigation management of the crop and hence the research. The research was further challenged by the small plot harvester becoming unavailable at the point of harvest due to SARDI’s concerns over the welfare of their equipment. The trial harvest process had to be modified with hand harvesting being invoked and occurring on 15/2/11.

Five randomly selected 0.49m$^2$ plots were hand harvested for each treatment and control (Photo 8). An electric hedge trimmer was used to cut out the crop from within a quadrat (Photo 8). The crop material was air dried and hand threshed. The seed was separated from the offal using a purpose built punch hole hand sieve. The unclean seed samples were cleaned by SARDI.

Photo 8  Quadrat area for hand harvesting.
2011/12 Harvest

DPI Victoria based at Horsham conducted small plot harvesting (Photo 9). Twenty windrowed plots (22.5 m²) were harvested on 19/1/12. Unclean seed samples were cleaned using the SARDI small seed cleaning system at Struan.

Photo 9  DPI Victoria small plot harvester.

Data Assessment

Applied water volumes as well as rainfall were recorded. All costs of production and income off the crop were recorded to be used in the calculation of the $net return/ML applied for each treatment.
Summary of Results

Overview

Over the duration of the research there were modifications to irrigation output and harvest technique. Whilst these changes are discernible in the reported results the resultant data has been expressed in industry standard units suitable for statistical analysis and comparison.

Rainfall and Irrigation Applied

Table 1 presents the rainfall and applied irrigation volumes during the seed production season for all treatments and control for each year of the research.

Table 1 Rainfall and irrigation amounts applied per treatment and control during the 2009/10, 2010/11 and 2011/12 seed production seasons. (Amounts expressed in mm).

<table>
<thead>
<tr>
<th>Year</th>
<th>Rainfall (Sept-Dec.)</th>
<th>Rainfall (Jan-harvest.)</th>
<th>Drop Tube Irrigation Output</th>
<th>IWOB Sprinkler Irrigation Output</th>
<th>Rotator Irrigation Output</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>75%</td>
<td>100%</td>
<td>125%</td>
</tr>
<tr>
<td>2009/10</td>
<td>157.6</td>
<td>50.2</td>
<td>276.2</td>
<td>394.5</td>
<td>473.4</td>
</tr>
<tr>
<td>2010/11</td>
<td>287.8</td>
<td>161.3</td>
<td>124.5</td>
<td>155.6</td>
<td>124.5</td>
</tr>
<tr>
<td>2011/12</td>
<td>112.8</td>
<td>10.8</td>
<td>241.9</td>
<td>302.4</td>
<td>241.9</td>
</tr>
</tbody>
</table>

Crop Water Use Patterns

Graphs 1 and 2 are the summed graphs for water use under 100% drop tube and IWOB sprinkler application in season 2009/10. It shows the irrigation and rain events and the crop water use patterns for the crop during the production period. The graph shows the predicted refill level zone for each crop growth phase. Photo 10 shows clover at 60% ground cover and Photo 11 at 80% ground cover/very early flowering. Photo 12 shows crop at 100% flowering phase with Photo 13 showing canopy depth during full flowering.
Graph 1  Summed water use graph for drop tube 100% application for 2009/10 seed production season.

Graph 2  Summed water use graph for IWOB 100% application for 2009/10 seed production season.
Photo 10  60% white clover ground cover (18/10/2011).

Photo 11  80% white clover ground cover/very early flowering (18/10/2011).
Photo 12  100% white clover flowering phase (16/11/2011).

Photo 13  100% white clover flowering phase canopy depth (17/12/2009).
Graphs 3 and 4 show water infiltration and crop water use patterns through the soil profile at depths 10-80 cm for the crop growth phases of the 2009/10 season.

Graph 3  Water use and water infiltration graph for drop tube 100% application across the crop growth phases of the 2009/10 seed production season.

Graph 4  Water use and water infiltration graph for IWOB 100% application across the crop growth phases of the 2009/10 seed production season.
Graphs 5 and 6 are the summed graphs for water use under 100% drop tube and IWOB sprinkler application in season 2010/11. It shows the irrigation and rain events and the crop water use patterns for the crop during the production period. The graph shows the predicted refill level zone for each crop growth phase.

Graph 5  Summed water use graph for drop tube 100% application for 2010/11 seed production season.

Graph 6  Summed water use graph for IWOB 100% application for 2010/11 seed production season.
Graphs 7 and 8 show water infiltration and crop water use patterns through the soil profile at depths 10-80 cm for the crop growth phases of the 2010/11 season.

Graph 7  Water use and water infiltration graph for drop tube 100% application across the crop growth phases of the 2010/11 seed production season.

Graph 8  Water use and water infiltration graph for IWOB 100% application across the crop growth phases of the 2010/11 seed production season.
Graphs 9 and 10 are the summed graphs for water use under 100% drop tube and IWOB sprinkler application in season 2011/12. It shows the irrigation and rain events and the crop water use patterns for the crop during the production period. The graph shows the predicted refill level zone for each crop growth phase.

Graph 9  Summed water use graph for drop tube 100% application for 2011/12 seed production season.

Graph 10  Summed water use graph for IWOB 100% application for 2011/12 seed production season.
Graphs 11 and 12 show water infiltration and crop water use patterns through the soil profile at depths 10-80 cm for the crop growth phases of the 2011/12 season.

**Graph 11**  Water use and water infiltration graph for drop tube 100% application across the crop growth phases of the 2011/12 seed production season.

**Graph 12**  Water use and water infiltration graph for IWOB 100% application across the crop growth phases of the 2011/12 seed production season.
Harvest Data

2009/10 Season

Table 2 presents the harvest data for the 2009/10 seed production season.

Table 2  2009/10 Clean yield from combined windrowed/small plot header harvested treatments.

<table>
<thead>
<tr>
<th>Irrigation Output</th>
<th>Yield (kg/ha)</th>
<th>Plot Size (m²)</th>
<th>No. of replicates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drop Tube 75%</td>
<td>444.8</td>
<td>460</td>
<td>8</td>
</tr>
<tr>
<td>Drop Tube 100%</td>
<td>505.1</td>
<td>668</td>
<td>8</td>
</tr>
<tr>
<td>IWOB 100%</td>
<td>504.2</td>
<td>395</td>
<td>8</td>
</tr>
<tr>
<td>IWOB 125%</td>
<td>468.0</td>
<td>718</td>
<td>7</td>
</tr>
</tbody>
</table>

2010/11 Season

Table 3 presents the harvest data for the 2010/11 seed production season.

Table 3  2010/11 Clean yield from hand and farmer owned header harvested treatments.

<table>
<thead>
<tr>
<th>Irrigation Output</th>
<th>Hand Harvested Yield (kg/ha)</th>
<th>Header Harvested Yield (kg/ha)</th>
<th>Hand Harvested Plot Size (m²)</th>
<th>No. of replicates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drop Tube 80%</td>
<td>552.40</td>
<td>400</td>
<td>0.49</td>
<td>5</td>
</tr>
<tr>
<td>Drop Tube 100%</td>
<td>429.36</td>
<td>438</td>
<td>0.49</td>
<td>5</td>
</tr>
<tr>
<td>IWOB 100%</td>
<td>531.12</td>
<td>444</td>
<td>0.49</td>
<td>5</td>
</tr>
<tr>
<td>IWOB 80%</td>
<td>468.16</td>
<td>464</td>
<td>0.49</td>
<td>5</td>
</tr>
<tr>
<td>Rotator 100%</td>
<td>424.80</td>
<td>450</td>
<td>0.49</td>
<td>5</td>
</tr>
</tbody>
</table>

2011/12 Season

Table 4 presents the harvest data for the 2011/12 seed production season.

Table 4  2011/12 Clean yield from windrowed/ small plot header harvested treatments.

<table>
<thead>
<tr>
<th>Irrigation Output</th>
<th>Yield (kg/ha)</th>
<th>Plot Size (m²)</th>
<th>No. of replicates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drop Tube 80%</td>
<td>399.45</td>
<td>22.5</td>
<td>20</td>
</tr>
<tr>
<td>Drop Tube 100%</td>
<td>407.04</td>
<td>22.5</td>
<td>20</td>
</tr>
<tr>
<td>IWOB 100%</td>
<td>448.62</td>
<td>22.5</td>
<td>20</td>
</tr>
<tr>
<td>IWOB 80%</td>
<td>385.19</td>
<td>22.5</td>
<td>20</td>
</tr>
<tr>
<td>Rotator 100%</td>
<td>405.11</td>
<td>22.5</td>
<td>20</td>
</tr>
</tbody>
</table>
**Efficiency Assessment**

Table 5 presents the income, expenditure and efficiency of the white clover seed crops. Clean seed yield was 520 kg/ha in 2009/10, 330 kg/ha in 2010/11 and 560 kg/ha in 2011/12.

**Table 5**  
Income, expenditure and efficiency of white clover seed production in seasons 2009/10, 2010/11 and 2011/12.

<table>
<thead>
<tr>
<th></th>
<th>2009/10</th>
<th>2010/11</th>
<th>2011/12</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Production</strong></td>
<td>$1,664.00</td>
<td>$1,056.00</td>
<td>$1,792.00</td>
</tr>
<tr>
<td>Grazing*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seed (Average price $3.20/kg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL INCOME ($/ha)</td>
<td>$1,664.00</td>
<td>$1,056.00</td>
<td>$1,792.00</td>
</tr>
<tr>
<td><strong>Inputs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seed (initial cost over 3 years)</td>
<td>$25.00</td>
<td>$25.00</td>
<td>$25.00</td>
</tr>
<tr>
<td>Fertiliser (Plain super/Gypsum/MAP)</td>
<td>$127.00</td>
<td>$65.00</td>
<td>$65.00</td>
</tr>
<tr>
<td>Chemicals (herbicides &amp; insecticides)</td>
<td>$155.00</td>
<td>$120.00</td>
<td>$109.00</td>
</tr>
<tr>
<td>Fertiliser spreading</td>
<td>$24.50</td>
<td>$5.50</td>
<td>$5.50</td>
</tr>
<tr>
<td>Boom spraying (@$13/ha)</td>
<td>$65.00</td>
<td>$65.00</td>
<td>$39.00</td>
</tr>
<tr>
<td>Plane spraying (@$15/ha)</td>
<td>$45.00</td>
<td>$0.00</td>
<td>$0.00</td>
</tr>
<tr>
<td>Harvest</td>
<td>$250.00</td>
<td>$250.00</td>
<td>$250.00</td>
</tr>
<tr>
<td>Certification</td>
<td>$57.00</td>
<td>$45.00</td>
<td>$52.00</td>
</tr>
<tr>
<td>Seed cleaning</td>
<td>$113.00</td>
<td>$73.00</td>
<td>$126.00</td>
</tr>
<tr>
<td>Pollination (1 hive/ha)</td>
<td>$45.00</td>
<td>$45.00</td>
<td>$45.00</td>
</tr>
<tr>
<td><strong>EXPENDITURE ($/ha)</strong></td>
<td>$996.50</td>
<td>$693.50</td>
<td>$716.50</td>
</tr>
<tr>
<td>Irrigation Output</td>
<td>75%</td>
<td>125%</td>
<td>100%</td>
</tr>
<tr>
<td>Irrigation (Fuel, maintenance, water)</td>
<td>$295.00</td>
<td>$505.00</td>
<td>$400.00</td>
</tr>
<tr>
<td>TOTAL EXPENDITURE ($/ha)</td>
<td>$1291.50</td>
<td>$1501.50</td>
<td>$1396.50</td>
</tr>
<tr>
<td><strong>NET PROFIT ($/ha)</strong></td>
<td>$372.50</td>
<td>$162.50</td>
<td>$267.50</td>
</tr>
<tr>
<td><strong>WATER PUMPED (ML/ha)</strong></td>
<td>2.76</td>
<td>4.93</td>
<td>3.95</td>
</tr>
<tr>
<td><strong>EFFICIENCY ($ return/ML pumped)</strong></td>
<td>$135.00</td>
<td>$33.00</td>
<td>$68.00</td>
</tr>
</tbody>
</table>

(* Grazing value not quantified. Constant across all treatments and control.)
Discussion of Results

Crop Water Use Patterns

Graphs 1-4 show similar clover water use patterns despite different irrigation application methods. There is some evidence that under the drop tube irrigated span the clover was extracting moisture slightly deeper (40 cm) compared to the IWOB irrigated span once the crop was in the flowering phase. Experience with drop tube application in lucerne would suggest that once the application is switched from spray to bubbler delivery (which occurred at onset of clover full flowering) there is a tendency for uneven infiltration through the soil profile. This can result in plants responding with increased soil moisture extraction at depth as well as increased deeper root development. It is probable that opportunistic probe positioning can detect this occurrence. In this instance it is evident that clover root development was at least down to 40 cm in the early flowering phase under both irrigation systems and that the bubbler application was responsible for moisture use at this depth in full flowering by comparison to IWOB application (Graphs 1-4). The data shows classic water use ‘stepping’ as described in Life Among the Clover (pg. 16).

It is clear from soil moisture graphs 1-4 that irrigation was too frequent, especially during the flowering phase once crop canopy was fully developed. Irrigation was completed just prior to Christmas 2009 and it is evident that the crop was capable of utilising significant moisture through the 10-50 cm zone of the soil profile. Through the ripening period the crop extracted moisture from 60 cm deep once the top of the soil profile had been depleted of moisture.

Examination of the data suggests that it would be safe to the crop to increase the time gap between irrigation events during full flowering. Soil moisture levels should safely be permitted to decline into the zone between the upper and lower refill points (Graphs 1, 5 and 9). This would cause the soil profile to dry down and create an environment more conducive to seed production. By increasing the time between irrigation events at least one entire irrigation could have been eliminated equating to approximately 10% of the total irrigation applied. It is suggested that this may not have been possible for the 75% application as this irrigation regime applied 25% less irrigation at each irrigation event.

Graphs 5-8 show a similar trend to the previous year. No discernible crop water use difference existed between drop tube and IWOB irrigation application. The significant rainfall was apparent as water draining through the 80cm soil profile being monitored. This highlighted the fact that soil moisture availability was full at points in time after irrigation or rainfall. It is suggested that irrigation through the flowering phase could have been strategically delayed due to available soil moisture in the profile. Irrigation scheduling based on the soil moisture probe could have removed one complete irrigation event equivalent to 20% of the irrigation applied. The lack of irrigation due to rainfall provided the opportunity to record crop water use at the 60 cm depth with no visible duress on the clover seed crop. It is suggested that the lower refill point predicted in the ‘completion of flowering phase’ zone could be lowered due to evidence of consistent soil moisture availability and use below this estimate. The rain event of 137 mm on 14 January completely refilled the soil profile (Graphs 6 and 8). This highlights that fact that once the crop canopy is 100% and the soil moisture profile is full that it would be possible to dry down the soil profile during the seed setting phase with minimal risk. Strategic use of this knowledge with the use of soil moisture monitoring technology could enhance seed production and reduce the number of irrigation events and the volume of irrigation applied.

From graphs 9-12 it is evident that it would have been possible to extend the time between irrigation events. It is estimated, based on the predicted refill points during the crop phases that half of the irrigation events could have been avoided. This could have been achieved by delaying irrigation events to allow the crop to utilise available moisture in the profile. It is recognised that it is important not to have the soil surface dry out as the crop canopy develops. Once full canopy is achieved the crop should be able to utilise the profile moisture as it is evident from the data that irrigation water was passing beyond the root zone and was effectively wasted.
Harvest Data

2009/10 Season

Statistical analysis of the data ($F_{0.95}$ test 5% LSD = 55) revealed a statistically significant difference between the drop tube 75% application treatment and the 100% application of both delivery methods (Table 2). The difference was slight and may be classed as spurious. However the output was adjusted to 80% in the subsequent seasons. It is evident that there may have been a trend towards yield suppression at the 75% and 125% irrigation application rates.

2010/11 Season

Due to the method of harvest and small number of replicates, no statistical analysis was undertaken on this data (Table 3). Comparison of the data between the two harvest methods highlighted the variation between and within treatments due chiefly to soil type variation. The header yields indicated strong similarity between the treatments except for the drop tube 80% treatment. It is suggested that this difference is due to chance when compared to the hand harvested yield results for all the treatments and rotator control. These results advocate the need for adequate plot replication to manage the soil type variation within all treatments and control.

2011/12 Season

Statistical analysis of the data ($F_{0.90}$ test 5% LSD = 46.2) revealed no significant difference between the treatments and rotator control (Table 4). The slight statistical difference between drop tube 80% and Spray 100% is deemed to be spurious. The results suggest that 20% less applied irrigation by either drop tube or IWOB did not cause a reduction in clover seed yield.

Efficiency Assessment

Table 5 shows a predictable higher cost of production in year 1 of white clover establishment due to additional inputs such as herbicides and fertiliser. Season 2010/11 was a low return season due to significant rain during the seed production season (Table 5). The final 2011/12 research season gave a more expected net profit (Table 5).

Due to there being no significant difference in seed yield between treatments, projections were made of the possible gain in financial return/ML applied when less water was used. The irrigation efficiency (measured as net $ return/ML) was 46% more in 2010/11 and 35% more in 2011/12 for the 80% application.

In the first season net $ return/ML was halved when 25% more irrigation above the owner’s aims was applied at each watering (Table 5). Conversely the $ return/ML was doubled when 25% less water was applied below the owner’s aims per irrigation (Table 5). It is debatable whether such a reduction is too optimistic but an 80% reduction in irrigation output per irrigation appears safely achievable with no negative affect on seed yield.
Implications

Apart from the 100% application in the 2009/10 season, the combined irrigation applied and rainfall amounts never exceeded those recorded in the *Life Among the Clover* research. The best producing crop was in the 2011/12 season when rainfall was limited during the production period. In this season the 100% irrigation volume applied was at its lowest compared to the previous two seasons and in the 80% application the combined water application was only 353 mm. Given no significant yield differences were evident provides confidence that there is scope for reducing irrigation volumes applied for white clover seed production.

The research reinforces the recommendations given in *Life Among the Clover* that producers should focus on the $ return/ML pumped and utilise continuous soil moisture monitoring for irrigation scheduling.

If irrigation scheduling techniques were applied to the 2011/12 seed crop utilising the soil moisture data, and the previous two years data, half of the irrigation events could have been avoided. This supposition is made from assessment of the water use patterns (Graphs 1-12) and assessing water use trends in relation to the predicted refill point ranges. By exploiting the available soil moisture reserves once the crop reached 100% canopy it is predicted that at least a further 25% of applied irrigation could have avoided. This suggests that approximately 300 mm of water is required to grow a white clover seed crop when application is appropriately timed. This reduction could have been achieved with adjusted timing of irrigation events that “pushed” the crop to extracting more moisture from the profile between irrigations. The fact that the 80% application rate with either application method caused no yield penalty reinforces this prediction. At 100% application rate the $ return/ML applied was calculated to be $257.00. It is proposed that at 25% reduced total volume the $ return/ML would have increased by at least $118 to $375.00/ML.

The research’s original design, based on *Life Among the Clover*, set the comparative output at 75% of the producers’ standard rate. This rate was judged to be the amount by which irrigation output can be reduced, together with appropriate timing, that would not significantly reduce seed yield. The 2009/10 results supported this but a decision to increase output to 80% was made in consultation with the producer. The research highlights the opportunity for overhead irrigating white clover seed producers to modify irrigation strategies and reduce the overall irrigation output. In conjunction with reduced irrigation output, savings can be accrued from reduction in irrigation operating expenses such as fuel and infrastructure wear and tear. In terms of aquifer management there exists scope to reduce the volume of water extracted with no detriment to the volume of white clover seed produced.

Installation of drop tubes to existing pivots or investment of this sprinkler design on new pivots has been questioned by white clover producers. Anecdotally it is known that drop tubes offer advantages for lucerne seed production. In circumstances where the pivot infrastructure is used for both types of pasture seed production or crops other than white clover uncertainty existed about drop tube suitability. The research highlighted that there appears to be no detriment to using drop tubes for white clover seed production. No increase in seed yield was determined suggesting that pollination was not advantaged by drop tube application. A consistent benefit of drop tube application is the ability to irrigate in weather that is too windy for spray irrigation application. When irrigation scheduling using continuous soil moisture monitoring is invoked the distinct advantage of drop tubes over spray irrigation is the ability to hold off irrigation timing until it is due. Drop tubes offer confidence that irrigation can take place in any weather thereby not suffering reduced efficiency or delay due to wind effects. The research findings support drop tubes as an effective method of irrigation delivery for white clover seed production.
Recommendations

The following are recommendations from the research key findings.

Irrigated white clover seed producers:

i. utilise continuous soil moisture monitoring to permit accurate irrigation scheduling with the aim of applying appropriate irrigation volumes at specific times based on crop water use requirements.

ii. focus attention of irrigation management on the net $ return/ML pumped.

iii. utilise drop tube sprinklers as a means of improving irrigation application and net returns.

iv. produce a suitable fact sheet addressing the key findings of this research.


References


De Barro J.E. (2010). *Life Among the Clover: An investigation into the centre pivot irrigation impacts on white clover seed production at Frances and Bool Lagoon in South Australia*. RIRDC pub. no. 10/005.

Irrigating for white clover seed production

By James De Barro

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