



Australian Government
**Cotton Research and
Development Corporation**

HONOURS SCHOLARSHIP REPORT: 2016-17 SEASON

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| 1. Project Title (Maximum 15 words) | : | Uniformity and energy use of Australian lateral move irrigation machines |
| 2. Proposed Start Date | : | 30/11/2017 |
| Proposed Cease Date | : | 12/10/2017 |
| 3. Honours Scholar and University | : | Bachelor of Engineering (Honours) (Agriculture), University of Southern Queensland |
| 4. Organisation & Location for the project | : | National Centre for Engineering in Agriculture, Toowoomba QLD |
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Project Collaborators (Name and Organisation):

SUMMER SCHOLARSHIP REPORT

(Maximum FOUR pages)

1. Executive Summary:

To demonstrate the influence of the diesel engine's speed over the energy consumption and performance of large lateral move (LM) irrigation machines, 10 field tests were conducted on four LMs on the Darling Downs of South East Queensland. A key objective of the research was to identify if a relationship existed between the performance (uniformity) and energy consumption of the machines, allowing an optimum point to be established.

The main findings of the field testing and analysis were: 1) in general, the emitter discharges were found to decrease with increasing distance from the supply pump; 2) the uniformity was found to decrease in all cases when the engine speed decreased the total flow rate below that of the design; 3) the energy consumption increased with each increase in engine speed; 4) the energy consumed per ML of water pumped, and hence energy cost per year, increased significantly with each increase in engine speed; and 5) a relationship was found to exist for two of three LMs whereby the highest uniformity was achieved at engine speeds that put the pump operating point closest to that of the design.

2. Background:

LM irrigation machines are becoming more and more popular throughout the Australian cotton and broadacre industries. Consistent pressure on water resources and increasing labour costs have driven the adoption of these machines over the past two decades. While these machines typically outperform traditional surface irrigation techniques, they consume a larger amount of energy during operation and require a significant initial investment.

LMs consume energy during operation at their pump carts, where the diesel engine, supply pump and generator (alternator) are housed. The diesel engine is directly coupled to the supply pump which pressurises the lateral pipeline of the machine delivering water at the required pressure to each emitter along the machine's length. The generator, which is driven by the engine using belts and pulleys, supplies the electrical power required by the control panel, guidance and travelling systems of the machines. These machines typically require between 450 and 500 V for operation.

As a warning light or safety switch are often used to determine if the machine is operating outside of this power range (450 V to 500 V), this figure, to some extent, has become a benchmark figure by which growers and managers will set the engine speeds of their LMs. This does not, however, account for the pump operating point which directly influences the performance (uniformity) of the machine. Resultant non-uniformities may directly reduce the potential crop yield, and thus economic return from beneath these irrigation machines (Solomon, 1988 as cited by Foley et al, 2001).

3. Aims and Objectives:

The overall aim of the project was to demonstrate the influence of the diesel engine's speed on both the energy use and uniformity of large LM irrigation machines. It was known that the diesel engine's speed directly influences the pump operating point – flow rate and total dynamic head (TDH) – which would consequently influence the power requirements, resulting in altered energy use; and machine hydraulic characteristics, resulting in potential performance fluctuations.

To carry out this overall objective, the specific aim of the project was to analyse the existence of a relationship between the uniformity and energy use of the large LM machines. It was intended that this would demonstrate the influence of the diesel engine's speed on both of these input and output variables for the LMs.

A further objective was to determine changes to the energy input cost (\$/ha) incurred as a result of the altered energy consumption. When multiplied over the irrigated areas of each LM producing a cost per year figure, it was anticipated that this would demonstrate the potential savings attainable by the proper setting of the engine speeds of LM irrigation machines.

4. Materials and Methods:

To fulfil these objectives, ten field tests of four LMs on the Darling Downs were conducted. One field test was carried out as an initial test to validate the field testing equipment and make the necessary modifications before the winter irrigation season commenced. The final nine field tests were conducted on the final three LMs, three field tests on each. The configurations and makes of these three LMs are as follows: a centre feed (CF) Bauer; end feed (EF) Valley and a CF Valley at lengths of 730, 735 and 800 metres respectively. The system parameter that was changed between each field was the engine speed.

Three field tests were conducted at three varying engine speeds for each LM. The first engine speed tested was initially set by the grower on start-up of the machines. The engine speed was then decreased and increased within the working voltage range of the generator.

During each field test, measurements to analyse the energy (diesel) use, uniformity and energy grade line (EGL) were performed. To determine the energy consumption rate, the flow rate of diesel being consumed by the engine was measured. This was done using a 2.5 L glass bottle as a small auxiliary diesel reservoir which was plumbed into the supply and return fuel lines of the engine. Where the hoses from the auxiliary reservoir teed into the engine fuel lines, a brass, quarter-turn ball valve was fitted upstream of the tee and on the tee side of the hoses to and from the reservoir. This allowed for the fuel lines to be switched from the main tank to the auxiliary reservoir easily.

When the fuel lines were switched from the main tank to the auxiliary reservoir a timer was initiated, recording the time of the consumption. As the level of diesel got close to the bottom of the glass bottle, the valves were switched at the same time as the timer was stopped. The volume of diesel consumed was then measured back into the glass bottle using a 500 mL measuring cylinder. The consumption times were typically around 3 minutes (180 seconds).

Along with the measurement of the direct energy usage, evaluations of the EGLs for each machine were conducted during each field test. This consisted of a pump test and further pressure and elevation measurements along the lengths of the machine. These evaluations were carried out in an effort to understand where the energy was being consumed once it was transferred from the engine to the pump and finally, from the pump to the water.

To assess the application uniformity, the discharges from two emitters per span were measured along the whole length of each machine. The discharges were measured using an ABB Aquamaster electromagnetic flow meter. The flow meter was mounted on a small steel base and was attached to a 150 mm drain waste and vent (DWV) collector by a 25 mm clear flexible reinforced hose. Handles were mounted on both the DWV collector and the flow meter base for carrying the setup under the machines.

The discharges measured during the field testing were then used to determine the Christiansen's coefficient of uniformity (CU) for each field test. The discharges were plotted against the lengths of the machines to identify significant trends that were occurring. The CU values for each LM were plotted against the energy consumption values (L/hr) for the same LM. Plots of the EGLs were also produced against the distance from the pump for each field test of each LM.

5. Results:

As mentioned above, plots of uniformity against the energy consumption rate were produced in order to assess if a relationship between the two variables existed, but more broadly, to demonstrate the influence of the engine speed on both.

From the plot produced for the 730 m, CF Bauer (Figure 1), it was observed that an increase in engine speed induced an increase in both the energy consumption and the uniformity of the LM. In this case, the engine speeds were 1530, 1630 and 1718 RPM producing total flow rates that were 0.965, 1.022 and 1.069 of the design total flow rate. The most notable features of this graph were the increase in yearly operational costs (\$3300) incurred at the final engine speed and the drop in uniformity at a total flow rate below that of the design.

Figure 2 displays the data collected for the 735 m, EF Valley in which it can be seen that the highest uniformity occurred at the grower set engine speed where the total flow rate was closest to that of the

design. The engine speeds for these field tests were 1696, 1768 and 1821 RPM producing total flow rates of 0.94, 1.025 and 1.035 of the design. Again, the energy consumption and cost increased significantly at the highest RPM which was only 53 RPM high than the grower set engine speed.

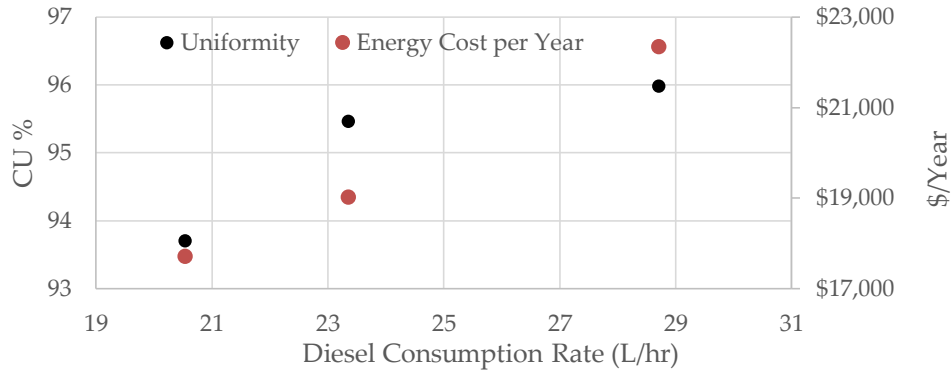


Figure 1 - Application uniformity against energy consumption for the centre feed Bauer

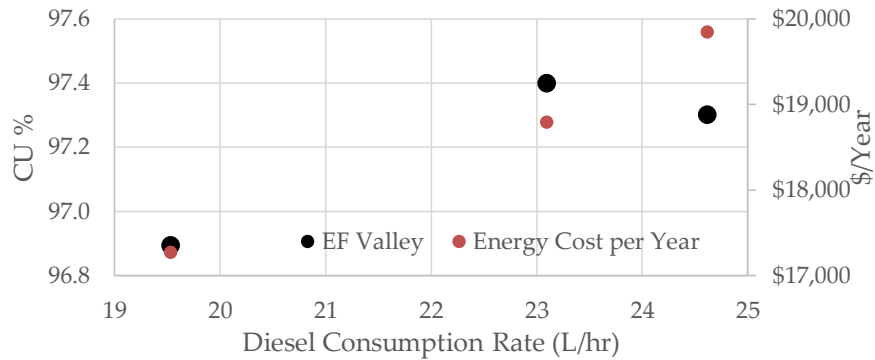


Figure 2 - Application uniformity against energy consumption for the end feed Valley

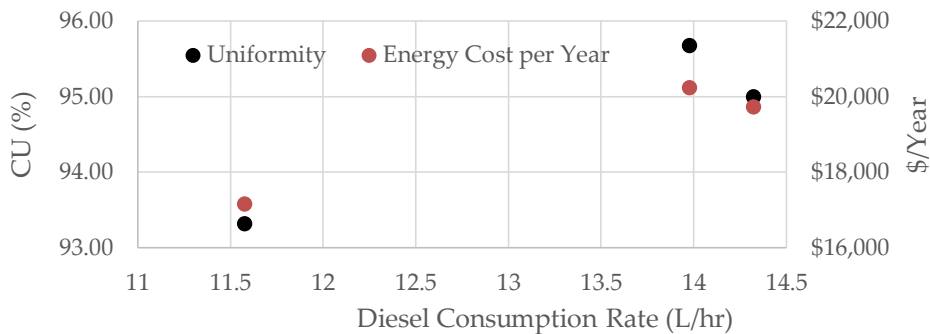


Figure 3 - Application uniformity against energy consumption for the centre feed Valley

The final plot (Figure 3) depicts data collected from the 800 m CF Valley. It can be observed here that highest uniformity again occurs at the engine speed which puts the pump flow rate closest to that of the design flow rate. The engine speeds tested during the field tests were 1733, 1780 and 1858 RPM with total flow rates of 0.97, 0.99 and 1.043 of the design flow rate.

While the shape of this curve for the uniformity was similar to the EF Valley, the energy consumption did not match either of the other LMs. The energy consumption was highest at the grower set engine speed and was found to only slightly increase at the highest engine speed. The energy consumption (L of diesel) per megalitre of water pumped was equated for each field test, and was found to drop at the highest engine speed for this LM. This was not consistent with the other tests or the literature examined beforehand which indicated that an increased pump shaft speed would induce an increase in flow rate and TDH, thus drawing more power and using more diesel, exponentially. It is likely that this does not appropriately reflect that actual energy consumption of the machine at this engine speed.

6. Discussion and Conclusions:

Several key trends were apparent throughout the results from the field testing and subsequent analysis. One which could not be demonstrated, for lack of report space, was that the emitted discharges were almost always found to decrease with increasing distance from the supply pumps. This brings into

question the performance of the pressure regulators which claim to regulate the downstream pressure for any supply pressure above an additional 34.5 kPa (5PSI) on the regulated pressure, 69 kPa (10 PSI).

Secondly, the uniformity was found to decrease when the engine speed lowered the pump operating point below that of the design. This was found for all three LMs, and was caused by the reduced TDH of the pumps which was inadequately supplying water to the pressure regulators causing them to emit varied pressures. For two of the three LMs, the uniformity was found to decrease when the engine speed increased the pump operating point above that of the design. This was likely due to the increased TDH supplying water at excess pressures causing the pressure regulators to produce increased “regulated” downstream pressures.

Thirdly, in all cases the energy consumption was found to increase with each increase in engine speed. Furthermore, for all but one LM, the energy consumed per ML of water pumped increased with each increase in engine speed. As this was directly related to the operating costs, the energy costs per year for each LM were found to increase with each increase in the engine speed. Increases of between \$1000 (6%) and \$3300 (18%) per year were induced by increases in engine speed of between 50 RPM and 100 RPM.

From the field testing, analysis and subsequent discussions, it was recommended that the engine speed that puts the pump flow rate and TDH closest to that of the design is the optimum point of operation for these large irrigation machines. Both increases and decreases in energy input did not increase the performance of the machines, but in fact incurred additional operating costs and/or decreased the performances, and thus the potential crop economic return.

7. Highlights:

- Application uniformity decreased when the engine speed decreased or increased the pump operating point from that of the design.
- Energy consumption increased with each increase in engine speed.
- Increased energy consumption at the diesel engine increased the amount of energy dissipated in the initial spans of the laterals.
- A relationship was found to exist between uniformity and energy consumption whereby both an increase and decrease in energy consumption from that of the design decreased the application uniformity.
- Engine speeds putting the pump operating point above that of the design caused the energy consumption per ML of water pump to increase, resulting in increased energy costs per year without any increase in irrigation performance.

8. Future Research:

Further field testing is required to completely validate these findings over a larger range of engine speeds, however, these findings confirmed what was found during the initial literature review. Further research is required to understand the appropriate operating pressure ranges for the number of common pressure regulators on the market.

9. Presentations and Public Relations:

The project was presented twice at USQ to a group of teaching staff and engineering students. These presentations were made during a ‘Professional Practice’ practical course in September this year (2017).

10. Reference List:

- Foley, JP & Raine, SR 2001, ‘Centre pivot and lateral move machines in the Australian cotton industry’, *National Centre for Engineering in Agriculture Publication* 1000176/1, USQ, Toowoomba.
- Foley, JP & Smith, RJ 2011, Performance Evaluation of Commercial CP&LM Machines, *Biannual Conference of the Australian Society for Engineering in Agriculture 2011*, proceedings held 29-30 September 2011, Surfers Paradise, Queensland, pp. 169 – 178.
- Solomon, KH 1988, *Irrigation System Selection*, No. 93740-0018, California State University, Fresno, California.

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