Controlling Sprinkler Rotation Speed to Optimize Water Distribution Uniformity of Travelling Rain Guns

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Presented by
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Frame of the presentation

1. Actual performance of travelling rain guns
2. The Uniform device
3. Field test
4. Data collection and analysis
5. Performance comparison
6. Conclusions
1. Actual performance of travelling rain guns

- Bell-shaped distribution pattern of old models (>10 years old)
- Poor uniformity
- Low application efficiency
- Water and energy waste
- Reduced working capacity (overlap of wetted areas)

Actual performance of travelling rain guns

Recent big sprinkler models benefit from improved hydraulic and mechanical performance

Irrigation strip width is about 85 percent of sprinkler diameter (i.e. 1.7 the sprinkler radius)
Flattening the water distribution curve by varying the instantaneous irrigation time over the irrigated sector

This condition can be achieved by accelerating the sprinkler rotation speed while irrigating the central sector of the wetted area.
2. The *Uniform* device

*Uniform* is a mechanical device, designed and manufactured by *SIME Idromeccanica*. It is made of two parts, one of which is fixed on the riser and the other which rotates with the sprinkler. The core is a locked cam-shaped ring, over which a pulley rotates.
The **Uniform** device

The up-and-down motion of the pulley during rotation over the ring, changes the clamping force on the brake:
- when the pulley approaches the lower part of the cam, the braking force diminishes;
- when towards the upper part of the ring, the braking force increases and rotation speed decreases.

The angle regulated by the cam is 60° and corresponds to the wetted sector over which the water jet moves faster.
3. Field test

8 September
10 September
17 September

explorer

uniform
Performance indicators

Christiansen's uniformity coefficient, CU

\[
CU = 100 \times \left( 1 - \frac{\sum Y_i}{\sum h_i} \right)
\]

Uniformity of the lower quarter, DU_{lq}

\[
DU_{lq} = \frac{h_{lq}}{h_{avg}}
\]

Sprinklers setting

- Wetted sector: 180°
- Sprinkler nozzles: 28 mm Ø
- Working pressure at the nozzle: 500 kPa
- Jet radius: 56 m
- Measured flow rate: 16.8 l/s
- Travelling speed: 20 m/h
### Sprinklers setting

#### Average Time to Cover 60° Sector (s)

<table>
<thead>
<tr>
<th>Sprinkler Rotation</th>
<th>Uniform</th>
<th>Explorer</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>L C R Total</td>
<td>L C R Total</td>
</tr>
<tr>
<td>Clockwise</td>
<td>32 19 32 83</td>
<td>18 18 18 54</td>
</tr>
<tr>
<td>Anticlockwise</td>
<td>24 17 24 65</td>
<td>19 19 19 57</td>
</tr>
<tr>
<td>Round Trip</td>
<td>56 36 56 148</td>
<td>37 37 37 111</td>
</tr>
</tbody>
</table>

**L=left**  
**C=central**  
**R=right**  

### Experimental fields (ISO 8224-1 n. 584)

- **Sprinkler cart**
- **Travel lane**
- **Collectors line**
- **Hose**
- **Hose reel**
- **Meteo station**
- **explorer**
- **uniform**
4. Data collection and analysis

Water depths (mm) collected during test events (8, 10, 17 September) by the 28 catch cans (Cc n.) of the three lines (L1, L2, L3) placed along the sprinkler radius [R (m)] on the left (Ln.) and right (Rn.) side of the hose travel lane.

Aligned collector lines (e.g., L1-L1; L2-L2; L3-L3) were irrigated simultaneously.

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</thead>
<tbody>
<tr>
<td>R(m)</td>
<td>60</td>
<td>56</td>
<td>52</td>
<td>47</td>
<td>43</td>
<td>38</td>
<td>34</td>
<td>29</td>
<td>25</td>
<td>20</td>
<td>16</td>
<td>11</td>
<td>6.5</td>
<td>2</td>
<td>2</td>
<td>6.5</td>
<td>11</td>
<td>16</td>
<td>20</td>
<td>25</td>
<td>29</td>
<td>34</td>
<td>38</td>
<td>43</td>
<td>47</td>
<td>52</td>
<td>56</td>
</tr>
<tr>
<td>L1</td>
<td>0</td>
<td>0.5</td>
<td>8.9</td>
<td>17</td>
<td>24</td>
<td>28</td>
<td>32</td>
<td>37</td>
<td>41</td>
<td>46</td>
<td>51</td>
<td>56</td>
<td>60</td>
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<td>52</td>
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<td>43</td>
<td>38</td>
<td>34</td>
<td>29</td>
<td>25</td>
<td>20</td>
<td>16</td>
<td>11</td>
<td>6.5</td>
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<tr>
<td>L2</td>
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<td>4.8</td>
<td>14</td>
<td>21</td>
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<td>37</td>
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<td>47</td>
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<td>107</td>
<td>112</td>
<td>117</td>
<td>122</td>
<td>127</td>
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<tr>
<td>L3</td>
<td>0</td>
<td>0.3</td>
<td>8.3</td>
<td>16</td>
<td>24</td>
<td>29</td>
<td>34</td>
<td>39</td>
<td>44</td>
<td>49</td>
<td>54</td>
<td>59</td>
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<td>114</td>
<td>119</td>
<td>124</td>
<td>129</td>
<td>134</td>
</tr>
</tbody>
</table>

8 September Uniform Explorer
10 September Uniform Explorer
17 September Uniform Explorer
Mean depth of water in collector lines (L1, L2, L3), mean ($h_{\text{mean}}$), maximum ($h_{\text{max}}$) and minimum ($h_{\text{min}}$) application depth for the strip, and total water supplied (WS).

<table>
<thead>
<tr>
<th></th>
<th>8 September</th>
<th>10 September</th>
<th>17 September</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water measurement</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Sprinkler model</td>
<td>Explorer</td>
<td>Uniform</td>
<td>Explorer</td>
</tr>
<tr>
<td>L1 (mm)</td>
<td>28.9</td>
<td>30.1</td>
<td>29.4</td>
</tr>
<tr>
<td>L2 (mm)</td>
<td>30.3</td>
<td>29.6</td>
<td>27.8</td>
</tr>
<tr>
<td>L3 (mm)</td>
<td>30.7</td>
<td>28.1</td>
<td>30.4</td>
</tr>
<tr>
<td>$h_{\text{mean}}$ (mm)</td>
<td>30.0</td>
<td>29.2</td>
<td>29.2</td>
</tr>
<tr>
<td>$h_{\text{max}}$ (mm)</td>
<td>50.4</td>
<td>40.5</td>
<td>51.6</td>
</tr>
<tr>
<td>$h_{\text{min}}$ (mm)</td>
<td>1.0</td>
<td>0.3</td>
<td>1.5</td>
</tr>
<tr>
<td>WS (m$^3$)</td>
<td>668</td>
<td>655</td>
<td>671</td>
</tr>
</tbody>
</table>

Example of water distribution of *Uniform* and *Explorer* for line of collectors (L3-8 Sept)
5. Performance comparison

Uniformity for irrigation strips

- Measured water depths were used to assess DUlq and CU for irrigation strips.
- For water distribution system operating in adjacent travel lanes, application depths include those in areas of overlap.
- Calculation is made by translating to the irrigation strip the out-of-strip data by a distance corresponding to the irrigation strip width, i.e., by adding the values that fall outside the right part of the strip to the values in the left part of the strip and vice versa (ISO, 2003).

Performance comparison - DUlq

![Graphs showing performance comparison for DU1q on 8 Sept, 10 Sept, and 17 Sept.](image-url)
Performance comparison - CU

- Explorer performed better than Uniform when overlap increased (spacing less than 75% of SD (1.5 R));
- Effectiveness of the speed rotation controller increased with spacing;
- For strip widths exceeding 1.5 R, the advantage of Uniform under the same uniformity value was about 5% the irrigated width;
- Under the same spacing, difference of DUlq and CU increased up to about 10% and 5% respectively;
- On average, and under test conditions, when adjacent hose travel lanes were spaced from about 75% to 90% the SD (1.5 R to 1.8 R), DUlq of Uniform ranged from 0.80 to 0.88, and CU varied from 88% to 92%;
- In the same spacing interval, DUlq of Explorer ranged from 0.70 to 0.86, and CU from 82% to 90%;
Performance comparison-2

• The highest average DULq and CU values for Uniform occurred when adjacent travel lanes were around 85% of SD, for Explorer when spacing was 80% of SD;

• For Uniform, maximum spacing allowing acceptable values of DULq and CU was about 92% and 97% of the SD (more than 1.8 R and 1.9 R), respectively. For Explorer, maximum spacing declined to 88% and 92% of the SD for DULq and CU, respectively;

• Under test conditions, both Explorer and Uniform were over the acceptable threshold of DULq and CU in a wide range of spacing;

• Compared to Explorer, potential water saving due to better uniformity ranged from 6% to 14% as the irrigated strip width increased from 94 to 103 m, that is from 69 to 212 m³ of water saved every 1000 m³ of net irrigation requirement.

6. Conclusions

• Appreciable improvement in water distribution uniformity of modern big rain gun (Explorer) in comparison with older models.

• Further improvement is given by the speed rotation controller, that proved effectiveness in flattening the radial distribution pattern.

• Practical advantages:
  • uniformity values higher than those performed by the normal model;
  • achieved under minimal overlapping;
  • potential higher irrigation efficiency and increased working capacity.

• Quite a simple mechanical device enabled appreciable potential water saving, proving that irrigation performance can benefit from relatively small investments.

• Improvements of the rotating speed controller are in progress, and further benefits on water use and farm economy are expected.
Thank you for your attention!