Efficiency of sprinkler irrigation systems

T C. Calder
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Efficiency of sprinkler irrigation systems

By T. Calder,
Department of Agriculture,
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Shallow-rooted vegetable crops growing on sandy soils in hot, often windy, summer weather, pose a difficult watering problem for most West Australian vegetable growers.

This situation requires regular and uniform water applications to maintain growth, and irrigation systems with excess capacity to cope with high water requirements during particularly hot, windy conditions.

Observations of market garden sprinkler systems in and around the Perth area have indicated that many systems are inefficient. Irregularities in wetting patterns are common, largely because of variations in sprinkler spacings and capacities. Wind effects are seldom taken into account in system design. The increasing popularity of knocker-type sprinklers makes these considerations particularly important.

Water needs
To maintain satisfactory growth, water used by plants and lost through evaporation has to be replaced by the irrigation system. For best growth in the Perth region the replacement rate is reckoned at some 80 to 90 per cent of the measured evaporation rates summarised in Table 1.

Table 1 indicates that water needs of a crop on an average January day will be some 7.5 to 8.5 mm (80 to 90 per cent of average evaporation). For days with high evaporation conditions the sprinkler system must be capable of supplying 13.5 to 15 mm.

Wind effects
Wind reduces sprinkler effectiveness because of its effects on evaporation and the watering pattern as indicated by Table 2. Because the interaction of wind velocity, temperature and humidity changes constantly, these figures are only approximations. For example, tests on a cool morning with no wind and high humidity showed efficiency losses as low as 4 per cent, compared with similar tests done on a hot day with no humidity and light winds, when the loss was over 40 per cent. Also, Table 2 does not take account of extreme conditions. If severe wind effects were added to the 40 per cent loss, efficiency could be reduced to less than 50 per cent.

Table 2 indicates that on a normal day, even under relatively calm conditions, only some 60 per cent of water leaving the sprinkler actually reaches the ground. This percentage may improve as humidity builds up during watering but loss rates do remain at a high level.

The importance of this is obvious: to supply 8 mm of water under hot, dry, windy conditions, as much as 16 mm needs to be pumped out through the sprinkler system. For average conditions in January, when 7.5 to 8.5 mm of water are necessary to replace 80 to 90 per cent of evaporation, the 60 per cent watering

<table>
<thead>
<tr>
<th>Depth of water applied</th>
<th>0-8 km/h</th>
<th>9-16 km/h</th>
<th>17 km/h and above</th>
</tr>
</thead>
<tbody>
<tr>
<td>25 mm ....</td>
<td>67</td>
<td>63</td>
<td>62</td>
</tr>
<tr>
<td>50 mm ....</td>
<td>69</td>
<td>67</td>
<td>65</td>
</tr>
<tr>
<td>100 mm ....</td>
<td>73</td>
<td>69</td>
<td>68</td>
</tr>
<tr>
<td>150 mm ....</td>
<td>78</td>
<td>72</td>
<td>70</td>
</tr>
</tbody>
</table>

The importance of this is obvious: to supply 8 mm of water under hot, dry, windy conditions, as much as 16 mm needs to be pumped out through the sprinkler system. For average conditions in January, when 7.5 to 8.5 mm of water are necessary to replace 80 to 90 per cent of evaporation, the 60 per cent watering
efficiency to be expected under calm
to 8 km per hour wind conditions
requires that the sprinkler system
must deliver 12.5 to 13.5 mm
(125 000 to 135 000 litres per hectare)
per day to ensure adequate moisture
This does not take account of water
applied for cooling only.

Spray patterns
Besides increasing water loss, wind
severely affects sprinkler distribution
patterns, as indicated by Figure 1.
To counteract this expected effect
wind velocities should be considered
when designing sprinkler layouts and
 spacings. Generally accepted rela­
tionships between wind velocities and
 sprinkler spacing are indicated in
Table 3, and the expected range of
wind velocities for Perth is sum­
marised in Table 4.

Wind velocities are often above
17 km/hr (and therefore exert severe
effects on spray patterns) for much of
the main irrigation season from
September to March. Using this
data, the necessary sprinkler spac­
ings may be derived from Tables 3
and 4.

For example, in a situation where
winds of over 17 km/hr can be
expected, small knocker type sprink­
ers with a spray diameter of about
27 m should be spaced at not more
than 8 m if they are to provide an
efficient wetting pattern.

Sprinkler pressures
Operating pressures for various jet
sizes are given in Table 5. If other
 sprinkler pressures are used the
 spray pattern produced will be less
efficient.

Table 3—Reduction of sprinkler effect­
iveness with increasing wind velocities.

<table>
<thead>
<tr>
<th>Wind velocity</th>
<th>Spacing requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Wind</td>
<td>65% of spray diameter</td>
</tr>
<tr>
<td>0-8 km/h</td>
<td>60% of spray diameter</td>
</tr>
<tr>
<td>9-16 km/h</td>
<td>50% of spray diameter</td>
</tr>
<tr>
<td>Above 17 km/h</td>
<td>22 to 30% of spray diameter</td>
</tr>
</tbody>
</table>

Table 5—Recommended pressures for a
range of sprinkler jet sizes.

<table>
<thead>
<tr>
<th>Jet size</th>
<th>Pressure required</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.4-4.8 mm</td>
<td>240-345 kPa</td>
</tr>
<tr>
<td>4.8-6.3 mm</td>
<td>310-415 kPa</td>
</tr>
<tr>
<td>6.3-9.5 mm</td>
<td>345-480 kPa</td>
</tr>
</tbody>
</table>

Knocker or pulsing type sprinklers on a
grassed area. The pressure is correct
and misting is reduced to a minimum.

Testing sprinkler system output
Figure 2 shows a suggested layout
for testing a sprinkler system. The
area between sprinklers is divided
into equal squares and a vertical
sided can is placed in each square.
The system should then be started
under typical weather conditions and
the can contents measured at the end
of the test period.

The system can be operated for a
given length of time, then a thin rule
used to measure the water depth in

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</tbody>
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METRIC CONVERSION

1 mm = 0.0394 inches
1 m = 3.28 feet
1 km = 0.62 miles
1 ha = 2.47 acres
1 l = 0.22 gallons
1 kPa = 0.145 lb. per sq. in.
each can. The time to supply the minimum water necessary can then be calculated from the water depth in the cans with least water.

It must be realised too that unless the distribution efficiency of the system is close to 100 per cent (equal quantities of water in each can) problems will arise not only through uneven water distribution but also when fertiliser is applied through the sprinkler system. Cans with least water may represent areas suffering a nutrient shortage.

It is therefore misleading to average out the readings from all cans as a means of calculating running time.

The above analysis indicates that full account should be taken of the effects of wind, temperature and humidity on precipitation rates, together with the effects of wind and sprinkler spacings and pressures, when designing or re-designing a sprinkler system. The discharges of individual sprinklers on any one lateral should be uniform and not vary by more than 20 per cent.

### Table 4—Average daily 9 am and 3 pm wind velocities for Perth—km/hr.

<table>
<thead>
<tr>
<th></th>
<th>J</th>
<th>F</th>
<th>M</th>
<th>A</th>
<th>M</th>
<th>J</th>
<th>A</th>
<th>S</th>
<th>O</th>
<th>N</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 a.m.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Calm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>16</td>
<td>16</td>
<td>20</td>
<td>29</td>
<td>28</td>
<td>20</td>
<td>27</td>
</tr>
<tr>
<td>0-8 km/h</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>38</td>
<td>33</td>
<td>32</td>
<td>32</td>
<td>34</td>
<td>38</td>
<td>34</td>
</tr>
<tr>
<td>9-16 km/h</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>44</td>
<td>47</td>
<td>44</td>
<td>36</td>
<td>33</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td>Above 17 km/h</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>74</td>
<td>70</td>
<td>70</td>
<td>51</td>
<td>45</td>
<td>51</td>
<td>51</td>
</tr>
<tr>
<td>3 p.m.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Calm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>4</td>
<td>2</td>
<td>11</td>
<td>16</td>
<td>17</td>
<td>14</td>
</tr>
<tr>
<td>0-8 km/h</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>24</td>
<td>26</td>
<td>27</td>
<td>37</td>
<td>37</td>
<td>30</td>
<td>33</td>
</tr>
<tr>
<td>9-17 km/h</td>
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<td></td>
<td></td>
<td>44</td>
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<td>36</td>
<td>33</td>
<td>34</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td>70</td>
<td>70</td>
<td>51</td>
<td>45</td>
<td>51</td>
<td>51</td>
</tr>
</tbody>
</table>

**Fig. 2.—Layout of cans for testing a sprinkler system.**

Misting is increased by excessive water pressure to these sprinklers operating on a vegetable crop. This increases water loss from evaporation and could cause a significant rise in salinity of water reaching the crop.