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Irrigation and fertilizer management for horticultural crops on the Swan Coastal Plain

By Ian McPharlin and Greg Luke, Research Officers, Division of Horticulture and Division of Resource Management, South Perth

The Swan Coastal Plain is an important area for the production of vegetables, flowers and fruits in Western Australia. The yellow Cottesloe, Karrakatta and the white-grey Bassendean Sands upon which most of this production is based are infertile in their natural state and require large inputs of fertilizer for successful production of horticultural crops.

Unfortunately, these soils have very low capacities to retain nutrients and water. Consequently, much of the applied fertilizer may leach and find its way into ground and surface water bodies of the coastal plain. This leaching is increased by excessive irrigation.

Phosphorus fertilizers applied to horticultural crops (mainly vegetables) and pastures on sandy soils have been implicated in the pollution of the Peel-Harvey estuary and wetlands of the coastal plain. Piggeries and sheep holding yards are also a source of phosphorus in surface waters.

Nitrate levels greater than 10 mg/L nitrate nitrogen are also considered unsafe in water used for drinking (Cargeeg et al. 1987). Horticulture, along with industry and urbanization, are sources of this nitrate.

Improved irrigation and fertilizer management will be needed to reduce nutrient leaching from horticultural crops on the coastal plain. This will probably involve applying fertilizer and water more frequently, but in smaller quantities than currently practised. The result should more closely match water and fertilizer supply to crop demand.

Treatment with high phosphorus fixing amendments will probably be necessary to reduce phosphorus leaching from the white-grey sands.

Value of production

Horticultural production in Western Australia in 1987/88 was valued at $204 million (Table 1).

Most of the vegetables grown on the Swan Coastal Plain are exported. They set the quality standard in South-East Asia and contribute to Western Australia being the premium vegetable-exporting State in Australia, accounting for over 80 per cent of the national exports of carrots, cauliflowers and cabbages and half of the celery and lettuce. This distinguishes the Swan Coastal Plain as one of the most important vegetable production areas in the southern hemisphere.

There is little financial incentive for vegetable growers to reduce fertilizer or pumping costs since they represent only about 10 per cent of the direct costs of production (Anon. 1988). In addition, under-fertilizing or under-watering severely reduces quality and yield.

Table 1. Value of horticultural production in Western Australia for the year ending June 30, 1988

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Value ($ m)</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetables</td>
<td>97.2</td>
<td>48</td>
</tr>
<tr>
<td>Fruit</td>
<td>65.2</td>
<td>32</td>
</tr>
<tr>
<td>Cut flowers/Nurseries</td>
<td>41.6</td>
<td>20</td>
</tr>
<tr>
<td>Total</td>
<td>204.00</td>
<td>100</td>
</tr>
</tbody>
</table>

† Australian Bureau of Statistics, 1989
Table 2. The fate of nitrogen and phosphorus fertilizer (in kg/ha/crop) after application to five major vegetable crops on the coastal sands

<table>
<thead>
<tr>
<th>Crops</th>
<th>Status of land</th>
<th>Applied</th>
<th>Exported</th>
<th>Residual</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>N</td>
<td>P</td>
<td>N</td>
</tr>
<tr>
<td>Carrots</td>
<td>New</td>
<td>(72)</td>
<td>372</td>
<td>(24)</td>
</tr>
<tr>
<td></td>
<td>Old</td>
<td>(0)</td>
<td>300</td>
<td>(0)</td>
</tr>
<tr>
<td>Lettuce</td>
<td>New</td>
<td>(600)</td>
<td>850</td>
<td>(200)</td>
</tr>
<tr>
<td></td>
<td>Old</td>
<td>(120)</td>
<td>370</td>
<td>(40)</td>
</tr>
<tr>
<td>Cauliflower</td>
<td>New</td>
<td>(600)</td>
<td>1,050</td>
<td>(200)</td>
</tr>
<tr>
<td></td>
<td>Old</td>
<td>(120)</td>
<td>570</td>
<td>(40)</td>
</tr>
<tr>
<td>Onions</td>
<td>New</td>
<td>(600)</td>
<td>800</td>
<td>(200)</td>
</tr>
<tr>
<td></td>
<td>Old</td>
<td>(120)</td>
<td>320</td>
<td>(40)</td>
</tr>
<tr>
<td>Potatoes</td>
<td>New</td>
<td>(600)</td>
<td>740</td>
<td>(200)</td>
</tr>
<tr>
<td></td>
<td>Old</td>
<td>(120)</td>
<td>360</td>
<td>(40)</td>
</tr>
</tbody>
</table>

1 Based on recommended rates for new and old land respectively.
2 Amount of nutrients applied as poultry manure given in brackets. Assumes poultry manure contained 1% P, 3% N and 50% moisture (Phillips and Hawson 1986).
3 Amount removed in harvested product.
4 Includes nutrients remaining in inorganic and organic form.

Current fertilizer management

Both organic (fowl manure) and inorganic fertilizers are applied at high rates to irrigated vegetables (Table 2) on the coastal sands to maximize yields. Rates of fowl manure (0 to 40 t/ha/crop), phosphorus (50 to 120 kg phosphorus/ha/crop) and nitrogen (140 to 770 kg nitrogen/ha/crop) vary considerably according to crop type and age of the property. These rates are much higher than those for phosphorus applied to pastures (8.5 to 11.0 kg/ha) in the same area (Kinhill Engineers 1988).

Removal of nitrogen and phosphorus in harvested vegetable crops represents less than 30 per cent of applied nutrients (Table 2), leaving significant quantities available for leaching. Despite this apparent inefficient use of nutrients most research has shown that these high rates are necessary to maximize yields under current management systems. Nevertheless there are several management options that may increase the efficiency of use of these fertilizers by vegetable crops and reduce leaching.

Management of nitrogen fertilizers

Fowl manure is used as a soil amendment/fertilizer for early crop growth. Often more nitrogen is added in the fowl manure than in the inorganic fertilizers applied to the same crop (Table 2). Fowl manure is normally applied one to two weeks before planting and most of the nitrogen is leached two to four weeks after crop establishment. Nitrogen fertilizers (such as urea and ammonium nitrate) are then applied for the remainder of the growing period, usually at two-weekly intervals to satisfy growth requirements.

Over-irrigation increases the leaching of nitrogen (nitrogen is very soluble in water) and hence the amount of applied nitrogen required for maximum yield (Figure 1). For example at 200 kg nitrogen/ha maximum yields of lettuce were attained by irrigating at 1.5 times the daily pan evaporation (1.5 E pan). However, at 600 kg nitrogen/ha maximum yield was still not achieved at irrigation rates of 1.8 E pan (Figure 1). The high rates of nitrogen decreased crop yield and extra irrigation was necessary to flush the excess nitrogen out of the root zone. This is an inefficient use of nitrogen and water. Improvements in both fertilizer and irrigation management are needed to reduce nitrogen leaching.

Increasing the frequency of application of nitrogen fertilizers (i.e. small daily versus larger fortnightly applications) may enable the total amount of nitrogen applied to crops to be reduced since the revised application rate more
closely matches nitrogen supply to crop demand. More closely matched crop irrigation requirements should also further reduce nitrogen requirements through reduced leaching.

Management of phosphorus fertilizers
Phosphorus fertilizer is normally all applied preplanting to vegetable crops on the coastal sands. As with nitrogen, considerable quantities of phosphorus are added in the fowl manure. In some instances the phosphorus applied from the fowl manure may satisfy the crop requirements and extra fertilizer may not be necessary.

The practice of applying all phosphorus preplanting renders considerable quantities of phosphorus prone to leaching early in the crop growing cycle. Since less than 30 per cent of phosphorus is removed by the crop considerable quantities of unused phosphorus remain. On low phosphorus-fixing sands it may be possible to reduce the rates of applied phosphorus (and therefore its leaching) by applying some of the phosphorus after planting.

Proper management of irrigation appears to be important in reducing phosphorus leaching on the coastal sands. For example, under a conventional irrigation (1.4 E pan in two waterings per day) 150 kg phosphorus/ha was required to produce maximum yields of carrots on a previously uncropped sand at Medina. When irrigation was modified to reduce the volume of water applied at each irrigation (1.4 E pan in four waterings per day), less than 100 kg phosphorus/ha was needed for maximum growth. The irrigation strategy was more important than pre or postplanting applications of phosphorus in reducing leaching.

Even under improved irrigation and fertilizer management phosphorus will still leach from the coastal sands. However, the yellow Cottesloe and Karrakatta Sands leach less phosphorus than the white-grey Bassendean Sands because they have a higher phosphorus adsorption capacity (15 to 20 ppm compared with less than 2 ppm).

Research has started on the use of soil amendments such as ‘red mud’ (a residue from bauxite mining) to reduce phosphorus leaching from horticultural crops on the coastal sands. This strategy has been successful with pastures (Summers et al. 1987) and it may be economically feasible for horticultural crops. Though vegetable crops need more phosphorus than pastures, the preliminary results from pastures are encouraging.

Irrigation management
Vegetable growers on the Swan Coastal Plain usually water once a day during cool weather and twice daily during hot conditions. Crops need more frequent watering in summer because the soils retain insufficient moisture to sustain growth.

Irrigation systems have been mainly manually operated. The time and difficulties involved in this operation discourage growers from matching the crop's water use and soil moisture holding capacities with an efficient irrigation schedule. It is easier to over-water than risk the crop drying out.

Research has started to achieve a match between crop water requirements and irrigation. Two vital factors are evident.

- Water drains through sandy soils so rapidly that excess water is readily lost to deep drainage. If a sandy soil is saturated with water, and the rate of drainage is measured, the full impact of overwatering can be seen. If the soil starts at 15 per cent moisture, after 12 hours (equivalent to overnight drainage) the moisture will drop to 10.5 per cent and nearly one-third of water is lost. After several days the soil moisture levels out at about 9.8 per cent. This is the amount of moisture the soil can hold without further drainage, and is known as its field capacity.

- Plants on such sandy soils suffer severe water stress once the soil moisture falls below field capacity. Measurements taken on rockmelons demonstrate this phenomenon. The plant’s stomatal conductance (a measure of how open the leaf stomates are and how effectively they are transpiring) drops rapidly
Figure 2. Marketable yield of rockmelons increased and less water was used under a trickle system than with sprinkler irrigation.

Under a manual irrigation system growers were not able to closely control the irrigation process. With the development of new technology such as automatic controllers, electric solenoids, soil moisture meters and trickle irrigation it is now possible to improve irrigation management systems. Department of Agriculture research is investigating these new sprinkler and trickle irrigation systems.

Work in 1987/88 comparing trickle and sprinkler-irrigated rockmelons showed production increased considerably and less water was used under trickle irrigation (Figure 2).

Even though the use of trickle irrigation substantially increased the yield of rockmelons, soil moisture measurements showed that even at 60 per cent of pan evaporation replacement water drained passed the root zone. Also, regardless of the irrigation rate, within several hours of the water being turned off, the crop’s stomatal conductance was reduced and the crop stopped growing. The crop grows well while the irrigation is running and the soil moisture is above field capacity. However, most of the water drains below the root zone and once irrigation stops the crop quickly uses the available moisture, and runs into water stress.

In a 1988 trial on greenhouse carnations, the day’s water quota was applied in 10 equal pulses (amounts) at hourly intervals through trickle, instead of all at once as was the grower’s practice. The results (Figure 3) showed that the pulse irrigation achieved a constant soil moisture, close to field capacity, throughout the day. The grower’s system produced a large excess for part of the day. That excess was wasted. The pulse system resulted in a water saving of 65 per cent. As well as the water saving, the ‘pulse irrigated’ plots outyielded the ‘grower’s’ plots by 15 to 20 per cent depending upon the variety.

This pulse trickle technique was tried on rockmelons at Medina in 1988/89. By pulsing the water, maximum yield could be achieved with 60 per cent evaporation replacement, compared with 120 per cent for conventional trickle and 180 per cent for sprinklers.

Soil moisture levels for the 60 per cent treatment were maintained close to field capacity for most of the season. During several heat waves the system of irrigating based on the previous day’s evaporation failed to supply sufficient water, but the pulse trickle technique proved its value. Similar investigations are underway with other crops.

Figure 3. Soil moisture levels in the root zone of trickle irrigated carnations under two watering systems (after Luke 1988). Arrows indicate time of watering: ‡ = pulse; † = conventional trickle.

when soil moisture falls below field capacity. This reaction limits the photosynthetic activity of the leaf, reducing growth and yield.

These two factors, and the physical problems of operating a manual system, have prompted growers to apply more water than the soil could retain. By the time the second irrigation cycle was due, the soil was still above field capacity and the crop had not started to suffer from water stress.

This practice of over-watering developed after years of experience. Under-watering meant poor crop yield and quality. Over-watering, though costing more, only occasionally caused problems as it is difficult to waterlog a sandy soil. But the hidden cost of over-watering is the leaching of fertilizers and its impact on the environment.
In initial investigations of sprinkler irrigated crops the daily waterings were split into four rather than two applications. The results showed yield increases of 10 to 20 per cent for zucchini, parsnips, corn and cucumber, 100 per cent yield increase for beetroot, no change in lettuce and a 45 per cent yield loss due to disease for beans. These investigations are only preliminary and no recommendations can be made from them, but they suggest that more work is needed.

Substantial improvements in irrigation efficiency are possible using a variety of new techniques. Additional costs associated with new technology should be offset by yield increases and savings in water and fertilizer expenses.

Research priorities
The Department of Agriculture has started a major research programme to improve the irrigation and fertilizer management for the major vegetable crops (carrots, lettuce, cauliflowers, onions and potatoes) on the coastal sands. The aim of this programme is to reduce the leaching of nitrogen and phosphorus from vegetable crops without reducing crop yields. This will be achieved by more closely matching fertilizer supply and irrigation to crop demand. Strategies to be investigated include:

- Increasing the frequency of nitrogen fertilizer application to vegetables (i.e. small daily versus larger fortnightly applications) to more closely match nitrogen supply to crop requirements and to reduce leaching.
- Development of a fertilizer management programme based on soil test standards for phosphorus on the better quality Cottesloe and Karrakatta sands.
- Applying a proportion of the phosphorus to vegetables after planting on the poorer sands to more closely match phosphorus supply to crop requirements and to reduce leaching.
- The role of soil amendments, such as neutralized ‘red mud’, in reducing phosphorus leaching from vegetable crops on the white and grey sands.
- A re-assessment of the role of fowl manure in vegetable production on the coastal sands.
- Alternative management strategies for existing sprinkler systems and an evaluation of the interaction between irrigation and fertilizer management.
- The value of trickle irrigation for vegetable crops.
- Further development of the pulse technique for trickle irrigation.

• The value of subsurface barriers such as asphalt and plastic sheeting in reducing drainage and thus nutrient leaching.

The objective of the programme is to develop a more efficient and environmentally acceptable management package for horticulture. The ultimate benefits of the system should be improved profits and reduced environmental damage.

References