Potato production on sandy soils: are farmers over-irrigating?

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Introduction

Water is a scarce resource in South Africa and the optimum use of water in potato production is a crucial aspect defining the sustainability of potato production. Water use efficiency of potato production, that is the amount of potato tuber produced for a certain amount of water applied, indicates how efficient the water supplied to the crop through irrigation or rainfall is used to produce potatoes. A high use of water can lead to water losses through deep drainage, which also leads to losses of nutrients such as nitrogen.

A survey among potato growers in South Africa (Steyn et al., 2016) highlighted large differences in water use efficiency among potato growers in South Africa. Such large differences can be anticipated between production regions, as each region has unique soil and climatological characteristics. However, also major differences in water use and use efficiency were observed between growers within regions where farming takes place under relatively homogenous agro-ecological conditions. Most likely, these differences within regions can be attributed to differences in crop management. To explain this wide variability in water use and use efficiency and to derive optimal ways of managing water resources during potato production, we measured water inputs (rain and irrigation) and losses (evapotranspiration and drainage) on a daily basis in a range of potato fields. The field activities focussed on potato farms in North West (Louwwa region) and the Sandveld, as both regions have mostly sandy soils, with a low water holding capacity and therefore a high risk of losing water through deep drainage, and both regions depend mainly on borehole water for irrigation, being particularly susceptible to over-use. As far as we are aware, this is the first time that drainage rates are measured and published in irrigated field crops on commercial farms in South Africa.

Methodology

To derive a soil water balance, the inputs and losses of water in the soil need to be quantified. Water is added to the soil primarily through irrigation and rainfall, while water is lost from the soil primarily through evapotranspiration (ET) and deep drainage. Water inputs from irrigation were quantified through pressure transducers installed at the centre of the pivot
measuring the time when the pivot is irrigating. This, combined with a measurement of the flow delivered by the pivot allows for an accurate quantification of the amount of water applied. The amount of rainfall was quantified with automatic rain gauges. Deep drainage beyond the potato roots was assessed with the help of a lysimeter (Decagon G3) measuring the drainage that passed beyond 1 m soil depth. We assumed that water draining below 1 m depth is not accessible to the potato crop anymore. Drainage was quantified through a pressure sensor at the bottom of the lysimeter and by pumping out and measuring the volume of the water collected by the lysimeter. ET is difficult to measure directly and was derived from weather data collected by nearby weather stations. The calculated grass reference evapotranspiration (ETo) was assumed to be representative of the crop’s ET. However, in case the crop is stressed for water, the actual ET may be less. This set of measurements was done in 4 potato fields in North West and 8 fields in the Sandveld during the 2017/18 cropping seasons. In North West, the crops following potato are currently being assessed in a similar manner, while in the Sandveld additional potato fields are being monitored. In this article, we show the results from a selection of six fields and highlight some general principles that we can derive from these results at this stage.

Results

Table 1 shows characteristics of the six potato fields that were monitored. In the Sandveld, the crops were planted in May, July and October, giving crops growing in winter, spring and summer, respectively. Due to differences in radiation, the potential yield of a crop growing in summer is higher than that of a winter crop, provided that excessive heat stress can be avoided in summer. The actual yields reflect this difference in available radiation. Rain in the Sandveld primarily occurs in winter. This, combined with lower ET rates in winter, implies that the irrigation requirements of a winter crop are considerably less than those of a summer crop. In North West, the ideal planting window for potato is narrower and crops were planted between late August and early October. Although most rain falls in summer, the crops in North West received only little rainfall.

To understand the figures showing the daily irrigation and rainfall, the daily ETo, as well as the accumulated drainage over time for each field, we need to compare the daily inputs (water + irrigation) with the ET of the crop. As sandy soils have a poor ability to store water and the rooting depth of potato is relatively shallow, drainage can be expected to occur soon when the water inputs into the soil exceed the ET of the crop.

On Field 1 (winter crop in the Sandveld) between 13 June and 4 July, frequent rainfall implied that water inputs were considerably above ETo values, with substantial drainage as a result, especially after the heavy rainfall of 1 July. Also, after 4 July, occasional rain showers and irrigation rates that were above daily ETo rates led to additional drainage, giving a total drainage over the season of 313 mm. In Field 2, ETo
values were higher than Field 1, as the crop in Field 2 was growing during the warmer spring period. In Field 2, irrigation rates were well in line with daily ETo rates and rain was scarce in this growing season, with the exception of one major shower on 22 October. As a result, almost no drainage was recorded for this field. For Field 3, the crop was growing through the middle of the warm summer months, and ETo was even higher than for Field 2. While rainfall was scarce in this growing season, irrigation rates often exceeded ET rates, which resulted in substantial drainage.

In North West, the farmer at Field 4 generally irrigated less than the potential ET of the crop. It is therefore likely that the crop somewhat suffered from water stress because actual ET values were less than the potential. As rain was almost non-existent in this season, no drainage was recorded in this field. Field 5 could be considered a special case. As a result of a power failure on 23 Nov, the irrigation boom probably came to a standstill above the lysimeter and the automatic rain gauge recorded 104 mm of water overnight (23-24 Nov). This obviously led to a major surge in drainage. As the soil in this field consisted of coarse sand with a very low water holding ability and no limiting layers in the profile, drainage continued to be substantial during the growing season, although irrigation did not exceed ET for most of the season. In Field 6, irrigation rates did somewhat exceed ET rates for most of the growing season, but nevertheless no drainage was recorded in this field. This was the only field that did not have a freely draining, sandy soil. Instead, it had a loamy soil with a better water holding ability and a chalky layer at 0.8 – 1.0 m depth that impeded vertical water flow. This explains the lack of drainage observed in this field. Soils with a water table are considerably less susceptible to drainage, although water logging can be a problem when rainfall is excessive.

Water use efficiency (WUE) was calculated based on total amounts of rain and irrigation applied, or based on irrigation amounts only (Table 1). It is more common to calculate WUE based on both rain and irrigation. However, farmers have no control over rainfall, while irrigation water is scarce and should be used as efficiently as possible. The winter crop in the Sandveld produced a relatively low yield, which is typical for a winter crop. Due to the high rainfall and low irrigation amounts, this crop achieved a low WUE based on both rainfall and irrigation, but a high WUE based on irrigation only. Field 3 and Field 4 both achieved high WUEs, but for different reasons. Potato Field 3 achieved a very high yield (118 t/ha),

<table>
<thead>
<tr>
<th>Field</th>
<th>Region</th>
<th>Planting date</th>
<th>Yield (t ha⁻¹)</th>
<th>Water inputs</th>
<th>Water losses</th>
<th>WUE (kg tuber mm⁻¹ rain + irrigation)</th>
<th>WUE (kg tuber mm⁻¹ irrigation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field 1</td>
<td>Sandveld</td>
<td>May 2</td>
<td>42</td>
<td>232</td>
<td>313</td>
<td>216</td>
<td>347</td>
</tr>
<tr>
<td>Field 2</td>
<td>Sandveld</td>
<td>July 31</td>
<td>54</td>
<td>71</td>
<td>550</td>
<td>631</td>
<td>4</td>
</tr>
<tr>
<td>Field 3</td>
<td>Sandveld</td>
<td>Oct 11</td>
<td>118</td>
<td>54</td>
<td>913</td>
<td>669</td>
<td>233</td>
</tr>
<tr>
<td>Field 4</td>
<td>North West</td>
<td>Aug 29</td>
<td>76</td>
<td>19</td>
<td>590</td>
<td>706</td>
<td>0</td>
</tr>
<tr>
<td>Field 5</td>
<td>North West</td>
<td>Oct 3</td>
<td>92</td>
<td>128</td>
<td>906</td>
<td>785</td>
<td>488</td>
</tr>
<tr>
<td>Field 6</td>
<td>North West</td>
<td>Oct 4</td>
<td>86</td>
<td>129</td>
<td>960</td>
<td>870</td>
<td>0</td>
</tr>
</tbody>
</table>
which led to a high WUE, despite a high irrigation amount (913 mm) and substantial drainage. So for this field there was an opportunity to further save irrigation water by matching irrigation amounts with measured daily ETo values and achieve even higher WUE. In Field 4, the farmer achieved a fair yield with a low irrigation use, giving a high WUE. This is a sensible strategy in a water-scarce environment.

**Conclusions**

The results show that in case a farmer is able to irrigate the potato crop in line with the daily ET of the crop, drainage can be kept to a minimum, even on sandy soils with little water holding capacities. On half the studied fields almost no drainage was recorded, indicating that many farmers manage their irrigation
Acknowledgements

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