TOOLS FOR ESTIMATING PLANT AVAILABLE WATER IN THE PADDock

Introduction

The plant available water capacity (PAWC) is the maximum amount of soil water that can be extracted by a crop plant from a given soil. It is the difference between the drained upper limit (DUL) of water in the profile, commonly referred to as field capacity (FC)) and the crop-specific lower limit of plant available soil water, also referred to as the wilting point (WP). Crop roots vary in their ability to extract water from a soil depending on the species of crop and also the tension with which that water is held in the profile. Therefore the value for the wilting point obtained by a standard lab technique could be different to the crop-specific value. Similarly the lab-determined field capacity value will be different to the DUL value for a given soil. Despite these differences between measured values and what plants can do, measurement of plant available water can be a useful planning tool for grain growers.

All of the above values are generally expressed in millimetres of water for a given profile depth. Where the crop-specific rooting depth is clearly known, that expression becomes more realistic in terms of crop water use. An understanding of the PAWC of your soil will assist you in,

a. understanding the water balance of your soil  
b. estimating stored soil water throughout the growing season

Water in the soil

Water can occupy different volumes within the structure of the soil. Much of the water that is easily accessed by crop plants is generally held in small (micro) pores within soil aggregates and is called plant available water (PAW). Any water occupying the larger (macro) pores between aggregates or cracks between large structural units will essentially displace the air in those spaces and can cause disruption to root growth and other plant processes.

Table 1. The effect of soil depth and texture on plant available water capacity (after Baxter and Williamson, 2001)

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>Total soil water holding capacity (mm) (values in brackets are the PAW in millimetres)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sand</td>
</tr>
<tr>
<td>0-10</td>
<td>10 (1)</td>
</tr>
<tr>
<td>10-60</td>
<td>60 (6)</td>
</tr>
<tr>
<td>60-100</td>
<td>45 (4.5)</td>
</tr>
<tr>
<td>Total to 100 cm</td>
<td>115 (11.5)</td>
</tr>
</tbody>
</table>

Because PAW is held within the soil aggregates, the texture (or the composition) of these aggregates will determine the PAW capacity. Some of the water within the micro pores will be held so tightly by the soil particles that plants will not be able to access it at all. When the profile is depleted to this low soil water status, it is considered to have reached its wilting point. Water will also be held more tightly by clay particles than by sand particles and therefore plants have to exert more energy to draw water from clay soils compared to sandy soils. Clay soils may therefore reach WP at a higher water content than sandy soils, making less water available for use by plants (see Table 2). Sandy soils on the other hand have lower water holding capacity and the PAWC is also lower than in clay soils (Table 1).
Usefulness of the measure of PAW

Farmers may wish to determine the amount of PAW in their paddocks for a number of reasons. In recent years in the south-west regions of Victoria there has either been too much or too little pre-season rain, complicating the decision on when to sow crops. The timing of nitrogen fertiliser topdressing and fungicide application may also depend on the current soil water status. If crops do not have sufficient soil water for active growth and are “water-stressed” such applications of fertiliser or fungicide can tend to have adverse consequences. In the heavy clay basalt plains of south-west Victoria, the active root zone can often be confined to a depth of about 30-40cm (this would be greater under raised beds) and farmers would benefit from a simple technique for the determination of PAW at that depth in their day-to-day decision making.

In this fact sheet we provide some simple guidelines for the field determination of PAW.

A simple push probe may be all that is required for a fast assessment of the depth of wet soil. However, as PAW changes with the texture of the soil, more work is involved in making an approximate estimate of the PAW to the required depth. To do so, the following parameters need to be assessed for each depth of soil we are interested in.

a. the drained upper limit (DUL) of the soil
b. the crop wilting point (WP) of the soil and
c. the soil bulk density (BD)

Determining the drained upper limit

This is determined by taking a soil core in a soil that has been brought up to its DUL through prolonged wetting/flooding. The simplest way of doing this is to flood an area of soil and allow the free water to drain off over a period of time. In research trials sprinklers and drippers are sometimes used to achieve this flooding effect. In small plot trials in south-west Victoria, we use small metal rings of 40cm diameter that are driven into the ground, and the area within the ring is watered with a watering can until infiltration begins to slow down. This is done over two days and the rings are then covered and left overnight, to allow free drainage before the soil is sampled the next day at its DUL.

A steel coring tube of 35 to 50mm internal diameter is driven into the ground using the driver. If the tube is short, a few sideways movements will loosen the tube in the ground and it can be easily lifted out. When sampling deeper than 40cm, particularly when the subsoil is wet, a jack will be required to make the coring tubes easy to remove from the soil. Once the tube is out of the ground, a push rod (a simple wooden broom handle) will help to get the core into a cutting tray made of PVC tube. To account for the spatial variability that occurs within paddocks, it would be ideal to take a number of cores to make a representative sample.

The soil columns of all the cores from the paddock can then be separated into sections of suitable length, perhaps 100mm. The sections are then bulked together to form a representative sample of the soil at the different profile depths. These samples are then placed in marked paper bags and their fresh weight recorded. Once the fresh weight is recorded, the samples need to be oven dried at 105°C for 48 hours or until each sample reaches a constant weight, then weighed again. The difference between the two weights (wet weight – dry weight), divided by the dry weight is the ‘gravimetric’ water content (expressed as a %) for each sample at each of the depths (see Soil matters, 1998). The drying can also be done by a domestic microwave oven. This will be much faster but some calibration will be required depending on the power of the oven to determine the time required by samples to achieve a constant weight.
Determining the wilting point

The same procedure described above, taking cores and weighing and drying the depth sections, is used to determine the WP, but this is done at the end of the cropping cycle when the soil is expected to be fully depleted of PAW. Be aware that heavy storms often happen during summer and can immediately change the soil water status.

Determining the soil bulk density

The soil BD is determined for each depth using an intact core of known volume. Because of the shrink/swell nature of the heavy-clay basalts in south-west Victoria it is recommended, to ensure consistency of measurements, that sampling for BD is carried out when the soil is at its drained upper limit (see above). While the standard laboratory techniques for the determination of BD are generally laborious, a simple method would be to use the same coring tube and obtain the oven dry weight of a known volume of soil. Soil compaction within the tube can be avoided by appropriate design of the tube (Soil matters, 1998).

To be able to express the amount of water in the soil as a height of water (in millimetres) for a given height (or depth) of soil, the gravimetric water content (water content by weight) needs to be first converted to 'volumetric' (water content by volume) water content. This is done by multiplying the gravimetric value by the soil bulk density for that particular depth (see below for examples of the calculations). **Note:** At a soil bulk density of 1.0 g/cubic centimetre, 10% by weight of water in that soil sample will also translate to 10% by volume. However, as the soil gets more compacted within a given volume, 1.0 g of water will occupy a greater volume than one cubic centimetre.

The difference between the drained upper limit and WP is the PAWC and is expressed either as a percentage or simply as a height of water (in millimetres) per given height of soil. For example a PAWC of 30% by volume (volumetric) for a given 100mm section of soils would translate into 30mm of water per 100mm of soil. This enables us to directly add the rainfall into stored soil water in the profile and make calculations of PAW following rainfall.

PAWC of South-west Victoria soils

To show the further calculations in this process we have provided a table of data for three cropping soils in the south-west region of Victoria. This data was generated during six years of field trials in the region. Using this table of data as a guide, the PAW content in any soil, to a depth of 40-50cm, can be calculated approximately.

The grey and yellow Sodosols (heavy sodic clay soils) are the most representative of the cropping soils (about 80%) in south-west Victoria. Depending on the nature of your soil, the relevant data columns must be selected from the table for your calculations. Where a range of values are provided for soil BD, you may use the lower value if you are cropping on raised beds.

The first step is to calculate the gravimetric ($\theta_g$) water content using the wet and dry weight of the soil. This is then converted to volumetric water content ($\theta_v$) by multiplying $\theta_g$ by the soil bulk density for that depth. The difference between this value and the $\theta_v$ value at wilting point will give the PAW content in millimetres for that layer of soil.

| Table 2. The field capacity (DUL) and wilting point of some south-west Victoria soils |
Soil types

<table>
<thead>
<tr>
<th>Soil types</th>
<th>Black Vertosol (Heavy basaltic cracking clay)</th>
<th>Coastal Plains Sedimentary (Mottled brown, texture contrast / sodic subsoil)</th>
<th>Grey Sodosol (Heavy sodic/ erosive subsoil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil BD g/cm³</td>
<td>WP (θv) (%)</td>
<td>FC (θv) (%)</td>
<td>Soil BD g/cm³</td>
</tr>
<tr>
<td>Depth (cm)</td>
<td>0-10</td>
<td>11.0</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>10-20</td>
<td>14.0</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>20-30</td>
<td>17.0</td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>30-40</td>
<td>18.0</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>40-50</td>
<td>22.0</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Note: As a part of the process of assisting farmers use PAWC as a decision support tool and in crop forecasting, a state-wide program of modelling PAWC is currently being undertaken (Yield Prophet). PAWC data for different soils already characterised by Southern Farming Systems will be used in the Yield Prophet package and farmers will have access to them in due course.

Example calculation: Let us assume that the gravimetric water content (θg) value obtained for a soil sample in the 10-20cm depth in a Sodosol (Grey-brown sodic soil) Lismore was 25%. In order to find out the θv content of this sample we have to multiply this θg value by 1.5 which gives us a θv value of 37.5%. The approximate PAW content at that depth would be the difference between this value and the value of WP at this depth, which will be 12.5mm (ie. 37.5-25.0mm).

In Table 2 the θv value for WP has been calculated using the same soil BD value shown in the table. Once the values are all obtained for each of the layers of soil you are interested, the total of those values will provide you with an estimate of the amount of PAW (mm) in the soil.

Soil water deficit

In Table 2, we have also presented the values of FC (as an alternative to DUL) for each layer based on results generated from field trials. A frequent term that is used to define the soil water status of the soil at a given time is ‘soil water deficit’. This value for a given depth is the difference between the FC (or DUL) and the current soil water status determined by field assessment. Most cropping soils in south-west Victoria are volcanic in origin, high in clay content at depth and many of them have shrink-swell qualities, which means their soil BD changes with water content. The cracks in soil provide preferential pathways for water during rainfall events and often lead to non-uniform wetting of the soil. Therefore, depending on where you take your core sample in the field, the water content could be different. Some of these soils may never reach a uniform FC across the paddock no matter how much rainfall is received as water may leak below the root zone through cracks. Therefore the lab-determined FC values in the table are provided only as a guide.

Further reading:


For all other information, contact the Executive Officer, Southern Farming Systems, P O Box 916, Geelong 3220. Ph. (03) 5229 0566