Department of Pesticide Regulation
Environmental Monitoring Branch
1001 I Street, P.O. Box 4015
Sacramento, CA 95812-4015

Guideline to determine soil water content (moisture) at field capacity

Atac Tuli, Colin Brown, and Yvan Delgado

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Field studies and computer modeling approaches have both demonstrated soil water content (moisture) to be an important factor in limiting emissions of the fumigant 1,3-dichloropropene (1,3-D) following its application to agricultural fields. The California Department of Pesticide Regulation (DPR) has proposed that the pre-application soil moisture content should meet or exceed a threshold of 50% of *field capacity* when averaged over a 6 inch soil layer depth located 3 to 9 inches below the soil surface. Field capacity is defined as "the content of water, on a mass or volume basis, remaining in a soil 2 or 3 days after having been wetted with water and after free drainage is negligible" (Soil Science Society of America, 2008).

Field capacity will vary from field to field (and even within a field) due to variations in soil properties. It is not always necessary to measure field capacity to verify adequate soil moisture prior to fumigation. For example, DPR has recommended three methods by which the 50% field capacity target may be achieved, only one of which requires actual measurements of this soil characteristic. However, measurement of field capacity may be an option for growers desiring a quantitative way of describing their pre-fumigation soil conditions.

The following section outlines a simple procedure to estimate field capacity on-site. The field capacity can be categorized as one of the field properties and is a factor of soil texture, soil structure, and soil layering in the field. Soil preparation for fumigation, such as tilling and ripping of the hard pans in the soil, changes the soil profile structure and layering. Therefore, field capacity and soil moisture must be measured after the field is prepared for fumigation. For subsequent fumigations on the same field, the field capacity is expected to remain the same as long as the same field preparation methods are used. Field capacity only needs to be remeasured when organic matter is added to the field.

This guideline is prepared with specifications for the Acclima® Digital True TDR-315H Soil Moisture-Temperature - Bulk Electrical Conductivity (BEC) sensor. However, DPR does not endorse or promote any commercial product for this use and only describes the use of this sensor for demonstration purposes. If other sensors are used, their specifications must satisfy specific criteria listed in the following section.

Materials

1. 1 x electric drill with a drill bit size of 3/32 inch or smaller.
2. 6 x plastic 5-gallon buckets.
3. 25-30 gallons water.
4. 1 x trowel or a similar garden tool.
5. Duct tape.
6. Permanent marker.
7. Soil moisture sensor (soil moisture sensor must meet specific criteria listed in the following section).
8. 6 x plastic sheets or all-purpose/weather-resistant tarps measuring at least 4 feet by 4 feet.
9. Approximately 30 lbs (2.25 gallons) of playground sand (enough to form a 1 inch layer at the bottom of each bucket to slow the rate at which water leaves the bucket and infiltrates into the ground); OR, one and half inch thick sheets of sponge cut to conform to the inner diameter of the bottom of the plastic bucket.

Site-specific determination of field capacity

1. Divide the field into 6 approximately equal sections (Figure 1). The field capacity will be estimated for each of these sections and then a field average value will be determined, thereby accounting for variation within the field.

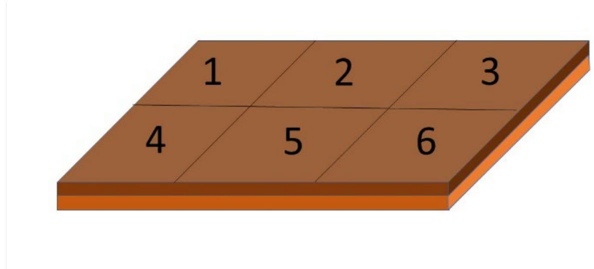

Figure 1. Dividing field into 6 approximately equal sections.

2. Using a drill and drill bit size of 3/32 inch or smaller, drill up to five holes at the bottom of 5-gallon buckets (Figure 2). To slow the speed at which water leaves the bucket and infiltrates into the soil, add 1 inch of playground sand to the bucket or prepare a circular sponge piece by cutting from the sheet of sponge foam into the inner diameter of the bottom of the bucket (Figure 2).

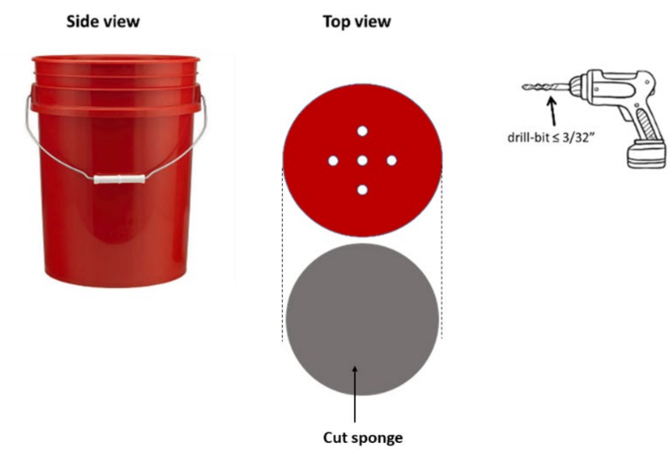

Figure 2. Making five holes at the bottom of the bucket with drill and drill bit and cutting a sponge the same diameter as the bottom of the bucket.

3. Trace the bottom diameter of the bucket onto the middle of the plastic sheet/ tarp (Figure 3a) with a permanent marker. Cut the sheet or tarp and attach the sheet/ tarp to the side wall of the bucket close to its bottom with a duct tape (Figure 3b).

(a) (b)

Figure 3. Attaching an all-purpose tarp (a) to the bottom of the bucket (b).

4. Place the circle-shaped pre-cut sheet sponge under each bucket and in each section of the field, place the bucket on the ground approximately in the middle of the section and cover the edge of the plastic sheet/tarp with soil to prevent water escape and evaporation. Fill the bucket with water. The water will gradually leak from the bucket through the sand or sheet sponge and infiltrate into the soil (Figure 4).

Figure 4. Covering the edge of the plastic sheet/tarp with soil and filling the bucket with water.

There should not be any runoff from the bucket. If runoff from underneath the bucket occurs, it indicates that the flow rate coming from the bucket is higher than the soil's infiltration rate. If any runoff is observed, prepare, and use another bucket with a reduced number of holes such that the flow rate from the bottom of the bucket is equal to or smaller than the infiltration rate of the soil. Fill the new bucket with water again. With time, water will flow from the bottom of the bucket into the soil and will re-distribute into the surrounding soil (Figure 5). It is recommended to leave a heavy (and small) object inside the bucket to add extra stability against wind.

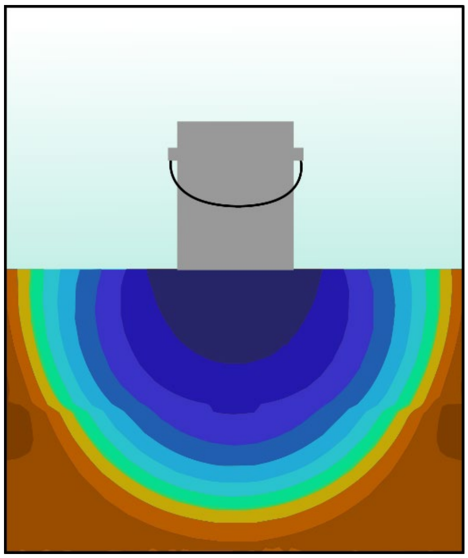

Figure 5. Water flows from the bottom of the bucket into the soil below. The soil under the bucket will be completely saturated (darkest blue) and water will re-distribute into the surrounding soil with time.

5. Leave the bucket and plastic sheet/tarp in place for an additional 48 hours (after all the water in the bucket has infiltrated into the soil, record the time and date) to allow for re-distribution of water within the soil profile and to minimize the evaporative loss (Figure 6).

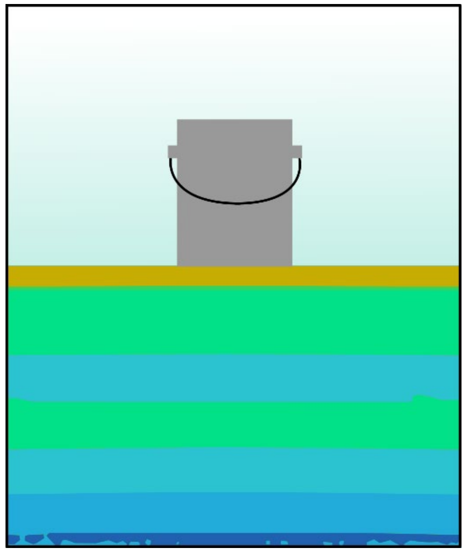

Figure 6. The bucket is kept in place (or plastic sheeting is weighted to the soil surface) for 48 hours. Water from the bucket has been re-distributed into the surrounding soil.

6. Remove the bucket and plastic sheet/tarp covering the soil surface. Using a trowel, remove the top 3 inches of soil from the wetted area (Figure 7).

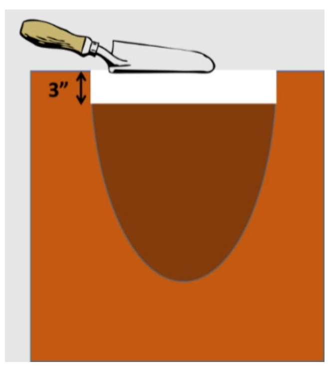

Figure 7. Removing the top 3-inch soil layer with a trowel.

7. Measure the soil moisture according to the procedure below at 5 different locations within this small, wetted area for each of the6 sites for a total of 30 measurements for the field (Figures 8a and 8b). Make sure to record each reading; you will need these later to calculate the field average value.
   7.1. The soil moisture sensor must measure the average moisture of a 6-inch soil layer, between a depth of 3 inches and 9 inches below the soil surface (Figure 8a).
   7.2. The measurement locations should be clustered toward the center (Figure 8b).

7.3. The soil moisture sensor must be inserted vertically and firmly into the ground avoiding any air gap between the soil and the probe.

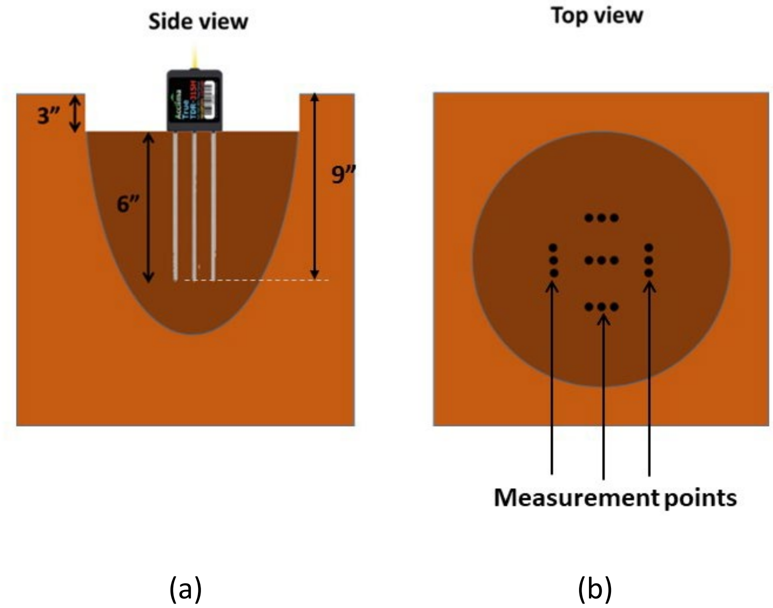

Figure 8. Measurement depths (a) and locations (b).

Since the field was divided into 6 sections, there should be a total of 30 (6 sections × 5 points per location) soil moisture readings. The average of these readings is an approximate representation of the soil moisture at field capacity for the soil layer between a depth of 3 and 9 inches below the soil surface.

Determining the percentage of field capacity

Once the soil moisture at field capacity is known, one can use the same soil moisture sensor/probe to measure the soil moisture (between a depth of 3 inches and 9 inches below the soil surface) at random locations (>10, but ideally 20) across the field (that is prepared for fumigation) and determine the average of field soil moisture. The percentage of field capacity can be calculated using the formula below:

Percentage of field capacity = (Average of field soil moisture/soil moisture at field capacity) x 100

Effect of soil heterogeneity

Spatial variation in soil properties at the field scale is a well-established fact. It is highly recommended that the number of locations and measurements suggested in the document are followed in order to include as much of this variation as feasible in the whole-field average.

Between 2020 and 2021, DPR conducted bucket experiments at seven locations to investigate the effect of soil heterogeneity on the estimated field capacity values at the time of 1,3-D applications. Figure 9 shows the variation of soil moisture (percentage of field capacity) across each of the 7 fields.

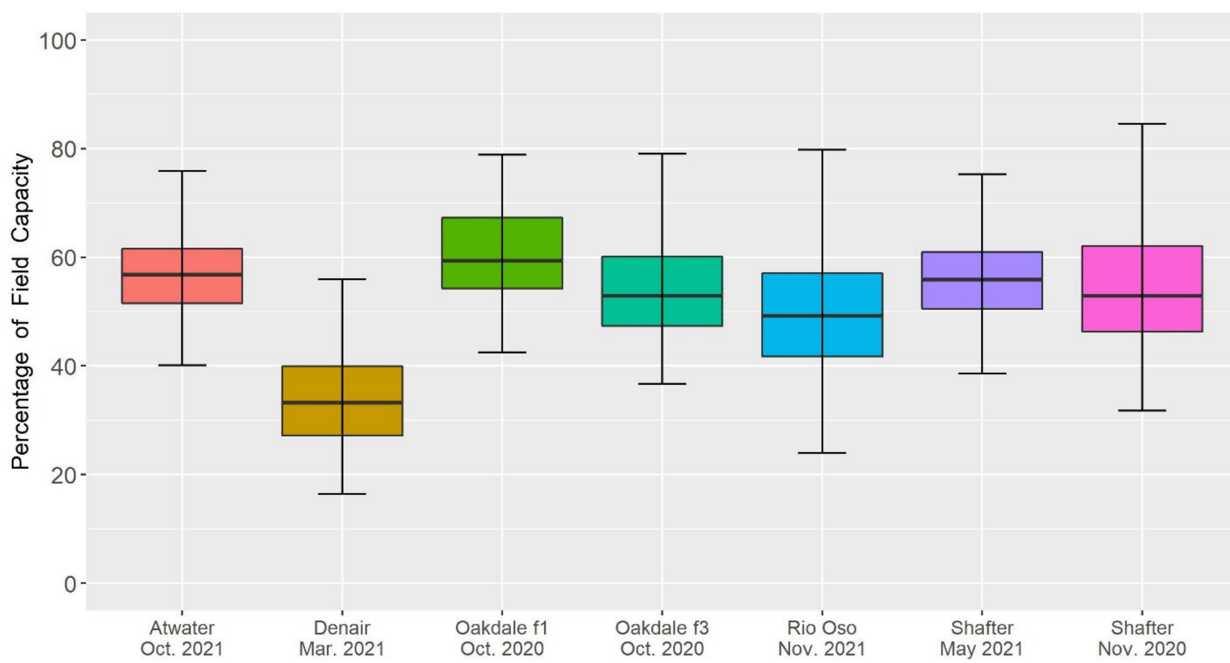

Figure 9. Soil moisture (percentages of field capacity) at the time of fumigation in the 1,3-D pilot study.

The 1,3-D pilot studies were conducted in Atwater (Atwater Oct.2021), Denair (Denair Mar.2021), at 2 locations in Oakdale (Oakdale f1 Oct.2020 and Oakdale f3 Oct.2020), Rio Oso (Rio Oso Nov.2021), at 2 different dates and locations in Shafter (Shafter Nov.2020 and Shafter May 2021) in California. The site IDs given below the *x*-axis in Figure 9 represent these studies. In Figure 9, the box in each site defines lower and upper quartiles (25^{th} and 75^{th} percentile, respectively), and the line in the center of the box represents the median of ratio percentages. The whiskers at the end of each box indicate the extreme (minimum and maximum) values within 1.5 box heights from bottom and top of the box. The box plot shows a considerable variation in measured soil moisture, confirming the existence of soil heterogeneity and the need for replicated measurements to determine a representative value for field soil moisture.

Criteria for soil sensor selection

Although this guideline presents and uses the Acclima® Digital True TDR-315H Soil Moisture-Temperature - Bulk Electrical Conductivity (BEC) sensor, other sensors available on the market can be used, but they should meet the specifications given below:

Features:

- Sensor head with 3 rods, 6 inch (or 15 cm) in length with stainless steel waveguide
- Operation based on a Time Domain Reflectometry (TDR) function in GHz range
- Waterproof housing for the sensor
- Easy and quick readout unit

Volumetric Water Content (VWC) measurement specifications:

Measurement range: 0 to 100 % VWC

Measurement resolution: 0.1 % VWC

Measurement accuracy: ± 1 percentage VWC points in coarse and medium texture soils; ± 2.5 percentage VWC points in fine-textured soils.

References

Soil Science Society of America. 2008. Glossary of Soil Science Terms. Madison, WI.