Plug testing: how, when, why?

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Preventing problems is the key to successful production of plugs. Test -- don't guess

Most pot production of greenhouse crops is like running in a 10,000 meter race - you don't want to make a mistake, but you have time to recover and regroup if you do not stumble too badly. Producing plugs is like running a 100 meter dash. You have to time your start exactly, reach your stride quickly, and maintain your form down the stretch. You can't afford to stumble, stub your toe, or even bump into something unexpected, or you will lose the race. Timing on plugs is critical. Any occurrence of cultural problems will cause unacceptable delays. Testing plugs PRIOR to problems occurring will head off costly delays.

OK, so testing is important. But what should I test, how do I do it, how often… The tests we will discuss here refer to on-site tests the grower can perform. The purpose of this testing is to give growers important information about the status of their crop so they can make any "in-flight" adjustments before the plants show symptoms. These tests fall into three categories: general operations, preplant, and post-plant tests.

General operations testing includes water quality and injector calibration. Preplant tests are substrate pH, soluble salts, and moisture content. Post-plant tests involve checking fertilizer delivery, and monitoring nutrients, pH, and soluble salts during the crop. All of these tests should be simple, and performed frequently to be useful to the grower.

Every greenhouse should be submitting water samples for complete chemical analysis at least annually. If your greenhouse has a history of alkalinity problems in the irrigation water, you should have an on-site test kit and should be testing your water source at regular intervals. For plug production, fertilizer and acid injectors should be *calibrated monthly*, more often when you suspect a problem. Remember, these devices are only as accurate as their last calibration. So if you have not calibrated an injector since you bought it , you're playing with fire.

Preplant testing of substrate pH and soluble salts should be done prior to tray filling, preferably one to two days before. For most growers a 2 : 1 (by volume) water : substrate test is the most convenient and reliable. If you are using a commercially prepared mix, this should be adequate, because the limestone used to adjust pH should have had time to initially react. If you are mixing your own substrate, you have additional concerns. Limestone may take two days to two weeks to fully adjust the pH. If you make your mix just before you fill the trays, the pH will be different than if you mix the substrate a few days ahead. This difference can affect the rate of germination and establishment of your plugs. You should know the rate of reaction time necessary for your mix to reach its final pH. The best way to do this is to establish a *liming curve* for your mix. The rate of reaction will change with changes in peat source and quality / type / particle size of the limestone used. (We will save this discussion for another article.)

In production pH and EC should be checked frequently. Frequency and locations to test will be discussed a little further in this article. Fertilizer delivery should be checked daily, or at least at every fertilization if done every second or third irrigation. This can be accomplished by simply capturing some of the fertilizer water in a glass, jar, or beaker and measuring the EC using an inexpensive EC pen (it is also a good idea to check pH while you are at it).

For the remainder of this article we would like to focus on procedures we have developed here at NCSU for testing moisture content prior to tray filling, quick tests for alkalinity and substrate analysis during production.

Moisture Content

Research by the Plug Research Group at NCSU has shown that air space in plug cells (a 288 tray) can be increased from the normal 2% to 7% when the moisture content of the mix is increased from 60% to 70%. Most growers will use mixes that have a 50 to 60% moisture content, but few people actually bother to measure; and most use the "feel" method to determine moisture content. Variability in moisture content of mixes prior to tray filling can account for variable or spotty performance of plugs in Stage 2 and early Stage 3, when air space is a limiting factor. Plug growers should stabilize the moisture content of their mix and strive to keep it uniform from batch to batch.

For plug production, it is important to determine water content of the mix and then adjust it to a preferred moisture level. Percent moisture content is defined as:

$$([IW - DW] \div IW) \times 100$$

where IW = initial weight of a known volume of substrate and DW = dry weight of that same volume of substrate.

To determine the moisture content of a substrate use the following step-by-step procedure: ❶ Fill three beakers half full with representative samples of a substrate. ❷ Weigh (and record as initial weight) the three samples and place in a drying oven for 24 hours at 225 °F (105 °C). ❸ Weigh again and record as dry weight. ❹ Average the three initial weights and dry weights separately. Calculate moisture content of the averages using the equation above.

The following chart shows the gallons of water present in a cubic yard of substrate at different percent moisture contents. Moisture content for plug mixes should be a minimum of 50% before tray filling. Our research here at NCSU shows a moisture content between 50 and 70% to be best for plugs. Below 50% air space is limiting, but increases dramatically with additional

moisture. Above 70% the mix becomes more difficult to handle and tray filling is cumbersome. Ideally, the mix should be pre-moistened and let stand over night. However, letting the mix equilibrate for one to two hours before use is still beneficial.

Water volumes present in one cubic yard of peat : vermiculite or peat : perlite plug mixes.*

Moisture** (% weight)	Water volume (gal/cu yd)
10	2
20	5
33	10
50	20
60	30
67	40
72	50
75	60

50 to 70% moisture content is best for plug substrates

* Calculations based on dry bulk density of 0.1 g/cc (6.25 lb/cu ft).
** Actual calculations based on mass wetness values of0.1, 0.25, 0.5, 1.0, 1.5, 2.0, 2.5, and 3.0 g/g, respectively.

Using the chart you can determine how much water to add to your mix depending on your situation. For example, if you are starting from dry baled peat and vermiculite or perlite straight from the bag, add 20 gallons per cubic yard of mix to get 50% moisture. If your peat is wet, determine moisture content and adjust it accordingly. If you test you mix and it is at 20% moisture, add 15 more gallons per cubic yard to bring it to 50%.

Alkalinity Testing

How often should alkalinity be tested? The alkalinity of a water source can change drastically with weather conditions and pumping fluctuations. We have measured alkalinity ranging from 2.8 meq/L to 5.4 meq/L in well water drawn from the same well in North Carolina during the course of one year! Municipal water in many locations is derived from different sources. Although municipalities try to maintain consistent output from water plants, it is possible to encounter alkalinity fluctuations from a municipal water source also.

Regular monitoring of alkalinity is essential if your water quality changes over time. For a plug producer, *weekly measurements* may be needed due to the rapid effects alkalinity can have on a plug substrate system, because of the small volume of substrate in each plug. Alkalinity effects on larger sized containers (larger substrate volumes) occur more slowly, and monthly testing may be sufficient to give growers enough knowledge to adjust for alkalinity fluctuations in the water source.

What type of test kit is appropriate? Water alkalinity is caused by the presence of carbonates, bicarbonates, hydroxides, and other dissolved salts. It is measured by titrating a water sample with an acid (usually dilute sulfuric acid) to an endpoint pH of about 4.6 (varies from 5.1 to 4.5 depending on the indicator dye used and the initial alkalinity). A pH indicator dye (usually bromcresol green plus methyl red) is added to a known volume of water, and acid is added until the solution changes color (with the bromocresol green plus methyl red dye system, the color will change from green to pink).

Most water sources acceptable for greenhouse use will have alkalinity in the range of 0 to 8 meq/L (0 to 400 ppm alkalinity expressed as $CaCO_3$). When looking for a test kit, this is the range that is needed. The level of accuracy does vary from kit to kit; ± 0.4 meq/L (20 ppm alkalinity expressed as $CaCO_3$) is accurate enough for most situations, but more precise kits are available. We have used Hach alkalinity kits #24443-01 (~$30 for 100 tests) and #20637-00 (~$155 for 100 tests) and are satisfied by both. Although the second model is more expensive, it does have twice the accuracy (± 0.2 meq/L) and also comes with a digital titrator that can be used to measure other parameters (using different titrants and indicators) such as water hardness, chlorine, iron, nitrite, and sulfite concentrations.

Nutrient Monitoring

In order to keep a grip on pH, EC, and nutritional status of plugs, growers to test these parameters very frequently. The Plug Research

Alkalinity is measured by adding an indicator dye to a sample, then titrating with an acid until the solution changes color.

The indicator dye in this kit turns from green to pink when all of the alkalinity has been neutralized (at pH ~4.6). The alkalinity of the solution equals the meq of acid required to reach the endpoint color change.

Group here at NCSU has developed a new procedure for extracting the soil solution from plugs we call the "Squeeze" method. The squeeze method provides a simpler, faster, and more representative method of sampling substrate for nutrient analysis than the saturated media extract (SME) or 2 water : 1 substrate methods. This method is fast because it is not necessary to dry the substrate as in the 2:1 method. The resulting solution may be used immediately for pH, EC, and specific nutrient determinations. The "Squeeze" is easy because once the plug is removed from the tray all that is necessary is to squeeze the solution from the substrate. It is more representative of the nutrient situation experienced by the root than the other two methods because no subjective step is involved in adding the correct amount of water during extraction.

When should you "Squeeze?" Squeeze extracts of plug substrate should be *taken only after a fertilization*. An irrigation with clear water would dilute the substrate solution yielding an entirely different result. Timing is very important. It is best to take the *sample one to two hours after fertilization.* At least one hour should pass after fertilizer application to allow it to come into equilibrium with the substrate solution. However, it is important not to wait too much longer after that hour since older seedlings can quickly deplete nutrients form the substrate. Four hours after fertilization is too long for older plug seedlings.

Where should you "Squeeze?" Be sure to *sample substrate from at least five plug trays*, each located in a different area of the crop to be tested. This provides you with an average of the whole crop. It would be best to set up testing trays in the five locations. The same trays could be tested on each sample date. The equivalent of at least one row of plants should be sampled on each date.

Do not mix species when sampling. As mentioned in the Plug pH Pandect article, bedding plant species have different nutrient and pH requirements. Our research also shows that species *change* the substrate pH over time, and the direction of the change (up or down) varies with species.

Regardless of extraction method you employ (squeeze, SME, or 2 : 1), you must sample species separately to accurately measure EC and pH for each. One goal of the NCSU Plug Research Group is to establish "sampling groups" of plug species (those that have similar pH requirements, similar nutrient requirements, and similar effects on substrate pH) so that growers only have to sample a few representative members of a sample group rather than sampling each and every species separately.

Collect plug samples from at least five plug trays, each located in a different area of the crop to be tested.

How often should you "Squeeze?" Since nutritional conditions within a plug seedling crop change rapidly, it is necessary to *sample weekly*. Once the substrate plugs are drawn from the tray they should be placed in a piece of cheesecloth and squeezed or twisted to force the solution out. Solution drawn from each tray is combined before analysis. Be sure to wear clean plastic gloves or wash your hands before handling the substrate to avoid contamination.

Combined plug samples are placed into cheesecloth, and the substrate is collected for analysis. Plastic gloves prevent solution contamination from your hands.

After the "Squeeze" then what? The solution you extract from the plugs can be analyzed in the same fashion as you would the extracts from 2 : 1 or saturated paste for pH, EC, or specific nutrients.

How do the values from the "Squeeze" compare to other methods? This is a new method and therefore the "meanings" of the test values are under development. We are using this extraction technique in all of our research because we think this method should be used for plug production. At the time this article went to press we have made the following observations: ❶ The pH values for the "squeeze" seem to be the same as when measured with the 2 : 1 and SME systems. ❷ Squeeze EC values are closer to those of SME than the 2 : 1 extraction system. Current guidelines show an EC range of 0.75 to 2.0 mmho/cm for plugs. ❸ "Squeeze" solutions can be used for specific nutrient determinations using equipment such as the CardiMeters for nitrate, etc, with values close to those from SME. However, we do not have enough data to recommend sending "squeeze" extracts to commercial labs for nutrient analysis. We will address this issue at the Plug Symposium at Grower Expo in January.

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