Managing root zone temperature

WP06

Introduction

Farmers, growers, cultivators all understand that water is a vital element in producing their crop. Regardless of plant, person, or production method, ensuring and maintaining high quality water is critical to producing consistently high-quality plants. Hydroponic plant production employs a spectrum of methods from container substrates (i.e. coco coir) to air (aeroponics), but the common denominator is that all of the required nutrients for plant growth and development come from an enriched water nutrient solution. Furthermore, hydroponic growers must closely monitor the water (nutrient solution) used during production as there is not the buffering capacity of a soil or container matrix.

Most often, hydroponic and container growers monitor the pH and EC to judge the capacity of the nutrient solution to support healthy plant growth and meet their goals; EC as a means to estimate total fertility and pH to manage nutrient availability. Though this is an essential practice, it is not enough to ensure healthy root growth and productive plants in hydroponics. Oxygen, temperature, and microorganisms all influence the health of the root and need to be considered when managing the hydroponic nutrient solution.

In-house monitoring of pH and EC as well as comprehensive analysis of the irrigation water was discussed in the ÆssenseGrows cultivation guide, *How to Test & Evaluate Water Quality.* Through that guide, the importance of regular monitoring of solution pH and EC was highlighted to ensure quality. This could be achieved with hand-held sensors, but a more integrated approach of real-time sensors as are present in the Ætrium system, is preferred. Like pH and EC, temperature too can be a relatively easy property to monitor and control with the right equipment in place. Temperature is often overlooked but is an essential property that can have both direct and indirect effects on plant growth and other components of the nutrient solution.

Temperature effect on plants

Temperature directly influences the metabolic processes of the plants and thus the rate of plant growth. This is true for both the air temperature as well as the temperature of the water. In general, as temperature increases, those metabolic processes increase as well. Above and below optimal ranges those processes slow or stop altogether, inducing plant stress and reducing overall rate of growth. Cornell researchers[1] found that nutrient solution temperature had a greater effect on productivity than air temperature. Specifically, lettuce production could maintain consistent and maximum yields at varying air temperature as long as the temperature of the nutrient solution remained optimal. Additionally, high and low temperatures of the nutrient solution can impact the membrane integrity of the roots[2] and can therefore affect the functions of the roots, resulting in lower nutrient uptake. In indoor hydroponic cultivation, growers are more often concerned with high root zone temperature, but during the winter months in northern climates low root zone temperatures can occur. These can result in slow growth and reduced leaf number, leaf length, and total biomass[5].

What else does temperature influence?

In addition to the direct effects, the temperature of the nutrient solution also has various indirect effects on plant health. In water, there is an inverse relationship between temperature and solubility of oxygen (fig. 1). As the temperature of water increases, the solubility of oxygen decreases[3]. So, the warmer the nutrient solution, the less dissolved oxygen there will naturally be. Plants need oxygen for respiration, the process in which carbohydrates from photosynthesis are converted into energy for growth and development. Plants produce oxygen as a by-product of photosynthesis which can in turn be used during respiration. This is possible across the plant except for parts of the plants that photosynthesis does not occur, like the roots. Respiration still occurs in these not-photosynthetic tissues, and to facilitate that reaction, oxygen must be absorbed from the environment in order for those parts to grow and survive. Therefore, it is essential that the root zone, whether in hydroponics or a container, have ample oxygen to support active root growth. When temperature increases, the amount of oxygen decreases and respiration and root growth could be limited. Though oxygen availability is typically not a problem in aeroponics, where the plant roots are just periodically misted with the nutrient solution, it is of greater concern in DWC (Deep Water Culture), where the roots are always submerged in water. Additionally, low dissolved oxygen levels have been associated with an increase in the infection of Pythium root rot (fig. 2). The development of Pythium in the nutrient solution is further enhanced by extreme temperatures, lower temperatures favoring establishment of *P. dissotocum* and higher temperatures favoring the development of *P. aphanidermatum*[4]. A reduction of growth or membrane integrity as a result of suboptimal root zone temperature can further increase the susceptibility to Pythium infection.

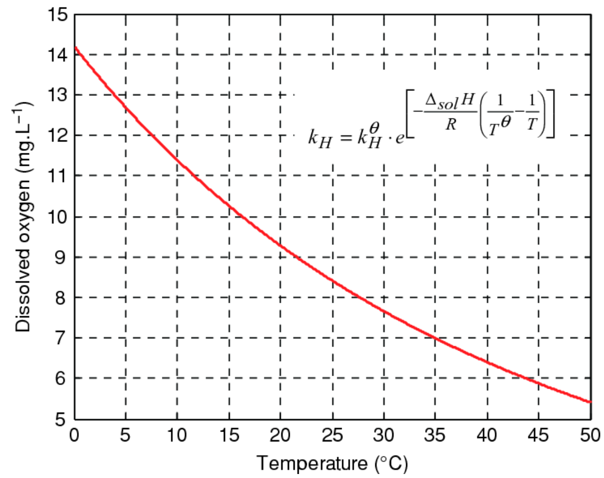

Fig. 1: Effect of temperature on oxygen solubility in water under standard pressure[5].

Fig. 2: Pythium root rot (www.growell.co.uk)

Temperature also affects the solubility of fertilizers in the nutrient solution. The fertilizer solubility value is the saturation point at which a fertilizer can be dissolved in water before precipitating out. Typically, an increase in temperature will increase the solubility of a fertilizer.

Optimal range

Fig. 3: Handheld temperature sensor.

Each species of plant will have a minimum, optimum, and maximum temperature for growth. For instance, the optimal temperature for lettuce was determined[1] to be 24° C (~75° F) independent of air temperature, but adverse effects occurred at 31° C (~88° F). Consistent yields could be maintained at varying air temperature as long as the temperature of the nutrient solution remained optimal. Though a given temperature may be optimum for growth, we need to consider the other impacts of temperature, especially in regard to pathogen (Pythium) development. If the optimum temperature is not known for the crop grown, it is best to maintain target root zone temperature of 20-24°C (68-75° F)[4]. This temperature range provides a range for active and healthy root growth but does not favor Pythium development.

Maintaining root zone temperature

Most importantly, the temperature of the nutrient solution should be continuously monitored. Periodic samples can be measured with a handheld thermometer but do not provide continuous tracking and information about 'off-hours' conditions (i.e. at night when the sun is down, or lights are off and the air temperature decreases). Utilization of data loggers can provide contiguous tracking of temperature, and in some cases real-time and remote feedback may be available. The AEtrium system integrates sensors into the reservoir to provide real-time and contiguous tracking of temperature, EC, and pH of the nutrient solution (fig. 4).

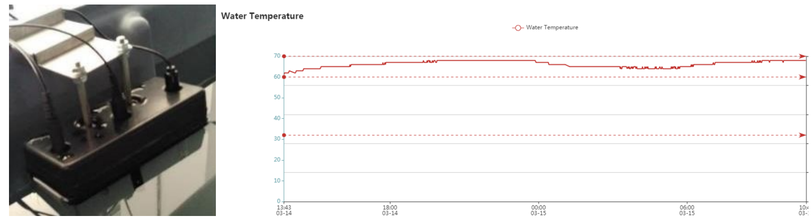

Fig. 4: Ætrium system sensor suite in nutrient solution reservoir (l) and real-time sensor data report in the Guardian Grow Manager software (r).

As mentioned above, in most cases greenhouse growers or indoor cultivators need to remove heat from their nutrient solution reservoir (or cool) to maintain healthy conditions. In order to do so a mechanical chiller or a stainless-steel loop of chilled liquid can be used to remove heat from the solution. Mechanical chillers have integrated thermostats to maintain a given temperature, but by nature of design are inefficient as they remove heat from the reservoir and discharged in the air. Chilling coils are often a more efficient method of controlling temperature with integrated control (fig. 5). The Ætrium system's unique integration of sensors and software can allow for real-time monitoring of nutrient solution temperature and can control chilling to maintain a target temperature to support healthy plant growth.

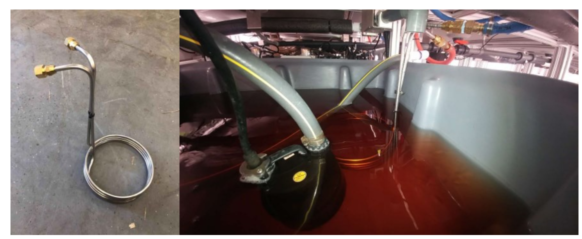

Fig. 5: Stainless steal cooling coil (l) is integrated in Ætrium 4 reservoir (r).

During the winter months of northern climates, nutrient solution temperatures can drop below what is optimal for healthy plant growth. If this occurs, the nutrient solution reservoir should be insulated and separated from the concrete floor. If fresh irrigation water piped into the production space is too cold, it may be best to have a holding tank indoors to allow the temperature to rise to ambient temperature or to preheat if needed.

Conclusion

Though air temperature often dominates management decisions compared to water temperature, it is critical to monitor the irrigation water and especially the nutrient solution of a hydroponic production system. Temperature is a vital component in creating a healthy root zone and has clear direct and indirect effects on plant growth and development. It is important to determine a proper target temperature to allow for healthy plant growth, but limit pathogen development. Managing temperature, EC, pH, oxygen, and microorganisms will provide a wholistic approach to root health and plant quality.

References

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