ROOTS
Sustainable Agricultural Technologies Ltd.

Cooling the Roots Zone: Benefits of Using the ROOTS Root zone Cooling System

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Abstract

The heavy heat that prevails during the summer greatly affects the ability to grow plants in all kinds in greenhouse structures. Due to the impact of ongoing global warming, greenhouses designed to provide relative warmth during the winter, becomes an especially hot environment during hot seasons. In addition to the effect of very hot air temperatures in the greenhouse, the consequence of excessively hot roots became apparent in recent years.

In the past, most agricultural cultivation was planted in the ground, but today more and more growers are switching to substrate farming (grow-bags and pots). When farmers disconnect growth from the soil, they prevent the insulation of the root from the soil and create a root environment that is largely impacted by the ambient temperature. This creates an additional problem on top of the aforementioned increasing greenhouse heat issues during the summer, leading to a critical heat problem for crops and wilting.

There are several methods to provide cooling in greenhouses, but most of them are relatively inefficient, with large capital and operating requirements and severe environmental impact. In this document, we will review the outcomes of cooling a plant's root zone and the impact of instituting the Roots Sustainable Agriculture LTD System. In addition, we will examine the level of influence of greenhouse air control systems compared to traditional systems for cooling the root zone.

Cooling and Heating Roots: Literature Review

Root cooling outcomes on different crops were examined in order to conclude that the temperature-controlled root zone has a positive effect on plant species even in un-ideal ambient temperatures for growth (Stoltzfus et al., 1998; Lahti et al., 2005; Solfjeld & Johnsen, 2006). In 1989, researchers in Japan (Sasaki and Tositaka) performed an experiment with roots zone temperature controls at three cooling levels (20°C, 24°C, and 28°C), with a control temperature of 30°C-35°C. The results were yield improvement in cucumbers and tomatoes and no significant improvement in melons, where in the cucumber with the 28°C treatment provided the best yield improvement. Overall, the tomatoes (Figure 1) showed the highest yield improvement among the three crops tested.

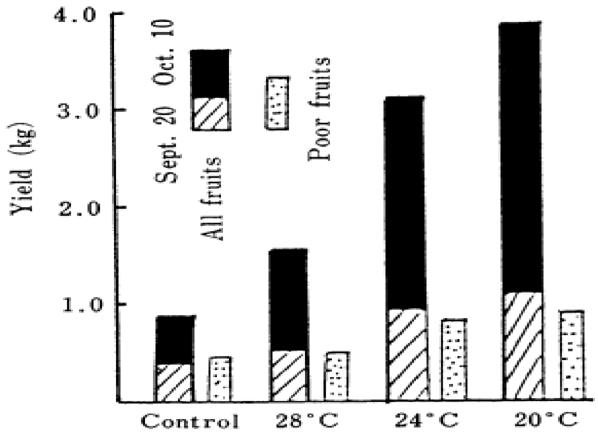

Fig. 3 Yield of tomato.
Fruit weight per one plant.

Figure 1: From Sasaki's research, tomato yield in the different cold root zone treatments represent the increased yield when cooling the root zone.

In 2006, Moon and his colleagues conducted a study on the effect of cooling the root zone in a perlite substrate by placing pipe extensions 15 cm deep under cucumber seedlings. The researchers kept the temperature 6°C below the control temperature in the root zone. Throughout the study, the control group lost crop weight, while the treated plants increased yield despite exposing the plants to high ambient air temperatures. The results of the study were statistically significant, with a positive effect on yield for the plants that received the roots zone cooling treatment.

In 2019, Al-Rawahy and his colleagues examined how cooling the root system impacts nutrient absorption in cucumbers. The experiment was conducted at three controlled temperatures (22°C, 25°C, and 28°C) and a control group (33°C on average). The researchers tested a variety of criteria including vegetation, yield, chlorophyll, and more. The study was carried out over two consecutive summer seasons.

Although the cold treatment did not impact the chlorophyll levels in the plant and almost no differences were recorded in the tested nutrient levels, it clearly showed how growth improves in terms of leaf size, plant height and in the overall yield. All the treatments showed an improvement in yield compared to the control in both seasons (Figure 2).

Table 2. Effect of RZT on Fruit number/m^2 and yield (t/gh) of cucumber grown in hydroponics, closed system during summer (June-August) in cooled greenhouse

RZT (ºC)	Fruit number/m^2		Yield (t/gh)	
	First year 2016/2017	Second year 2017/2018	First year 2016/2017	Second year 2017/2018
22	180 a	220 a	5.0 a	6.1 a
25	167 a	221 a	4.4 a	6.0 a
28	178 a	143 b	4.7 a	3.8 b
33	101 b	133 b	2.8 b	3.5 b

Figure 2: Table from Al-Rawahy's study, the results of the number of fruits and the yield per area. Both parameters are superior when a regulated temperature was provided to the root zone compared to the control.

Table 1:

The list of study cases of using the ROOTS System in cooling with variety of crops.

Crop	Facility	Yield increase	Comments
Cannabis	Greenhouses	64%	Multiple positive effects
NFT crops	Hydroponic	30%	Adding several cycles per year
Cucumbers	Greenhouse, in soil	25%	
Cherry Tomatoes	Greenhouse, in soil	20%	
Tomatoes	Net house, in soil	30%	Midsummer planting. First post-summer harvest
Lettuce	Net house, in soil	45%	

Performance of the ROOTS Root Heating and Cooling System vs. Air Cooling Systems in Greenhouses

The standard methods for cooling a greenhouse in Israel are a misting/fogging system, ventilation and cooling pads. These three cooling configurations cool the greenhouse's ambient air by adding moisture and movement to the air to create a "sweating" effect on the plant. In this paper, we will not address the significance of adding moisture to the air as it pertains to encouraging the appearance of diseases and pests in a crop. However, when using these standard methods, one must take into consideration the extra financial costs associated with preventative measures required to avoid diseases and pests. In addition, when using misting/fogging and cooling pad methods when calculating the cost of energy consumption for these systems the price of water and use of energy in pumps are usually not considered.

The ROOTS Sustainable Agriculture Technologies Systems operates as a closed-loop water system using a heat pump and a circulation pump. The system is monitored by a cloud-based app control. In Israel, the need for agricultural cooling lasts for 5 months, from May to September, although in recent years the high heat extends to late October. With global warming, this situation will likely only get worse.

Unlike greenhouse ambient air cooling, a system for cooling the roots zone of plants can maintain a temperature at a constant range throughout the day (Figure 3). The ROOTS system is less impacted by ambient temperatures because it operates in an insulated environment that creates a "bank" of cold or heat in the substrate and within the system itself. This operation enables a high level of precision in which each growth can receive its ideal target temperature.

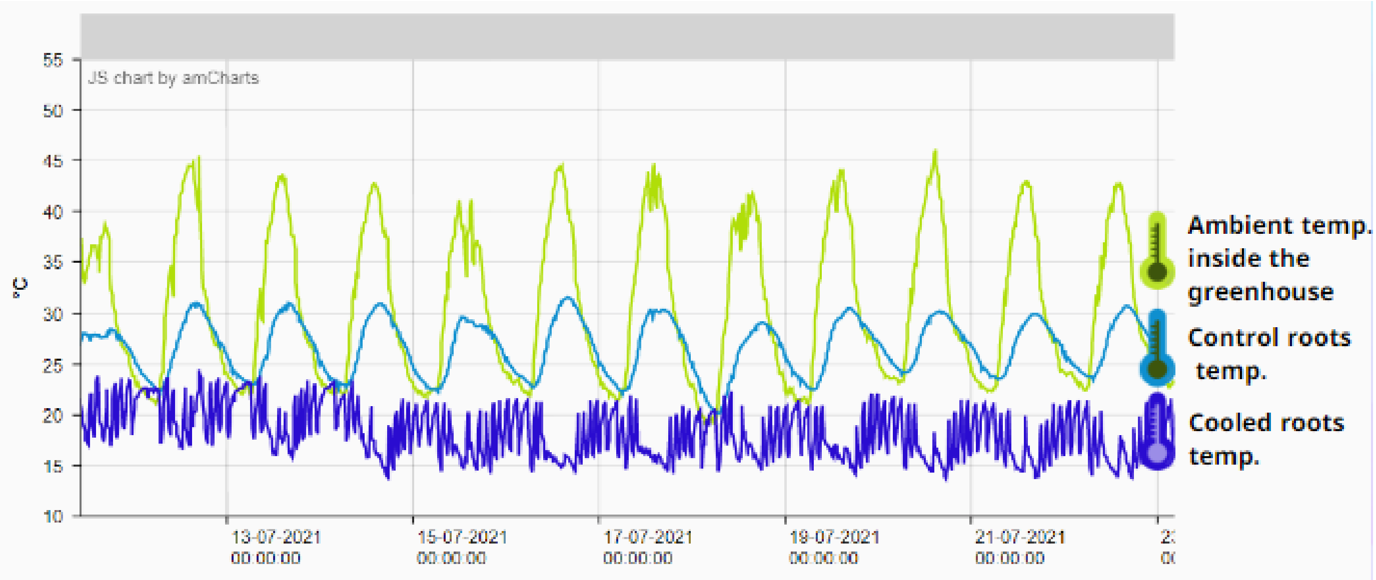

Figure 3: Temperature amplitude in the summer in a fully controlled greenhouse with a system of cold pads, ventilation, and thermal screens for growing medical cannabis in the central Israel.

The graph (Figure 3) represents roots zone temperature cooling with the ROOTS system (below), roots zone temperature without a system (middle graph), and ambient air temperature in the greenhouse (upper graph). The controlled roots temperature is maintained at a narrow optimal range while the ambient temperature, as well as the substrate in the control, moves up and down according to temperature changes during the day. Also, although air climate control systems are installed in this advanced greenhouse, the air temperatures are very high during the day as are the un-cooled roots zone.

Case study: Energy Cost with Roots System in a Hydroponic Nutrient Film Technique (NFT) System, Kfar Hess, Central Israel

The hydroponic NFT, in Kfar Hess village, is a 13,000-square feet greenhouse with 170 ft^3 of water in the system at any given moment**.** A total of 7038 kWh was consumed during the summer months (Figure 4) when 45% of the consumption was done during the peak hours (Israeli peak rate). The system operated for an average of 12.5 hours per day continuously and stopped at night when the roots zone fluid achieved and maintained the target temperature. During an average day, 113 kWh was consumed, at an average price of 25 USD per day. The price of electricity (according to IEC data) for July 2021 was 771 USD, and for August 2021 it was 816 USD, totaling 1,588 USD for two months.

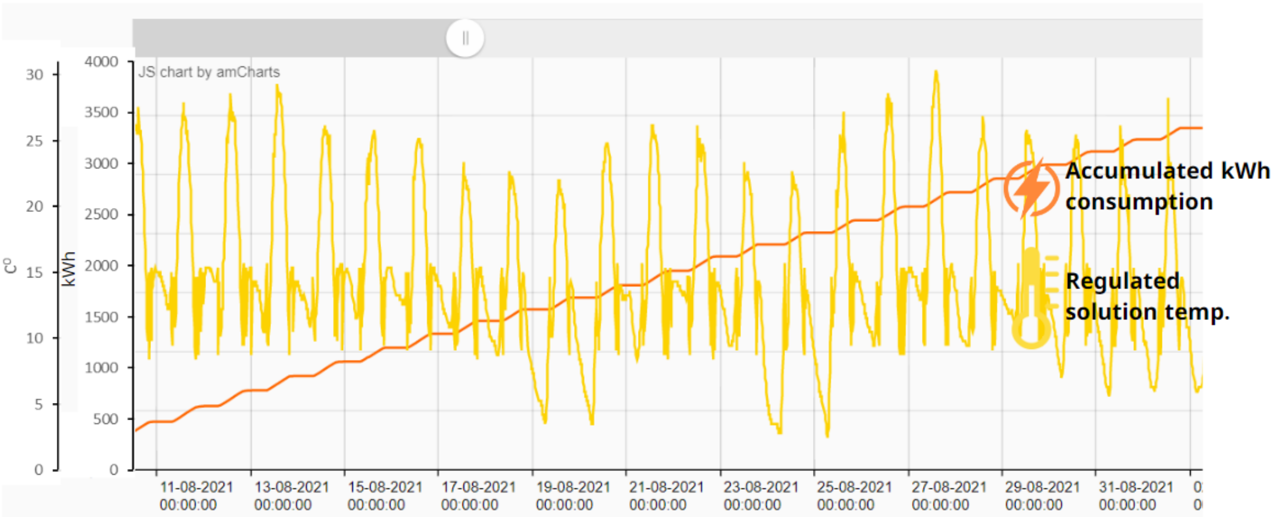

Figure 4: Temperature amplitude and kWh accumulation in a Hydroponic NFT System, Kfar Hess, Central Israel, mid to end of August 2021, with the ROOTS system. The temperature was kept under 30 degrees Celsius in the hydroponic solution. KWh axis accumulation baseline is 480 kWh.

Summary

The ROOTS cooling system provides precise agriculture that operates as needed using advanced technology. In addition, the grower can precisely direct the temperature required for the specific growth compared to air cooling methods which depend, to a large extent, on ambient temperature and local humidity levels. Further, the ROOTS system can be used all year round in the Mediterranean climate, without additional air control systems required, even for winter heating.

Temperature control in the root zone has been scientifically proven in several crops. Its effectiveness is not only in the ability to grow in the heat of summer but to improve the quantity and quality of the crop in addition to production security. ROOTS's system can achieve that feat while helping to avoid diseases resulting from the use of air cooling equipment that adds humidity to an already humid environment. From an energy point of view, there is a significant difference between air cooling systems and roots cooling systems in Hydroponic greenhouses, with a significant advantage for the ROOTS's system. ROOTS systems can provide a unique, energy-saving climate control without wasting water or energy or adding humidity in the greenhouse, and it's an excellent technological solution that provides security and increased yield during summer months.

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