MAXIMIZING GROWTH OF BELL PEPPER PLANTS BY OPTIMIZING CLIMATE CONDITIONS THROUGH INFRARED TEMPERATURE SOLUTIONS

The internet of agricultural things (IoAT) has revolutionary potential called The Third Green Revolution. A smart web of sensors, cameras, robots, drones and other connected devices allows for an unprecedented level of control and automated decision-making. The goal is more than ambitious: to make precision farming a reality and to take a vital step towards a more sustainable food production outcome using precise and resource-efficient approaches. Objective is that smart farming will finally realize the goal of feeding a fast-growing population (9.6 billion by 2050) in a sustainable and efficient manner.

Plant Lighting, based in Bunnik the Netherlands, provides innovations in protected crop cultivation by translating scientific knowledge into practical uses. It provides research and consultancy on crop yield optimization, photosynthesis, plant responses to light, light sources and phenotyping methods. They started a study on measuring the optimizing effect of the right light spectrum and daylength of bell pepper plants. The test was conducted in a field in Plant Lighting's test lab of 7 by 3.5 meters for over four months. The preliminary results have been very promising as infrared temperature sensing allows for optimized plant health monitoring (i.a. stomatal behaviour), showcasing an increased yield. The final results are expected to be released by Q4 of 2021.

Some background about stomata

Stomate are pores found in leaves or stems of plants, that can open or close to control the rate of gas exchange. They play a leading role in transpiration and cooling on the one hand and absorption of CO2 for photosynthesis on the other. When the plant temperature increases with rising radiation or increasing ambient temperature, stomata can open to evaporate (transpire) moisture and cool the plant (like humans perspire). A healthy plant under normal thermal conditions can maintain its body temperature by opening and closing its stomata. However, under strenuous conditions, a plant could simply get in trouble. It will then keep its stomate closed to retain water which then results in overheating of the plant and precluding CO2 uptake. A hampered CO2 uptake results in reduced photosynthesis, and thus reduced plant and fruit growth.

Vapor Pressure Deficit

One of the key parameters in measuring crop health, or, how well a plant can adapt to changing environmental conditions, is the Vapor Pressure Deficit (VPD). VPD is the difference (deficit) between the amount of moisture in the air and the saturated amount of moisture in a leaf given its temperature. In ecology, this expression is closely related to the Vapor deficit (VD), which is the difference between the actual water vapor pressure and the saturation water vapor pressure at a particular temperature. For VD only the RH and the air temperature have to be measured, but for VPD also the plant temperature has to be taken into account. For example, if a greenhouse warms up and

the relative humidity drops (as warm air can contain more moisture), the VDP value as a result will rise as the difference between vapor pressure in the plant and in the greenhouse increases. This triggers the plan to start evaporating moisture resulting in a lower vapor pressure in the plant due to a lower leaf temperature and a higher vapor pressure in the greenhouse. What you then will find is a decreased VPD.

This parameter is of paramount importance to measure because at low values, the plant can't evaporate because of the high humidity. At high values of , a plant evaporates more moisture than it can replenish. To protect itself from dehydration, it will then close it stomata. This inhibits the photosynthesis as the plant can't take up CO2.

So to calculate the VPD, the ambient (greenhouse) air temperature, the relative humidity and the canopy or leaf temperature must be measured. When, based on these variables, the VPD is determined, the grower can influence the VPD by simply adjusting the temperature in the greenhouse (heating or cooling) and/or by adjusting the humidity (irrigation/nebulization). This action will assure that the VPD is within the desired range for optimal plant conditions, on the one side preventing overheating which is a sign of water stress, and on the other side wet beating of the plants and so reducing the risk of fungal growth in the crop. The best advantage is optimal growth and yield with less energy consumption.

Pastoor Clercxstraat 26
5465 RH Veghel
The Netherlands
+31 (0)413 376 599
www.cleverir.com
info@cleverir.com

How to influence the cooling capacity of leaves of bell pepper plants via temperature?
Temperature affects the speed at which a plant develops, however not the ambient temperature within the greenhouse but the plant temperature is the primary regulator. The latter can be as much as 4°C lower to 6°C higher than the air temperature. If you only measure the air temperature, you have no insight into this temperature difference, so you cannot respond to it properly. Moreover you don't know what the VPD is.

We already mentioned that VPD influences how much water it transpires and how far the stomates open. In the last way how much CO_2 the plant absorbs as well. This is a short-term effect. There are also long-term effects: A decrease in plant water status usually gives smaller leaves and smaller stomates. But also the other way around counts! Leaves with more or bigger stomates can result in better crop cooling, a reduced dependence on the VPD and ultimately in a higher yield.

Survey and goal Plant Lighting
Plant Lighting aims to monitor and control the bell pepper plant conditions to optimize yield under a variety of conditions and at the same time, develop models and best practice measuring tools for greenhouses to monitor crops. For this they needed an infrared temperature sensor that is able to measure the temperature conditions in a very precise and reliable manner in order to optimize VPD, monitor stomatal behaviour and last but not least optimize absorption of CO_2.

Exergen Global AutoSmart AGRI Infrared Sensor Solution
Efforts have been made to measure leaf temperature with contact probes. This resulted in unreliable measurements. The main reasons are: 1) First of all, leaves change position frequently during the day. It is very challenging to ensure proper mounting of a contact sensor on a (moving) leaf. Any form of additive used to fix the contact sensor will undoubtedly influence the leaf physiology and temperature reading. 2) contact probes only measure the very small spot where they are mounted. In leaves it is known that temperature can vary locally, depending on specific phenotypical features: the structure of a leaf is not uniform. As a result, the leaf temperature can vary, depending on the particular spot that is measured. This makes spot temperature measurements unreliable for data acquisition. It is essential to get the average temperature of a leaf, not any spot temperature.

Non-contact infrared sensors are the sensor of choice for leaf temperature measurements. Exergen's non-contact temperature sensors are very suitable to measure leaf or crop temperature. They are unpowered devices that don't drift and don't need recalibration. They have an unparalleled resolution and repeatability.

The AutoSmart AGRI that Plant Lighting used in their research is especially calibrated for measuring leaf temperature. The AGRI solution comes with a flexible gooseneck for easy sensor positioning towards the leaf, even if they move during the day. It also includes a Teflon housing for protection and stability and a clamp for mounting. Moreover, the AGRI sensor measures the average temperature of a particular area, not just a small spot on a leaf. Last requirement was that the sensor needed to be extremely accurate as the VPD calculations depend on delta T (difference between leaf and ambient temperature). Delta T variations of simply tenths of degrees have already major consequences for VPD calculations. The AGRI solutions come with a resolution of 0,1°C so is ideally suited to measure minuscule yet significant temperature changes in leaves

Conclusion: temperature of leaves is BEST measured by Exergen's AutoSmart AGRI sensor