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Growing maize using LED lighting

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Growing maize all-the-year in the greenhouse requires supplemental lighting. Due to the high light requirement of maize for adequate growth and yield, high intensity discharge (HID) lamps (high pressure sodium vapor and/or metal halide lamps) are commonly used. The drawback of these lamps is the generation of high levels of heat mainly caused by infrared light. This makes it difficult to maintain constant temperature profiles, especially in summer and is a cause of heat stress occurring during pollen development. The vast amount of heat produced by these lamps may not only be problematic for the plants it also is a waste of energy and causing unnecessary CO_2 emissions and energy costs. An alternative to HID lamps are light emitting diode (LED)-based lighting systems. It has been shown that current LED lighting systems used for greenhouse illumination can cut energy costs by around 40 %.

We wanted to investigate whether LED lighting is suitable and eventually superior to sustain the proper growth and development of maize in growth rooms and whether it is possible to use it as supplemental greenhouse lighting for maize.

In a growth chamber 288 red LEDs and 144 blue LEDs (type “Golden Dragon Plus”: Hyper Red, 660 nm and Deep Blue, 450 nm, Osram Opto Semiconductors, Regensburg, Germany) were mounted at the ceiling at a height of 2.45 m on an area of 4 m^2. The overall power mounted per square meter was 205 W. In a control chamber with HID illumination metal halide lamps (Philips HPI-T Plus, 400W) and high-pressure sodium vapor lamps (Philips SON-T Agro, 400W) were installed alternating and at a total power of 523 W per square meter. The respective spectra emitted from each type of lighting are shown in Figure 1. Both rooms were run at long day conditions (16 h light, 8 h dark) and were set to 25°C at day and night. In each chamber we grew six plants of the maize inbred line H99 from germination to maturity. The photosynthetic active radiation in both rooms is given in Table 1 and was found to be 1.35 times higher in the HID chamber compared to the LED chamber. As therefore expected, the apparent photosynthesis rate was higher (1.5 times) in the HID chamber. The HID plants were slightly taller (1.18 times) and produced slightly more above ground dry matter (1.12 times). Nevertheless, developmental aspects, like number of leaves or flowering time were unaltered (Table 1). As shown in Figure 2 and Figure 3 the growth characteristics of the plants from both growth chambers are very similar. Nevertheless we found strongly reduced root growth in 4 week-old plants from the LED growth room (Figure 4). However, adult plants of the HID and LED growth chambers had a similar root penetration of the soil (data not shown). The lower photosynthesis rate of plants under LED illumination compared to HID illuminated plants is very likely responsible for the slight reduction in growth performance (height, biomass) and is a result of reduced light intensity. We therefore assume that the reduced growth performance may vanish or change into better performance under optimized light intensities and may play a minor or no role in a greenhouse, where lighting is only supplemental. Therefore we conclude that a LED-based lighting system can be a very suitable means to support the growth of maize plants in a greenhouse, without the risk of overheating the greenhouse, better pollen performance and with reduced energy costs. The LED lighting did not change developmental aspects of the maize inbred line H99. However, from these initial experiments we cannot conclude that other inbred lines will perform similar. Therefore we plan to test other maize inbred lines under the same and optimized conditions involving the usage of LEDs of different wavelengths.

Table 1. Photosynthetic active radiation (PAR) in LED and HID growth chambers, respectively, and phenotypical aspects with respect to apparent photosynthesis rate, number of leaves, flowering time, plant height and above-ground dry matter (biomass).

	PAR* (µmol m^{-2} s^{-1})	Photosynthesis** (µmol CO_2 m^{-2} s^{-1})	Number of leaves	Flowering time (days to silking)	Plant height (cm)	Biomass (g)
LED	212	10.04 ± 0.06	16.5 ± 0.5	58.3 ± 3.4	115 ± 5.7	79.2 ± 10.7
HID	287	15.16 ± 0,46	16.5 ± 0.5	56.3 ± 2.9	129 ± 8.8	93.3 ± 20.6

* Photosynthetic active radiation (PAR) at the height of 1 m; ** Apparent photosynthesis rate at the uppermost expanded leaf, measured 50 days after germination around noon time with the porometer LC*pro*+ (ADC Bioscientific Ltd., Great Amwell, UK). Since HID illuminated plants were on average 12 cm taller at the time of measurement, PAR intensity was up to 1.7 times bigger at the leaf surface of HID illuminated plants.

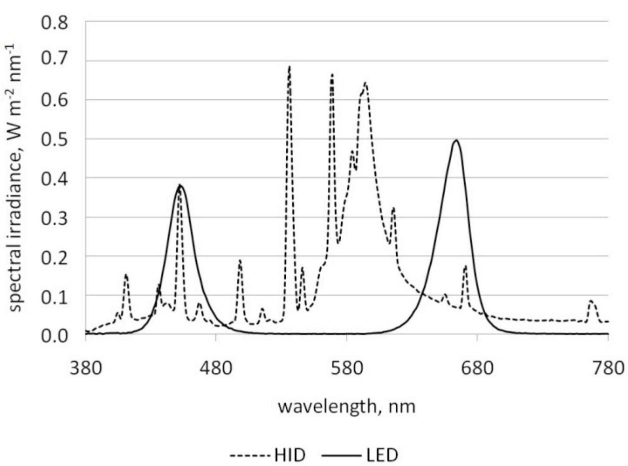

Figure 1. Lighting spectra of LED and HID growth chambers measured with the spectroradiometer Specbos 1211 (JETI Technische Instrumente GmbH, Jena, Germany). See text for details.

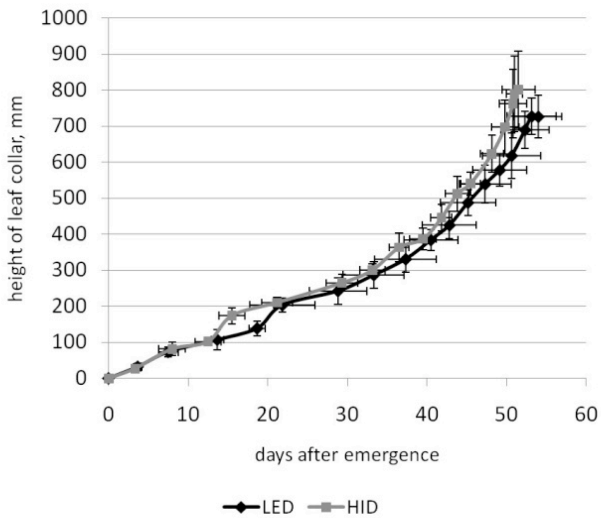

Figure 2. Vegetative growth and development of H99 maize inbred plants grown under LED and conventional HID lighting. The height of the uppermost leaf collar was measured as an indicator of plant height on the day when it appeared from the leaf sheath of the next lower leaf.

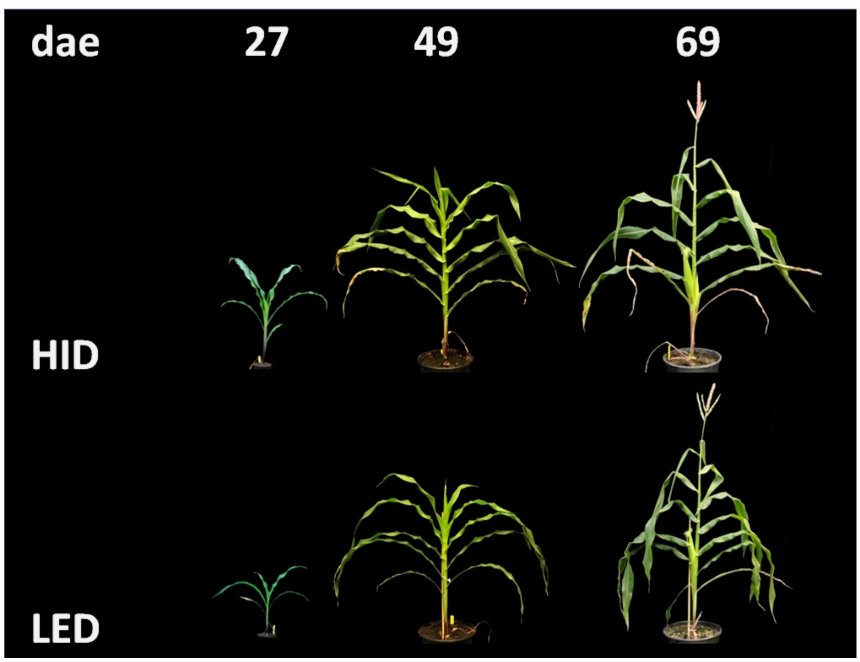

Figure 3. Phenotypes of H99 maize inbred plants grown in soil either under LED lighting or conventional HID lighting at 27, 49 and 69 days after emergence (dae) respectively.

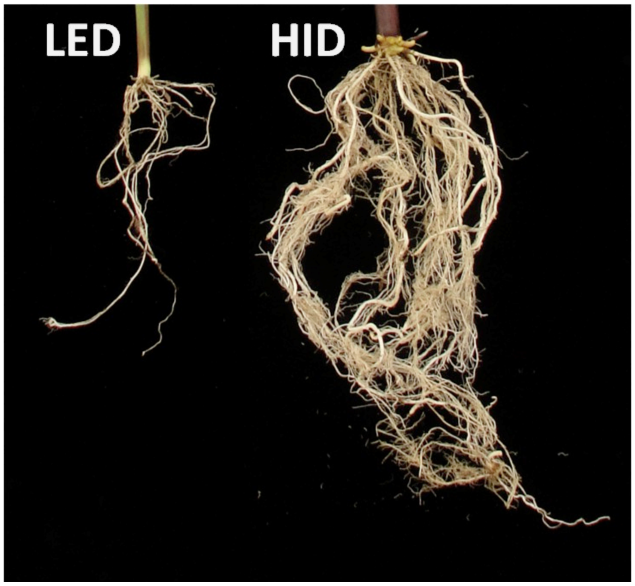

Figure 4. Root phenotype of 28 day old maize plants grown in soil either under LED lighting (left) or conventional HID lighting (right).