Imaging lettuce growth: a comparison between % ground coverage and % PPF absorption by lettuce grown in hydroponics.

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ABSTRACT

The present study was conducted with lettuce grown in growth chambers. Plants were grown in hydroponics, under three temperature regimes: 30/25°C, 25/20°C, and 20/15°C day/night. Percent ground cover was calculated using images taken with a digital camera. Percentage of PPF interception was measured with a line quantum sensor. The results show a very good correlation between % ground coverage and % PPF absorption. Their pattern is similar to a sigmoid model, like a lettuce growth sigmoid model. The lettuce growth can be represented as the function of horizontal projected leaf area by image processing.
Palavras-chave: Lactuca sativa, *image processing, canopy, digital image.*

INTRODUCTION

Image analysis has commonly been used to assist in estimating crop growth throughout the world). During the last decade, as the optics have improved, acquisition of images has become easier, faster, and more useful to achieve accurate values of leaf area. The image processing of plant growth is an effective tool for intact and non-destructive measurement, so as to digitize continuously the images of plant or leaves with the computer. A Scanner has been used as the most accurate way of getting images containing the minimum of light deviation, image distortion, and maximum of resolution. For detached leaves, it's relatively simple using scanners, but shoots do not permit its use, so another device should be used. Video cameras are adequate (Beverly, 1996), but their resolution is small digital cameras have been used because they have a resolution higher than 1 M Pixels, which allows for pictures to be taken with a high definition and is important to calculate the subject areas). In hydroponics, one of the problems in studying plant growth was related to the lack of a nondestructive method. Commonly, it has been used to grow a larger number of plants, and harvest them in a timely manner, but does not permit to conclude that one harvest would be the same the following harvest delete the phrase of the same plant. This increased the difficulty of many experiments), since a successive harvest experiment needs more plants, more physical structure, more labor, and more money. Using digital cameras, one can acquire images time through time without contacting the plants. This allows for measuring plant growth without any plant harvest, making the number more accurate and more reliable.

The objective of this study was to compare ground coverage determined from digital pictures to photosynthetic photon flux (PPF) interception in order to evaluate lettuce growth in hydroponics.

MATERIAL AND METHODS.

The study was carried out in three reach-in growth chambers (Crop Physiology Laboratory, UT, USA). Lettuce (*Lactuca sativa* cv Grand Rapids) was sowed in blue paper (germinated in rolled germination paper) and transferred (transplanted) to growth chambers. The deep flow hydroponic system was composed of four 30 L tubs covered with a polystyrene lid. Plants 2 days old were placed in 5cm holes, held by foam plugs. The nutrient solution was aerated using aquarium stone-air with filtered air from air pumps. Temperatures were set for each chamber to 30/25^{o}C, 25/20^{o}C, and 20/15^{o}C day/night. PPF interception was measured using a line quantum sensor (Model LQSV-ELEC, Apogee Instruments, Inc., Logan, UT, USA)). Ground coverage was measured with a digital camera (model DC3200, Kodak, USA)), with 2 M pixels of resolution that was positioned on a frame that held the camera in the same position) (Figure 1). Pictures were taken every two days. The pictures were processed using image processing software (Adobe Photoshop version 6.0, Adobe Systems, Inc. San Jose, CA, USA)) and the green remove the word color pixels were used to calculate the percentage of lid covered by leaves (Figure 2).

Figure 1. Frame to hold the digital câmera (left) and the frame position inside the growth chamber (right).

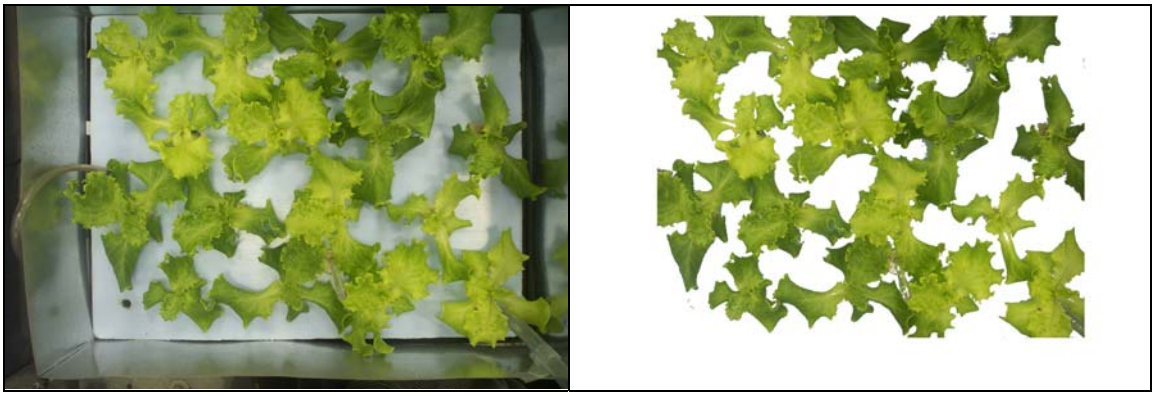

Figure 2. Image captured with a digital camera before treatment (left) and after cleaning up to measure green pixels.

RESULTS AND DISCUSSION

The digital imaging method showed a good pattern of the plant growth (Figure 3). Commonly, plants are considered to grow according to a sigmoid model, which can be easily seen in

30/25°C and 25/20°C day/night temperature regimes. In 20/15°C the plants grew slower, and the elapsed time was not enough to permit canopy closure. With the 30/25°C temperature treatment, plants reached 100% of coverage, while plants in 25/20°C only covered 97%. PPF interception did not match ground coverage so tightly, but, both ground coverage and PPF interception had the similar variation during the lettuce growth. The correlation between age in days after seeding and all the indexes showed were close to 0.9. Shibata et al. (1992) found indexes higher than 0.99. On the other hand, the correlation between % ground cover and % PPF absorption is about 1.0 in the three temperature regime. As PPF interception is a function of the leaf area, it means that the horizontal projected leaf area captured by the image correlates very well with the lettuce growth. These results agree with many other studies carried out to evaluate plant growth in soybean (Klassen et al., 2002), lettuce (Klassen et al., 2002, Shibata et al., 1992), especially in seedlings (Sase et al., 1992), broccoli (Suzuki, 1995).

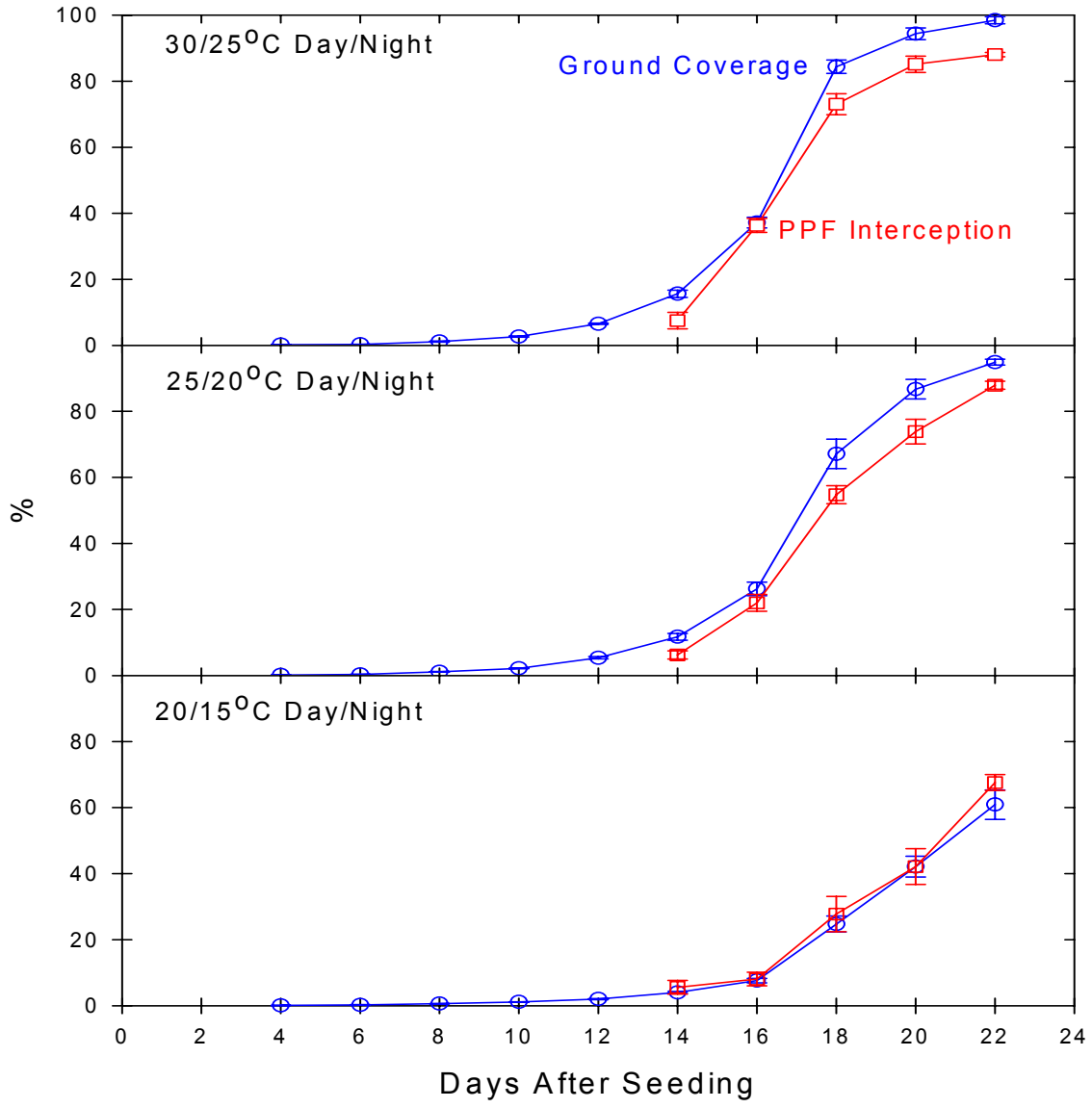

Figure 3. Ground Coverage and PPF Interception by Lettuce Grown in Controlled Environment with Three Temperature Regime.

Table 1. Correlations (r) among % Ground Coverage (GC) and % PPF Intercepted by Lettuce in Controlled Environment. DAS means Days After Seeding.

	DAS	*20/15 %* GC	*25/20% %* GC	*30/25 %* GC
20/15 % GC	0,84			
20/15 % PPFI	0,84	1,00		
25/20% GC	0,88			
25/20 % PPFI	0,90		1,00	
30/25 % GC	0,89			
30/25 % PPFI	0,91			1,00

In conclusion, the growth of lettuce was represented quantitatively as the function of horizontal projected leaf area by image processing. As ground coverage correlates very well with PPF interception, it is possible to monitor light absorption using images, which are faster and easier to be handle than light sensors. While there are limitations to the use of this method to measure additional light interception beyond 100% ground cover, smaller canopies can be measured in a non-destructive manner. Additionally, larger canopies are over estimated with the digital image technique due to additional leaf layers intercepting more light, which cannot be estimated beyond 100% ground cover, but is measured with the light-bar technique.

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