Reflections about Research on Supplementary Lighting in Greenhouse Cultivation

H. Challa
Horticultural Farm Technology, Wageningen University
Bomenweg 4, 6703 HD Wageningen
The Netherlands
Hugo.Challa@user.aenf.wau.nl

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Abstract

Some personal comments are given about research on supplementary lighting in horticulture. There is a rapid development in the use of supplementary lighting in horticultural practice. Generalisation is needed to share, transfer and apply the pertinent knowledge. Knowledge at process level is therefore indispensable. The distinction between photosynthesis enhancement and control functions of light should be considered explicitly. Especially in applied research experimental details are often insufficiently reported and experiments tend to follow too much a trial and error approach. An integrated problem analysis, taking system levels and scale problems into account, would contribute to efficiency in research. Rules for maximum day length for supplementary lighting, the role of the spectrum of HPS light and a more systematic approach in research on lighting for plant control are subjects that should be resolved in the near future.

INTRODUCTION

The use of supplementary lighting in protected cultivation is still expanding and knowledge about the subject definitely does increase. Yet, related basic questions, that are also being addressed nowadays, remain the same throughout the years. Examples are:
- the best level of photosynthetic active radiation;
- the best lighting regime;
- the best light source.

In spite of a wealth of research dedicated to the subject over the last decades, there seems to be only little progress in finding general answers. One may wonder what could be the reasons why such general answers are difficult to find. To examine that problem, let us imagine the kind of solution one may find to the first question, the best level of photosynthetic active radiation for, e.g. lettuce growing in the region of Québec city. The effect of the level of supplementary light on yearly profit of a nursery may look something like Figure 1.

In theory one could imagine that such a figure could be established after careful experimentation, but this figure certainly would not represent a general answer to the problem. In stead, the function should be a function of e.g. the crop, the cultivation system, the lighting regime, the nursery, the location and the growing period of the crop considered. In other words, we are dealing with an optimization problem fitting into a more complex system. The answer to this optimization problem will not only depend on the choice of criteria, but also on the response function which is not generic at all. Depending on the parameters and on the constraints of the function, a case specific response will be obtained.

To make progress in this type of research a reductionistic approach is probably required, because it is not unlikely that, at least some of, the underlying principles can be described adequately. In general terms the role of supplementary lighting can be attributed to:

type of lighting	process involved	affecting
Assimilation light (AL)	photosynthesis (# quanta)	yield, production time, product quality
Control light (CL)	morphogenesis (spectral effects, day length effects)	timing of production, product quality

Though the distinction of different types of lighting may be useful with respect to the processes involved, it is clear that the effects are interacting. Moreover, in many cases AL also functions as CL, because of the spectral quality of the light sources used and because the length of the day is usually affected as well. Nevertheless, we will first have a closer look at either type of supplementary lighting, before coming to some more general conclusions.

ASSIMILATION LIGHT

AL is primarily used to enhance the rate of crop photosynthesis, in order to enable, to increase, or speed up production during the dark season at higher latitudes, and to improve product quality. Because AL is expensive it is essential to weigh the benefits of AL against the costs. Questions regarding the use of AL in particular focus on optimum radiation level and the lighting regime.

Since AL, by definition, is used to enhance the rate of crop photosynthesis, there are good perspectives to generalise knowledge about AL. Contributions of Marcelis and Heuvelink clearly indicate the need and the potentials of crop growth models to quantify the effects of AL, in terms of the radiation level and duration, on crop production. Even when there is insufficient knowledge on a specific crop, generic, photosynthesis driven, crop growth models are valuable to design and to analyse AL experiments.

It should be noticed that in the approach to AL problems there is a great risk to be confused by scale related misinterpretations. Examples are the common belief that the photosynthesis response of single leaves could represent the response of a whole crop, or attempts to relate production to the daily light integral, ignoring the need to consider the influence of (instantaneous) natural radiation on the contribution of AL to crop photosynthesis. Also the contribution of light interception, especially in young crops with a low leaf area index, to crop photosynthesis is often insufficiently taken into account, or confused with the response of leaf photosynthesis.

Another source of confusion in studies on AL is the rather implicit formulation of criteria for the evaluation of an effect. Often, in practice oriented research, the question of the best radiation level, day length or threshold value of natural radiation for switching is considered. The criterion may be the economic optimum, but in other cases it may be crop photosynthesis or other implicit criteria. Obviously, a discussion about the best (optimum) AL treatment is not particularly fruitful, when it is realised that different conditions, nurseries and crops theoretically should give rise to different optima. To share information, it is therefore important to be explicit about the criteria and related background of the AL question under investigation. Finally it should be emphasised again that AL normally will evoke also CL effects, because of the spectrum of the light source and the length of the day.

CONTROL LIGHT

CL has primarily the purpose of steering crop growth and development, rather than affecting its rate. In particular the control of transitions from one developmental stage (e.g. the vegetative stage) into the next (e.g. generative stage) is an important application. Other examples are the use of light to control stem elongation and branching.

Even if we would understand the underlying mechanisms fully, the question is how this knowledge could be utilised in practical applications. For example, knowing the way the keyboard of a computer communicates with the hardware of a computer, it is the

software that really explains the events that follow this intervention. In plants the signals perceived from the environment act as triggers for predefined functions. These functions are often quite specific for a species, or even a variety and this certainly hampers attempts to generalise knowledge on CL. On the other hand it is clear from literature and from presentations of e.g. Blaquière and Bugbee, that when phytochrome or daylength mediated responses are involved, there are general principles that help to analyse crop responses. Because there are interactions with other factors and processes, such as photosynthesis, that may play a role in the expression of the responses, a proper set-up and analysis of experiments is crucial in this type of research. This interaction is another reason why a sharp distinction between CL and AL is often hard to make.

CONCLUSIONS

I would like to summarise my comments in the form of some recommendations:

1. aim for generalisation, at least by providing sufficient information about the experimental conditions (e.g. level of natural radiation), preferably also by a proper set-up of experiments;
2. build upon existing knowledge (such as incorporated in crop models), there is still too much trial and error, where relevant knowledge is available;
3. be careful in making an integrated problem analysis, before going into depth;
4. consider the system as a whole, before deciding a research strategy;
5. take scale problems into account.

Moreover, I recommend some problems to be resolved in the near future, because they are of general importance in research on supplementary lighting:

1. rules for the maximum day length for AL;
2. the role of spectrum of HPS light for AL;
3. systemise specific crop responses to CL and use this knowledge also in applied research.

Figures

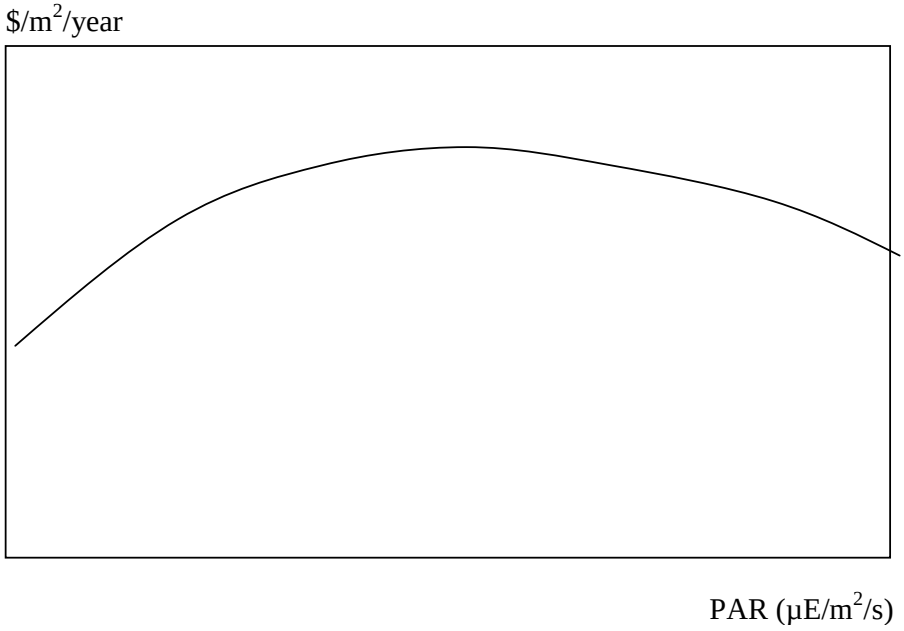

Fig.1. Hypothetical yearly profit of greenhouse production in relation to the level of supplementary radiation