CHOPPER LIGHT

An energy saving light technique for the cultivation of in vitro plants

The Reason

Corresponding to the present level of the technology, the production of in-vitro plants takes place in a climate room.
The plants stand in a grow chamber, tight packed in hundreds of containers on the shelves. The time from the initial bud up to a young plant, ready for planting, takes three months. In this time the plants are cultivated in the chambers under controlled light, air and temperature conditions. Such in-vitro method gives the assurance that all produced plants have the same quality standard.

For the production of plants in such a sterile grow room the electrical energy for the illumination is the costliest factor. Additional costs come into account for the air-conditioning of the growth room. The rule of thumb of climate engineers is that one thousand watts of illumination requires another three hundred watts to remove the unwanted heat of the lamps off the room. The in-vitro industry is a steady growing market and the end user dictates the standard of quality. The growers are always interested to hold the costs low and the quality high. If it was formerly the costs, which gave the reason to think economically, now the air-pollution control is as an additional factor coming into play.

An operator of an in-vitro production facility has several possibilities to minimize the energy costs. One of these is the choice to illuminate the plants with light at night, when the tariff of electricity is reasonable low. Another possibility is installing energy-saving light sources, which can bring a small improvement, but much better savings come from making the use of the new developed light technique.

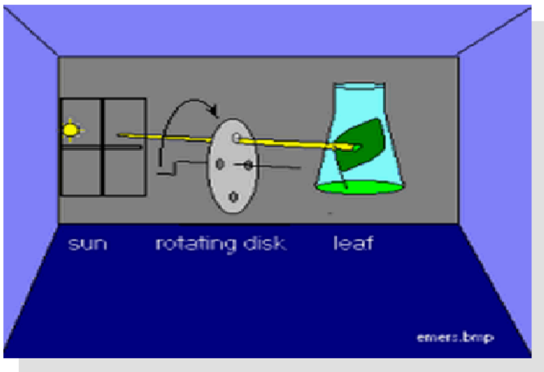
The History

This technology was developed at the beginning of the twentieth century (1), at approximately the same time as the artificial light appeared into the greenhouses. Researchers discovered that plants don't need to growth under continuous illumination. Plants are able to harvest light in intermittent sequences with equal net efficiency. The plants collect light energy in a manner similar to a production line of a well organized factory. Any production has an interruption, if it is the change of the shift or a break to maintain the machinery. In such pauses any applied energy is wasted energy, because it is momentarily of no use. In the plant kingdom, such a temporary halt does not count in hours, minutes or seconds, such a break lies in the area of milliseconds and shorter.

Over the course of years some researchers have examined this phenomenon of intermittent light, although more for scientific reasons than from a mercantile motive. In those golden days of unrestricted energy supply there was no motivation for deeper research into this field of interest. Because energy was cheap and the claims to quality and volume didn't have the today's pressing issues. The technical development of the lamps and the control supplements also were not as advanced as the current standard.

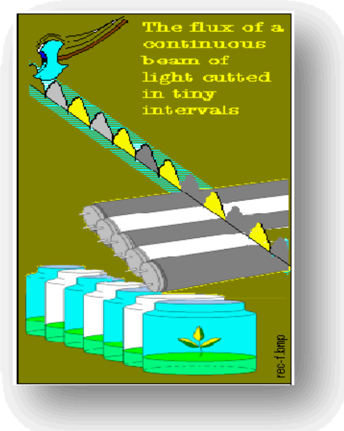
Theory

Progress was again made around the year 1988. At the Humboldt University Berlin, the faculty for plant physiology, **Prof. Paul Hoffmann** and his colleagues (2) made a detailed calculation about the time scale of the intermittent illumination. More precisely expressed, they found that a plant uses an intermittent illumination in a time cycle of 100 ms with most efficiency. They worked out the theoretical principle at the laboratory bench. For this purpose they chopped the light with a mechanical interrupter and varied the light phases wing a hole in a rotating disk. Theoretically they came to the conclusion that 75% of the light can be phased out, without decreasing the metabolism of the plant's photosynthesis and efficiency.



Practical side

To advance this knowledge into practical applications, a cooperation began between the faculty of the Humboldt University and the Oellerich GmbH Company. Now it became possible to develop the technical part for the application of the intermittent light for horticulture in a greenhouse. For this method, the name Chopper Light came into use, since a beam of light is chopped by a semiconductor chip into short intervals. Normally radiation from the light of a lamp is continually in flux, the Chopper Light controller modifies the beam of light to get a chain of pulses in a time scale of milliseconds. Such an application was a step into an entirely unfamiliar role of fluorescent tube, and the lighting of plants in the greenhouse.



Investigation and preparation

No lamp is usually constructed for such an application. The data sheets from lamp manufactures that refer the lifetime of the lamps is considerably shortened by too frequent intervals of switching. To overcome this limitation of the fluorescent lights, a long lasting investigation was begun to find a way for bypassing this problem. It was important to start with a detailed investigation to find a technique to allow tubes to withstand such a switching period in a time scale of 100 ms, without harming their longevity. In a grow room of an in-vitro factory are usual installed groups of fluorescent tubes, so any failed fluorescent tube handicaps the production.

The most critical case is to manage the heat that is emitted from the fluorescent tubes. **K.Ohyama** and **T.Kozai** of Chiba University (3) made a calculation of the energy balance of the tubes in a standard growth chamber. For a chamber in the size of **12 x 12 meters and a height of 3 meters** they have calculated **312 fluorescent tubes or 3120 kWH**. To **remove the heat** from the chamber an air-conditioner is necessary, and this equipment needs additional **1500 kWh**.

Energy side, real tests and verification

The modern energy saving fluorescent tubes promises an energy reduction of 20%. Additionally an innovation step forward is to change the light system from the traditional illumination technique to the Chopper Light technique that gives an additional 30%- 50% reduction of energy. This remarkable result isn't the end, because with further investigations concerning the interval sequences, and depending of the species, of plant promises an additional reduction aimed at a 75% reduction of energy consumption.

At the Humboldt University Berlin **Dr. Ina Pinker** (4) demonstrated the efficiency of the Chopper Light application in practical tests; she achieved immediately a 30%- 50 % level of savings, straight from the beginning. Many further on going examinations are necessary to find out what time sequence is profitable for each species. Since the beginning of the evolution, plant leaves have adapted to live in an intermittent light environment. To be sure, **Dr. Ina Pinker** tested many generations of plants to see if such light patterns have any depressing consequence on the morphology of the plants. However she found no such effects. A careful examination is still essential because, in nature, in a canopy, the light flecks irradiate above the floor in a random manner, and opposite the light intervals of the Chopper Light following in a strong order of millisecond. If, between natural light flecks and the predefined Chopper intervals, there is a difference, more in depth research will be required.


Lightflecks in the forest

Prof. R. Pearcy UC Davis (5) reported that the energy contained in short flecks of light delivers to the plant in the understory 75% of the energy essential for support of their metabolism. The most important is that the light flecks have a great brightness.

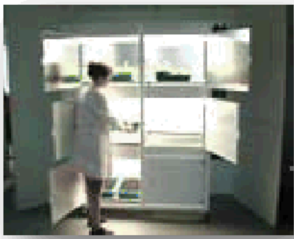
Chopper Light

The traditional practice of artificial light for plants is very simple the light, it allows only to switch it only on or off. The conventional illumination technology is not designed to run under a light pattern regime, which switches in fraction of a second. The method of Chopper Light technology is developed to overcome such limitations. On the way to change from the conventional light application to the new Chopper Light technology, it is recommended that the user consider a learning phase. Study, that doesn't mean training for the user, but examining of the plants and get the information which time scale of a chopped light, is profitable for a specific plant. If the user finds optimum method, then this formula is valued like its own very special formula of a nutrient solution. The composition of on and off intervals becomes a top secret of the company.

Plant Life

A plant is not such an unresponsive substance as inorganic matter, and also not a singular stand-alone, mobile creature. A plant is more, a plant is a cooperation of many single cells, and each of them fulfills its own special mission. It is better to view a plant as a cooperation like a beehive, or an anthill, or as a swarm of fishes, every follows individual its unique statute. All single individuals have in common a need to support the collective. With the in-vitro technique is it possible to put a tiny embryonic cell in an incubation vessel, and a new plant begins to sprout. In each small cell is all the information necessary to regulate its life cycle. The growth of the plant from the embryonic stage up to the fruit bearing condition has many phases and each phase has its special characteristics. For example, a blue light promotes the phototropism, the red light support the building of plant matter. Therefore with a certain combination of the pulse sequences it is probable to get a desired and optimal control over the growth of the plants. This is only one of so many other factors that rules the growth of a plant.

The Chopper Device



For a real example let's take an existing growth chamber, the model TallBoy from CLF Climatics. One shelf has a dimension 825 x 790 mm and a growing height of 280 mm. Enough space for 65 in-vitro containers with a size 100 x 100 mm. The distance between the rim of the container and the tube is 180 mm. To protect the plantlets against the physical heat from the tubes, a Plexi-glass cover separates the growth area from the tube. The shield is installed tightly under the tubes, and a constant air stream removes the heat from the tubes outward. A central air-conditioner stabilizes the temperature of the complete room. The demonstration shelf of the TallBoy has eight tubes, each 65 watt, that is the total power consumption 520 watt per hour. These light intensity 200 µmol from the eight tubes are sufficient for a traditional operating mode. The only possible variation for this grow chamber is a switch to control the light for the day and night cycles. Dimming the light is an additional improvement, and makes it easy to reduce the light intensity. For such standard equipment not much instruction and training is necessary. Much more variation gives the Chopper Light technique. This basic construction of the chamber has the same number of fluorescent tubes and wattage. The innovative difference it the way of the illumination.

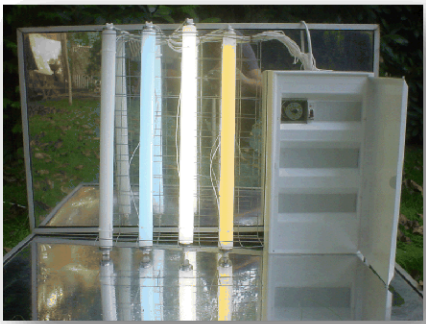
The main purpose of this lighting system is the energy savings. Following the investigation of Dr. Ina Pinker it is an outstanding saving of electrical energy saving possible. Just from the first steps of her experiments the reductions achieved thirty percent. The essential part of this effect is the selection of appropriate switch combination.

The Chopper Light Controller and its function

The Chopper Light Controller, which is attached to the grow chamber, has ten switches. Each switch controls one cycle of the 50-Hertz alternating current, that powers the tubes.

The 50 Hz timing is important to maintain the On and Off cycles for the lamps in an exact constant rhythm. Choosing a combination in a sequence of five ON followed by five cycles OFF gives a reduction of fifty percent of energy usage , but the overall growth rate of the plant was not diminished. Through her research, **Dr.Pinker** (6) discovered that certain plants prefer their own, very particular Chopper mode, a mode such as two ON followed by two OFF along the row of the ten switches gives a different reaction by the plant. Using these ten switches, a large variation of modes are possible. It ranges from one ON and nine OFF to nine ON and one OFF and sums up over six hundred combinations. Perhaps each of them has a different acceptance by the plants. Investigation of all the possibilities will open a wide field of new discoveries.

Future



At the time of the investigation of the Chopper Light, **Dr. Ina Pinker** discovered, that the overall spectra of the lamp depending on the Chopper mode. A Chopper mode of a sequence row of one single ON and Off has a different spectra than a sequence of five ON and Five OFF. In the mode of one ON-Off's the blue color dominates the spectrum. In another case the red color dominates the spectrum. With the suitable choice of the pattern, it is possible to influence or modify the structure of the plantlets.

Environment

In the beginning of the Chopper Light investigation; the energy saving effect was in the foreground. Today, with the problem of global warming, atmospheric CO2 plays also an important role. Reading in the news that a power plant releases tons of CO2 into the atmosphere gives no dramatic imagination. But reading the Kilowatts at a wattage meter of a power line, that gives a real feeling. In the electrical power station, for the production of one thousand watts of electrical energy, three hundred grams of coal are burned. As a result three cubic meter of smoke escapes from the smokestack of the power station. Each cubic meter pollutes eighteen per cent carbon dioxide in the surrounding air. This is six hundred times of the natural atmospheric CO2 concentration.

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