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Optimizing Greenhouse Corn Production: What Is the Best Lighting and Plant Density?

Robert Eddy  
*Purdue University*, robiddy@purdue.edu

Daniel T. Hahn  
*Purdue University*, dhahn@purdue.edu

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**What is the best lighting and plant density?**

Inbred and mutant corn lines grown indoors often don’t yield adequate seed, slowing progress of the project. The difference between 75 and 100 seeds on an ear may seem negligible compared to a hybrid ear with 600 seeds, but just may make the difference between having enough seed for the next round of breeding or not. We address lighting and plant density together in this document because of their relationship to light reaching the lower canopy, which has been shown to correlate to seed yield. We've learned the hard way that the same lighting that produces excellent vegetative growth may not produce adequate seed yield if the plants are too closely spaced. Ears abort, silks fail to emerge from ears or emerge long after pollen shed.

It is generally accepted that if other environmental stresses are reduced, the limiting factor in corn yield is light. We believe the growing system that we propose eliminates water and nutrient stress, so maximizing light should be a focus to improve seed yield. This is a challenge for plant growth facilities. Over the course of a day, we have measured a 40% loss in daily light integral (solar accumulation) in our modern glass greenhouses due to glazing and superstructure. We took light intensity readings inside a cornfield on an overcast July day (1250 µmol/m²/s) and were surprised to measure 314 µmol/m²/s at the lowest leaves of the stalks. In a greenhouse, we may get a third of that intensity. In a growth room, where light source is directly above with little penetration into the tall canopy from the sides, we've measured light at soil surface below 10 µmol/m²/s. Field research that supplemented light to lower canopy (Ottman and Welch, 1988) increased kernels per ear by 14% and number of ears in the plot by 25%. This was accomplished by adding only 121 µmol/m²/s. From this, we suggest that a lot could be gained by lighting and plant spacing strategies that increase light to lower canopy.

None of our studies compared lighting or plant density, but we will report on what we have observed, studies we have collaborated with, and consensus from other facilities. It is by no means comprehensive.

**Plant spacing and configuration**

We believe the minimum distance between the stalks in a row should be 30.5-cm (12-inch). This is further apart than most field corn is planted but—again—plant growth facilities have lower light than outdoors. The higher the daily light integral you can provide with supplemental lighting, the closer you may be able to position the plants. Though untested, there may be a
benefit from spacing the plants further during a critical period of 2-3 weeks. Prine (1971) reported that, in field tests done over three seasons, a rapid abortion of ears occurred 4 days before silks emerged to 8 days after silk emergence under unfavorable light conditions. Otegui (1997) determined kernel number per plant was related to the amount of intercepted light during the silking period and 15 days prior.

One trick we borrow from field production is the twin-row configuration. Two rows are spaced so that the stalks in each row are 30.5 cm apart (same as inter-row spacing), then 76-91 cm (30-36 inch) between the stalks and those of the next twin row. The 91 cm distance is enough for researchers to access the plants and to get a ladder in for reaching tassels. Controlled Pharming Ventures, an underground plant growth facility in southern Indiana, has compared evenly spaced rows against twin rows in a growth room. Even though the plant density was controlled, the twin rows yielded more seed (personal communication). These results agree with several field corn studies (Jones, 2007).

Supplemental lighting intensity and duration
Supplemental lighting is typically used for growing corn in a greenhouse. It is not an absolute necessity. One of the most experienced corn growers, Dick Christensen, formerly of Pioneer Hi-Bred, reports growing corn in ambient North Carolina greenhouse light sown in November that yielded adequately for the project. But for optimum seed production, northern greenhouses will require artificial lighting. Recommendations for the intensity of supplemental light range from 250-750 µmol/m²/s at a distance of one meter below the lights. Specialized corn growth rooms without sunlight are capable of 500-2000 µmol/m²/s. At our greenhouses, we provide 150-250 µmol/m²/s supplemental lighting in greenhouses and 1000 µmol/m²/s in our corn chamber. Note that these intensity recommendations are at canopy level of the crop. Spacing and configuration of plants would determine light reaching lower canopy. Lamp type is typically a mix of metal halide and high pressure sodium or only metal halide.

USDA Greenhouse Manager, Nathan Deppe, cautions that relative humidity must be kept above 40% when using high supplemental light intensity. All growers agree that pollen can be killed if tassels are allowed too close to the lights. See our document What other ideas for improving seed yield? for more details.

Most facilities report using a photoperiod of 14 hours. The Plant Growth Chamber Handbook suggests up to 20 hours during the vegetative phase. We used 16 hours for all stages of growth in our experiments. Several facility managers have seen damage to leaves under supplemental lighting of 24 hours, so it is not recommended. We've documented that 24 hour lighting exacerbates calcium deficiency symptoms on seedling corn (see Figure 2).

Methods to improve light intensity
Having a light system that raises and lowers (see Figure 1) is an excellent tool for maximizing light, if available. Another effective technique is to grow the corn on tables closer to the light while plants are short, then move them to the floor. This takes considerable time, especially with our proposed system that would require moving the drip irrigation system. One research reported an increase in yield by removing tassels after pollination so that lights could be lowered closer to the plants during the grain-fill period (personal communication). If true, this may work because of increased light during the critical window reported by Prine.
A new standard may be warranted
Recommending a light intensity for corn at canopy level may need to be reconsidered. Since seed yield increased when supplemental light was applied to lower canopy in a field, one would expect a similar benefit in a greenhouse. Because plant spacing, type of facility, photoperiod and other factors impact light reaching lower canopy, a new lighting standard may need to be developed that reports daily light integral reaching the lower canopy. Until that value can be determined empirically, we suggest growers try to achieve a minimum 1.5 moles/day at lowest leaf. This corresponds to a uniform intensity at this height of 30 µmol/m²/s for 14 hours per day. With supplemental lighting of 150 µmol/m²/s one meter below lights in a glass greenhouse, we were able to achieve 1.7-4.4 moles/day at lowest leaf for seven days in early March during seed ripening stage. It was enough light for very good seed yield of primary ear (583 seeds/ear), but secondary ears aborted.

Figure 1. Left: Spacing with 30-cm between stalks within the twin row (foreground) and 76 cm spacing between the twin rows. Right: Light banks at Controlled Pharming Ventures raise and lower to optimize light.
Figure 2. Seedling damage from 24-hour lighting.

Figure 3. A portable logging unit tracks daily light integral and other data at lowest leaf level.