Small Greenhouse Energy Curtain Performance
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This article was published in the January 2024 issue of GPN magazine and is expanded here with images that did not fit in the print version at
https://www.nxtbook.com/greatamericanmediaservices/GPN/january-2024/index.php#/p/16
A complete report of the 2023 Energy Curtain Study will follow this article in the form of several chapters discussing additional data and results not presented in the GPN article and how other features were integrated into the greenhouse to maximize energy use efficiency.

The Small Greenhouse and Farm Technology project (SGAFT) is collaborating with GPN for a series of research reports and articles on small scale technology application. SGAFT's mission includes providing small greenhouse and farm operators with technology guidance tailored to their scale of operation.

This article's research was conducted by Konjoian's Horticulture Education Services and designed to better understand energy curtain performance in a small greenhouse setting. This report transitions to the SGAFT website (sgaft.com) with additional pictures, data graphics, and discussion.

2023 curtain study

Six overnight data generating sessions occurred between February 25 and March 19, 2023. Yes, you read that correctly, six all nighters were pulled over three weeks, each thirstily stimulated by caffeine followed by a day or more of recuperation. It was a fun experience that generated pages of spreadsheet data. Figure 1 shows the 24 x 40 ft double poly covered research greenhouse attached to my basement, propane tanks, and winter conditions on February 25.

Figure 1

The first part of the study covered three nights; February 25, 27, and March 1. Main variables included three different outdoor temperatures and alternating energy curtain position between open and closed through the night. Greenhouse temperature was controlled by Bartlett Instrument Company’s Climate Boss system. The curtain fabric, Svensson’s Tempa 5557 (55% shade, 57% heat retention), was part of a Wadsworth Control Systems curtain package. The second part of the study included a third variable of alternating between Climate Boss and a mechanical thermostat through the night and is presented on the website.

Table 1 describes the study’s parameters; date, outdoor temperature, greenhouse heat set point, night start/end time, and curtain position sequence through the night.

Table 1

Night	**outdoor temp (^{o}F)**	**heat set point (^{o}F)**	**start/end p.m./a.m.**	**curtain open/closed position (hr)**
Feb 25	12	62	9:00/8:30	closed 1, open2/closed 2, open 1/closed 1, open 1/closed 1
Feb 27	28	63	9:00/9:00	closed 2/open 2, closed 1/open 1, closed 1/open 1, closed 1
Mar 1	35	63	7:00/6:30	“

Figure 2 shows the high efficiency Modine propane fired hot air furnace and curtain in closed position. Each furnace cycle included three manufacturer presets; 20 seconds between thermostat heat call and ignition, 30 seconds between ignition and heat exchanger fan start, and two minutes post ignition fan cool down. Total ignition (burn) time and total fan run time varied for each cycle and were recorded. Also recorded were cycle start and end time (duration) and time between cycles (frequency).

Figure 2

Air temperature was monitored at two locations, 18” above the bench and 6” above the curtain, at the start and end of each furnace cycle. Pictured in Figure 3 is a staged pair of sensors demonstrating temperature monitoring above and below the curtain as the curtain opened after a closed session. The above/below curtain temperature gradient shown is 46.0/62.7 F, the post opening period called a morning cold air dump.

Figure 3

Following each curtain position change (open or closed) the first heat cycle served as a transition cycle and was excluded from data analysis. Regarding bench temperature this cycle neutralized the cold air dump following opening. Regarding above curtain air temperature the transition cycle allowed for cooling of the warm air after closure. Excluding transition cycles more closely simulates continuous curtain use through the night.

Outdoor temperature

Three parameters in Figure 4 were averaged over both curtain positions, open and closed, to present the effect of outdoor temperature on greenhouse heating. Total minutes of furnace burn (ignition) time and number of furnace cycles are presented on a per hour basis along with average burn time in minutes per cycle. Graphs appear in order of descending outdoor temperature; green-35 F, blue-28 F, and red-12 F.

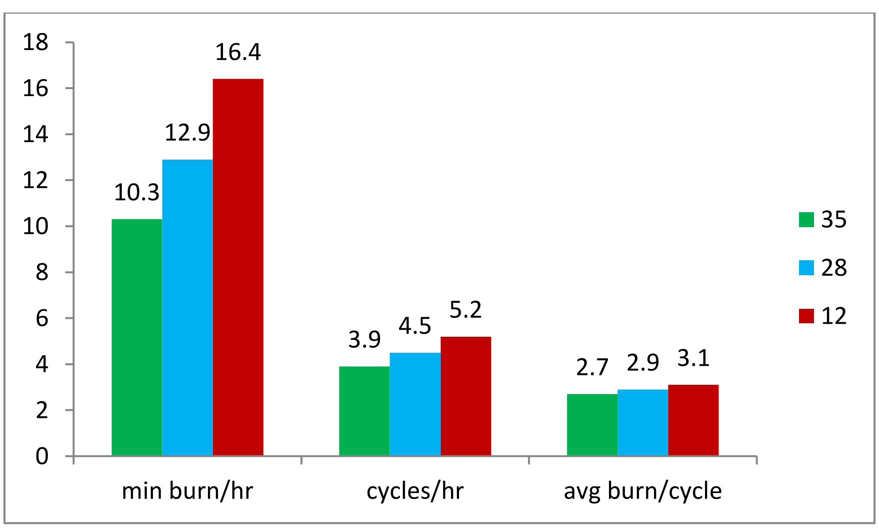

Figure 4
The left set of bars shows total minutes of burn time/hour with burn time (fuel consumption) increasing as outdoor temperature decreased from 35 to 28 to 12 degrees F. Burn time increased from roughly 10 to 13 to 16 minutes/hour as outdoor temperature fell. Between the warmest night (35 F) and coldest (12 F) total minutes of burn/hour increased 59% (10.3 to 16.4 minutes).

The center set of bars presents furnace cycles/hour and shows cycles increased as outdoor temperature decreased. As temperature dropped from 35 to 28 F the furnace required 0.6 of an additional cycle to maintain temperature and another 0.7 of a cycle as temperature dropped from 28 to 12 F. The right set of bars shows average cycle burn time in minutes which also increased as temperature fell but less dramatically. Allowing for rounding of numbers, within each temperature minutes of burn time/hour = cycles/hour x average burn time/cycle.

Curtain open vs closed
Figure 5 shows total minutes of burn/hour for the three night temperatures with the curtain open (red bars) vs closed (blue bars). At 35 F the curtain open vs closed split was 11.5 vs 9.1 minutes, a 21% reduction. At 28 F the 14.5 vs 11.3 split was 22%, and at 12 F the 18.2 vs 14.5 split was 20%. Closing or "using" the curtain resulted in 20-22% less fuel consumption.

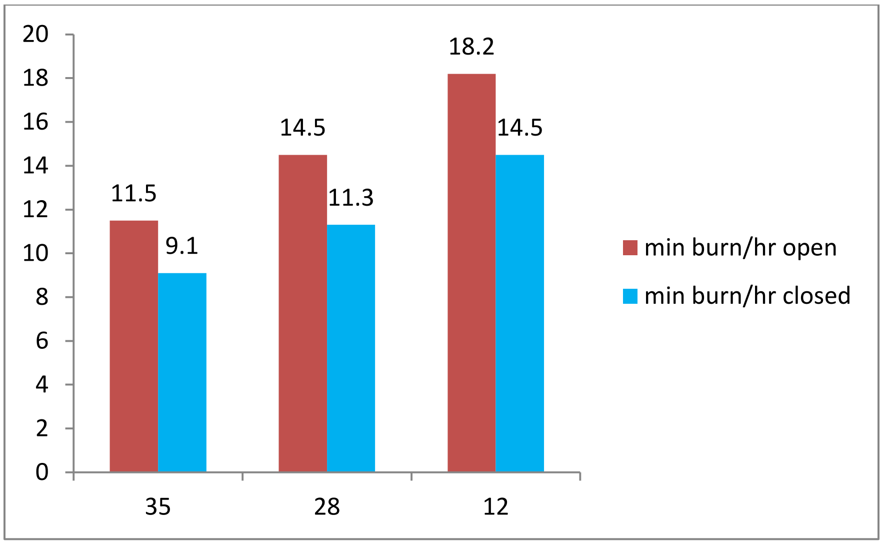

Figure 5

Figure 6 shows the number of furnace cycles/hour for the three night temperatures with the curtain open or closed. At 35 and 28 F closing the curtain reduced the number of heat cycles by about one cycle/hour. At the lowest temperature of 12 F the curtain reduced the heat cycles by one half of a cycle/hour.

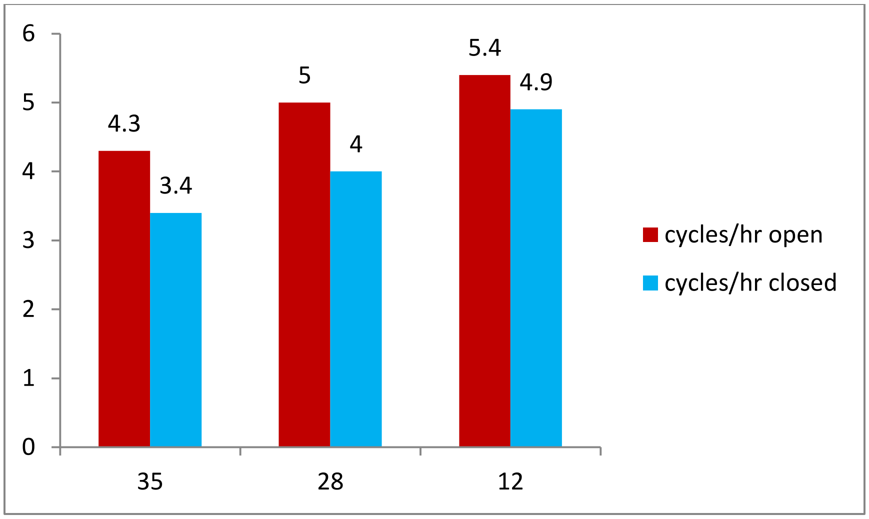

Figure 6

Figure 7 presents minutes of burn time/cycle which was minimally affected through the warmer nights of 35 and 28 F by curtain position. However, through the coldest night, 12 F, cycle burn time increased by half a minute when the curtain was open vs closed. Reciprocally, during warmer nights closing the curtain did not significantly reduce the furnace's burn time/cycle but on the cold night closing the curtain resulted in shorter cycle time.

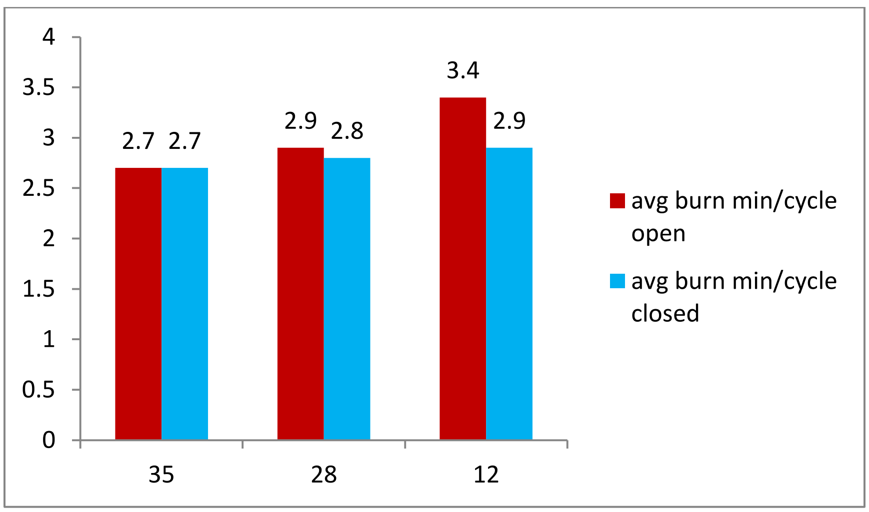

Figure 7

Conclusion

Energy curtain use in this small greenhouse study reduced night time fuel consumption by 20-22%. Differences were observed over both main variables; three outdoor temperatures (35, 28, 12 F) and two curtain positions (open vs closed). The fuel savings presented in this research can be described in a practical way as follows. The furnace worked less to maintain the greenhouse temperature when the curtain was in use and worked harder when the curtain was not used. Working less was a function of fewer total minutes of ignition (burn) time per hour resulting from a combination of fewer cycles per hour and shorter cycle time.

Additional chapter reports of this project will:

Present furnace performance data comparing a traditional thermostat to the Bartlett Climate Boss controller.
Discuss why this study's 20-22% energy savings is less than the curtain fabric's 57% heat retention rating.
Present an economic analysis of this greenhouse's energy consumption; the curtain system's cost of materials, installation suggestions, and roll-up side wall insulation.