Illinois Institute of Technology
Ipro: 344: inflatable greenhouse

FINAL REPORT

Thermal Analysis

Introduction

The thermal Analysis Part of the Ipro set out to research different methods of cooling an controlling temperature within an inflatable greenhouse.

Background

Current greenhouses use a fan and misters in order to maintain temperature but problems came trying to maintain a constant temperature.

Research methodology

We researched different types of temperature control by visiting different greenhouses an seeing what problems were with current cooling methods. We also contacted different companies in order to find different plastic coating being developed today in order to enhance our greenhouse.

Obstacles

Pricing was difficult to establish because we were unsure as to how big our greenhouse was actually going to be.

Results

We came up with several options for cooling: Misters, foggers, fans, and different plastic coatings.

We found two types of misters. One was a mister that attaches via a hose these misters are cheap and use water pressure to sprays a mist. The other mister involves using a pump which is a little bit more expensive but has easily controllable temperature.

Foggers cool greenhouses by generating a cooling fog. This method us a little bit more complex and expensive than misters. A usual fogger could go any where from $25-$250/unit. An advantage is that there are modular unite available where no tubing is required.

All cooling options require a fan. A fan can serves a double purpose by circulates air within greenhouse and by keeping greenhouses inflated. The size of fan depends upon the size of greenhouse. A typical circulation in a greenhouse can be up to 1 total air exchange per minute

Different Plastic coatings were researched and one was found which is produced by EMD Biosciences. Solarflair™870 is a pigment that offers a way to absorb the "Photosynthetic Active Light" (PAR) which has a wavelength of around 400-800nm. It also offers a way to reflect some of the UV and IR wavelengths that supply unnecessary heat for the greenhouse.

Structures

_01 Introduction

The Structural Investigation portion of IPRO 344 sought to design a "greener" greenhouse. Green house design of today primarily uses polyethylene plastic film and steel supporting structure to construct greenhouses. We undertook the challenge of designing a greenhouse design that eliminated the need for the steel structure hereby making a cheaper more energy efficient structure.

_02 Background

Structural plastic membrane structures are used in a variety of building types using both plastic and fiber glass based materials. Building types such as stadiums and and domes use this structural concept. Primarily supported by interior air pressure this is the concept we adopted for our own structural investigations.

_03 Purpose

The structural team of IPRO 344 took on the challenge of constructing a scale model of our "green" greenhouse for IPRO day to illustrate the efficiencies and structural beauty that can be achieved. Another objective of our team was to hypothesis and strategize alternative designs and assemblies using the concept developed by our scale model.

_04 Research Methodology

The structural investigation began with a research phase in which all members of the group took part. We researched building types, methods and materials presenting our research to one another during our scheduled class periods.

Concluding the research phase we began the design phase in which we built scale models and experimented with the different materials that were presented in the class. This phase produced many discoveries and spurred on continued experimentation throughout the semester.

_05 Assignments

We were successful in constructing the full scale model and proposing different building suggestions.

_06 Obstacles

We faced many obstacles this semester among a few team work coordination between the different groups and team members. Materials and the frustrations that are designed into them was also a challenge. Developing a fabrication and construction technique with the Polyethylene proposed the biggest challenge that finally resulted in our greatest victory using a modified household iron to assemble the final model.

_07 Results

The result of this team was a scale model of the "green" greenhouse that we designed throughout the semester. We also achieved multiple feasibility solutions using the module that we created.

_08 Recommendations

We recommend as the structure group that this "green" greenhouse should be brought into the mainstream. Steps need to be taken to take this method of making greenhouses to industry through teaming in a future IPRO with more manufacturing professionals from the public realm.

_09 Research

Our research was primarily supported by physical modeling and research from the internet and various periodicals that are to widespread to mention specifically.

_10 Acknowledgments

As the structural group we would like to jointly thank Professor Blake Davis for his encouragement and overarching vision that formulated the basis for this semesters work and combined effort.

Business

Ensuring Competitiveness

According to many research about greenhouse cost, we can categorized its initial cost by six main categories; Structure, Film, Heating and Cooling System, Growing Media, Equipment and Installation. The proportion of these factors is 22%, 3%, 43%, 12%, 11%, 9% respectively.

Our main technical strategies eliminating frame, reducing the volume, avoiding pesticide encourage us to reduce large part of its cost. This reducing allows saving up to 50% of initial cost.

For better understanding of comparing the cost between conventional and inflatable greenhouse, I assumed 2000 sq ft greenhouse.

Structure

In initial cost of building greenhouse, the largest part is framing cost. Using air pressure and inflatable designed structure, structure can be eliminated from our project. Hence, our greenhouse does not need the cost to build structure at all.

	Conventional	Inflatable
Structure	$ 2,940	-
Film	$ 520	$ 520
Heating and Cooling Sys	$ 6,581	$ 3,019
Growing Media	$ 1,940.50	$ 1,949.50
Equipment	$ 1,665	$ 915
Installation	$ 1,348.75	$ 1,348.75
TOTALL COST	$ 14,995.25	$ 7,391.25

Energy

Usually people can walk inside of it so that they can check the condition of plant and harvest by walking inside. However, this design force greenhouse owner to spend too much energy because they have to heat or cool whole air in the large volume of greenhouse.

In stead of that, we have developed small scale greenhouse which is fitted into plants, but not into human. Hence, this greenhouse system can save energy cost, since it does not heat or cool the unnecessarily space of growing plants.

In order to calculate cost of energy, I used a simple formula to figure out requirement of annual BTU and multiplied with cost of energy depending on the types of it.

Formula

$$Q = \frac{A \times Dh}{R}$$

Q: Btu/yr, A : Surface Area, sq ft

Dh (Degree Hour) : Degree Day x 24 hour

Degree Day = ΔT x Heating or Cooling days

Dd : 3800℉ Heating & 985℉ Cooling *Illinois*

R : Thermal resistance

Calculation energy cost of heating and cooling

Heating amount of Conventional greenhouse
A = 3,516.8 sq ft, Dh = 93,120℉, R= 0.8/Btu
- Annual required amount = 409,355,520 Btu/yr
- 454.83 MBtu/yr x $ 23/MBtu = $10,461.09/yr

Heating amount of Inflatable greenhouse
A = 1,526.04 sq ft, Dh = 93,120℉, R= 0.8/Btu
- Annual required amount = 177,631,056 Btu/yr
- 197.37 MBtu/yr x $ 23/MBtu = $4,539.46/yr

Cooling amount of Conventional greenhouse
A = 3,516.8 sq ft, Dh = 23,640℉, R= 0.8/Btu
- Annual required amount = 103,921,144 Btu/yr
- 30,450.8 kWh/yr x $ 0.2/kWh = $3,045.05/yr

Cooling amount of Inflatable greenhouse
A = 1,526.04 sq ft, Dh = 23,640℉, R= 0.8/Btu
- Annual required amount = 45,094,482 Btu/yr
- 13,213.34 kWh/yr x $ 0.2/kWh = $1,321.33/yr

TOTAL SAVINGS IN ENERGY = $ 6,945.35/yr

Pesticide

Providing alternative materials instead of chemical pesticide ensure our project more competitive as well as reducing cost. Cost of pesticide is one of the large parts in greenhouse operation. The ability to operate without using pesticide is more than reducing cost. It enable the greenhouse owner to be more suitable for organic. So, the crops without pesticide can bring higher revenue. According to Professor Mary M. Peet who is teaching Horticultural Science at North Carolina State University, rule of thumb for organic production in the field is that you have to charge 20% more because costs are 20% more.

Following by expert's opinion, this greenhouse can enhance the profit up to 40%, depending on the cost of alternative.

Reducing cost of pesticide

$ 169 / 6month = 340 $ / yr

TOTAL SAVINGS BY YEAR

$ 15,228 savings in initial year
$ 29,799.49 savings in 3 year
$ 44, 370.19 savings in 5 year
$ 80,796.94 savings in 10 year

Pest Control

Introduction
Pesticides in greenhouses can be costly and toxic to not only the environment, but the gardeners. Our objective was to design a cost-effective pesticide system that would be environmentally safe and non-toxic. Our main focus of experimentation was on Carbon Dioxide, since it is naturally available in the atmosphere in small amounts and available for a low cost in the form of dry ice. Dry ice expands to over 800 times its original size as it sublimes, making it ideal to use at room temperature. It is also a good item to have on hand for emergency cooling of overheated greenhouses. Below, preliminary experimentation of this gas to be used as a pesticide is outlined.

Materials

Glass condenser
Rubber Tubing
Glass Jar
Plastic jars (clear)
Warm water
Fermentation lock
Flowering house plants
Thermometer
Spray bottle of 25% sugar water
Spray bottle of 25% oil
Cardboard
Dry ice
1500 Ladybugs
Teflon tape

Methods

Sets of 25 ladybugs were used to test the effects of three different nontoxic substances as possible pesticides. Sugar water, oil, and carbon dioxide were all tested, but because the carbon dioxide was acquired from dry ice, a special experimental setup had to be designed to keep the temperature constant. An ultraviolet light was used during the daytime to simulate sunlight for the plants in each test. The experimental setup for testing carbon dioxide was put together as shown in the figure and photographs below. The compartment with the plant was placed with its opening in a dish of water in order to ensure it was airtight. A tube was connected from inside the plant chamber, to the dry ice jar, going through a condenser, which was sealed with Teflon tape, in order to warm up carbon dioxide. Prior to the experiment, a thermometer was placed inside the plant chamber, and the warm water running through the condenser was adjusted to keep the chamber at room temperature (23ºC). On top of the plant compartment, a fermentation lock ensured the pressure inside the chamber remained constant. Since carbon dioxide is 1.48 times heavier than oxygen, most of the air released by the fermentation lock should have been oxygen, not carbon dioxide. The other two nontoxic pesticides tested were sprayed ten times on a plant in a clear plastic jar with air holes in the top for the ladybugs. The variables were each a 25% concentration of sugar or oil and water. The control consisted of a plant with ladybugs in a clear plastic jar with air holes. Insect death was determined not by when the insects fell from the plants, but when they were motionless on the floor of the container. They were left for another several hours with the container opened after perceived death for verification.

Results/Discussion

Insects use tracheal respiration in order to transport oxygen through their bodies. Openings on the surface of the body called spiracles lead to the tubular tracheal system. Air reaches internal tissues via this system of branching trachea. Among the smaller or less active insects, gas exchange though the tracheal system is by simple diffusion. Large, active insects like grasshoppers, forcibly ventilate their tracheae. Contraction of muscles in the abdomen compresses the internal organs and forces air out of the tracheae. As the muscles relax, the abdomen springs back to its normal volume and air is drawn in. Large air sacs attached to portions of the main tracheal tubes increase the effectiveness of this bellows-like action. In our experiment, however, we cut off the oxygen supply to these insects by filling the container with carbon dioxide, the waste product of the insects' respiration. Our results shows that the testing insect, Coccinellidae or more commonly known as lady bugs, all died within three hours of high carbon dioxide exposure and oxygen deprivation.

Commerical Use

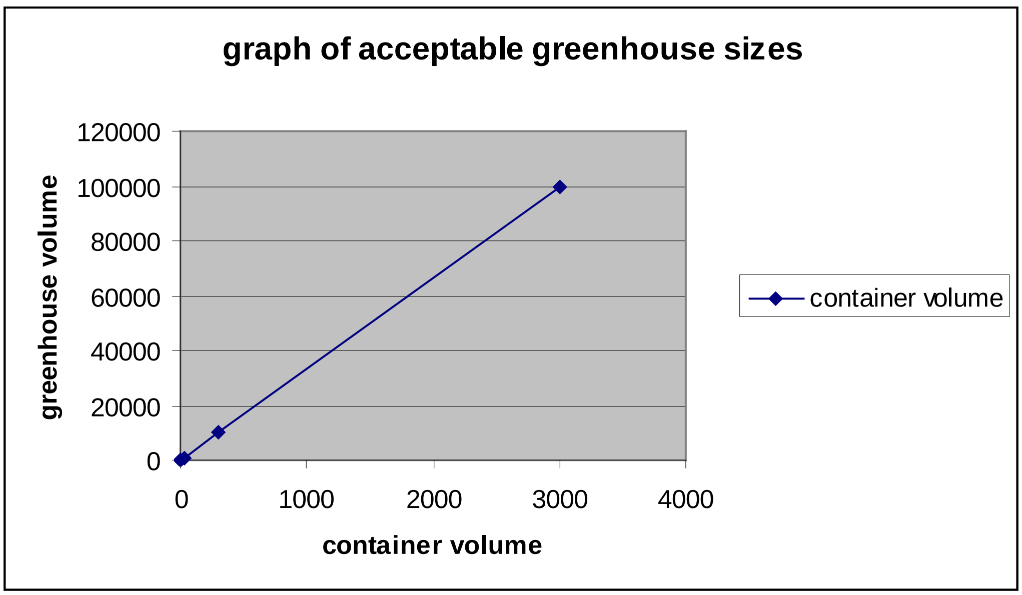
Although the preliminary results have shown that the depletion of oxygen and the increase in carbon dioxide levels in the air will effectively kill ladybugs, if there is no way to commercially use these findings in a working greenhouse these results will mean nothing. However, it would be foolish and unwise to replace an entire greenhouse's air supply with CO_2. To effectively treat plants for pesticides there must be an area in which they can be treated for a few hours, as the bugs are stunned within seconds but take hours to kill. The dosage must also be enough to kill the pests yet not pose a safety hazard to working.

Side tests were done during the experiment on the effectiveness of "washing" the pests with CO_2 from a nozzle, these results showed promise in that adequate concentration of CO_2 was delivered to the plants, however, the amount of time needed to kill the pests, and subsequent CO_2 needed, outweighs this option from the start. Instead, the most viable option is to have a treatment room that is large enough for the plants that can easily replace the air, most importantly oxygen, from its interior and replace it with CO_2. the most common flats available range from 12" x 12" to 21" x 10" while seedling rarely reach over 1.5 feet tall even with the pot underneath them. Knowing this a simple box that can be sealed and automated to exchange gases can be created. The main component of the container would be a large box with a side opening in which seedlings could be taken in and out of in flats. Knowing the approximate sizes of the flats and the average size for the seedlings a container of no more than 24" x 24" x 24" would be needed. An example of this is shown in figure 1.

Although carbon dioxide is in our atmosphere and part of our respiration, to much can pose a safety risk. As with all chemicals and materials, incorrect usage can lead to bodily harm. However, carbon dioxide is a relatively safe chemical to use, it takes high dosages for extended periods of time to create substantial damage. This does not mean that asphyxiation cannot occur. The typical level in the atmosphere is roughly .03%, a typical body can tolerate up to 4% CO_2 without side effects. At levels above 5%, stimulated respiration occurs and at 7 % to 10 %, unconsciousness occurs after few minutes of exposure. Levels above 10% are lethal as the body cannot breathe properly and asphyxiation occurs. To guard against this, CO_2 containers should be stored outside the green house and adequate ventilation should in use while treating the plants. The container must not exceed 3% of the total volume of the greenhouse. Figure 2 shows a graph of adequate sizes. For the example container explained above, the greenhouse must be at least 266 cubic feet, a greenhouse that is at least 6 feet by 6 feet by 6 feet.

Figure 1:

Figure 2:



Conclusion

Future studies into pest control will include experimentation with the device using various types of pests, including those pests, which live within the plant itself. The first test was performed with readily available insects (lady beetles) to test the basic feasibility of the device. Different types of pests have different metabolic needs, and will therefore respond differently to the conditions within the device. Further experimentation into different pest control techniques as comparable controls will also be performed.

Sources

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