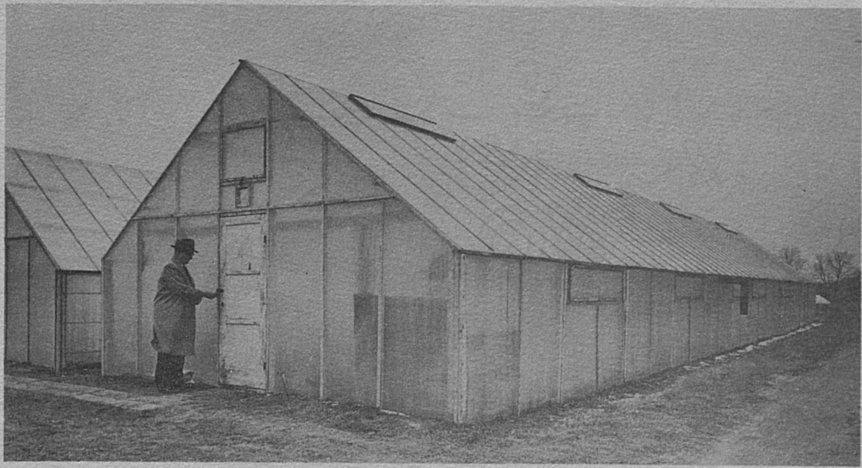

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Construction and Heating of Plastic Greenhouses

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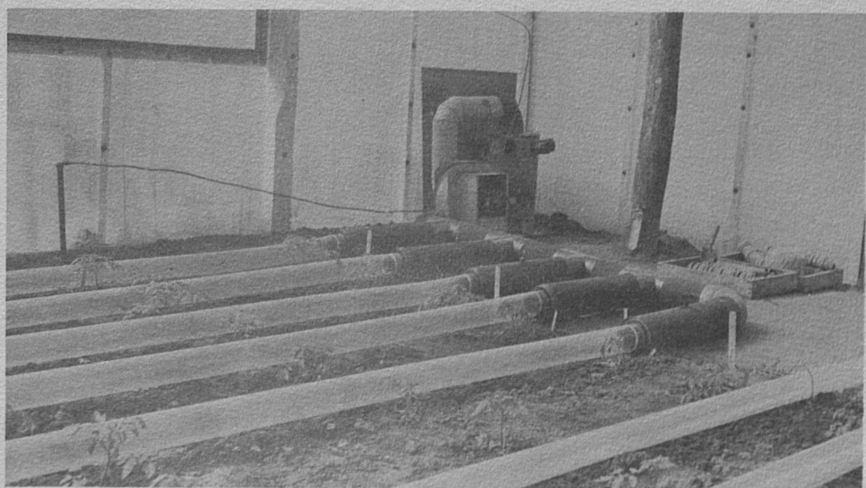

CONSTRUCTION AND HEATING OF PLASTIC GREENHOUSES*

By E. M. Emmert

Six years' use of plastic for greenhouses on the University of Kentucky Agricultural Experiment Station farm has given conclusive proof that good crops can be grown in such houses. For 12 years, however, crops have been grown in commercial polyethylene houses at the south edge of Lexington but no definite proof was established that crops grew well in them. Plastic greenhouses may make it possible to grow out-of-season crops cheaper than in glass greenhouses because overhead and heating costs are greatly reduced.

RESULTS WITH CROPS

1. Bibb lettuce produced solid, extra large heads in less time than lettuce grown in glass greenhouses. It seems to thrive under the conditions in a plastic house and is of very good quality.

2. Grand Rapids leaf lettuce grew well and was of good quality, just as good if not better than when grown in glass greenhouses.

3. Head lettuce has never headed well in plastic houses.

4. Kentucky Wonder beans grew vigorously. However, they tended to vine and not set pods, especially if the concentration of nitrogen in the soil was high. If plenty of air is admitted and the temperature is kept at 60°F or more, a good set can be obtained. Plastic apparently keeps the humidity too high if air exchange is limited.

5. Tomatoes grown at the same time in both glass and plastic houses were compared. Here again, there was some tendency towards vegetative growth in the plants grown in the plastic house, and good fruiting occured about a week later. The fruits, however, were somewhat larger than those grown under the glass house and were of good quality. Under plastic the yields have been better in most cases. There was some tendency towards fruit rot in tomatoes grown in the plastic house when air exchange was limited. Tomatoes grown in the glass house dry out much more rapidly and are less likely to rot; however, there was more tendency for blossom-end rot to occur in tomatoes in the glass house. Blights did not seem to be more severe, but more Botrytis and sclerotinia rot appeared in the plastic house tomatoes. These diseases are usually not serious if ventilation is used on all days possible. If ventilation is good and maneb fungicides are used liberally, diseases are not too troublesome in plastic greenhouses.

6. Several crops of cucumbers grown in 200-foot houses have shown that cucumbers grow very well under plastic. They apparently thrive in the high humidity of a plastic greenhouse.

7. About 10 different annual flowering plants have been tried in a small way and all did well.

*This publication supersedes Progress Report 28 "Low-cost Plastic Greenhouses" published in 1954 and now out of print.

While regular polyethylene is cheap and is good for growing plants, it lasts only one year. It is entirely dependable for one winter when put on in October, but breaks down in early summer of the next year. Some new, long-lasting types of plastic are being tested, but the best of these are more expensive than polyethylene.

Weatherable Polyethylene - One way to get an inexpensive long-lasting material would be to make the existing inexpensive one long-lasting. A compound has been devised which gives some promise of prolonging the life of the polyethylene. This is a special chemical formulation which is added to the melted polyethylene before being made into sheets. It adds very little to the usual cost of polyethylene. The product looks and seems the same as the regular polyethylene. It is being tried extensively, but no one is able to say definitely how long it will last.

Vinyl - Vinyl plastic costs about three times as much per square foot as polyethylene of the same thickness. For use on greenhouses it has to be considerably thicker than polyethylene; thus, it costs five to six times as much per square foot. However, the thicker grades last for two years. It is questionable whether the thicker grades will last through the third year, although 8-mil vinyl shows some indication it might last through the third year. One objection to vinyl is that it collects dirt much more rapidly than polyethylene or glass.

Weatherable Mylar (3-mil Mylar was used on the house in the cover picture) - Mylar is a tough, clear plastic. Varying thicknesses of weatherable Mylar are being tested at the Kentucky Agricultural Experiment Station. So far, weatherable Mylar has been commercially available in the 5-mil thickness only. The current price is nearly 15 cents a square foot for large amounts and considerably more for small amounts. This makes it cost about the same per square foot as glass. Of course, installation is much cheaper because a less expensive structure can be used. However, at the Kentucky Agricultural Experiment Station 2-mil weatherable Mylar lasted three years without a break. During the fourth year some bad breaks appeared on the side facing the south.

Weatherable Mylar has one defect in that if it is once broken, it will tear easily, even in the 5-mil thickness. This means that it must be fastened securely on the greenhouse so that tears will not start from nail holes or from wind or wind-carried objects. A jagged stone thrown on polyethylene will make a small hole which does not enlarge. This same stone may make the same size hole on Mylar, but from this hole "runs" will start and the Mylar will break down. On a two-foot spacing of sash bars, Mylar can be run lengthwise and the laps will stay together well. However, Mylar does not stay together in laps nearly as well as polyethylene. If wide spacing of sash bars is used, the Mylar should be placed up and over the frame.

Teslar - Teslar is a vinyl fluoride. It is related to vinyl chloride but is clearer, tougher, and more resistant to weather than Mylar. It does not get dirty like regular vinyl does. However, it is more costly than Mylar. If it proves satisfactory, it may be cheaper when made in larger quantities. One older type has lasted four years on a University of Kentucky greenhouse, and tests in Florida show that it may last 7 years. The new type has been on the University of Kentucky house only abou[t] one year, but it appeared to be in good condition after the first summer.

Weatherable Tenite - Still another plastic being tested is weatherable Tenite. Like the others, it was not satisfactory as first developed. However, chemicals have been added to make it resistant to oxidation. It has remarkable clarity and can be readily joined together by the use of a solvent. With this material the plastic "welds" together and makes a permanent joint. The first year of testing showed that a 3-mil thickness did not last. The 5-mil is doing better, and the 8-mil has lasted well in the second year. A few tears appeared the third year. It is not quite so costly as Mylar, but because a thick grade has to be used makes it rather expensive.

SOURCES OF PLASTIC

The various types of plastic needed in greenhouses can be obtained from one or more of the following (Polyethylene can be obtained from all companies mentioned):

E. I. DuPont DeNemours & Company, Film Department, 1007 Market Street, Wilmington, Delaware (Mylar, Teslar).
The Continental Can Company, Mt. Vernon, Ohio.
Gering Plastics, North 7th St. and Monroe Ave., Kenilworth, N. J.
The Visking Corporation, Chicago, Ill.
The Eastman Chemical Company, Kingsport, Tennessee. (Tenite)
Peter & Co., 3618 Lexington Road, Louisville, Kentucky.

(Mention of commercial products in this report is made only for purposes of information. The Kentucky Agricultural Experiment Station does not guarantee or warrant the standard of the products, and the use of the names in this report does not imply the approval of these products to the exclusion of others which may also be available.)

HEAT AND MOISTURE RETENTION

Sunlight does not cause as great a temperature build-up in plastic as in glass, and the heat loss at night is less. With a double layer of plastic, the heat loss is about half that with glass. This fact was determined by measuring the fuel needed to heat plastic houses.

Plants grown in plastic greenhouses retain much more moisture than those grown in glass greenhouses because plastic has fewer laps and is tighter. This lessens the amount of watering needed. If the houses are not ventilated, there is more danger of disease. Ventilation and the application of fungicides are required to prevent disease.

LIGHT TRANSMISSION

Ordinary types of plastic such as polyethylene will transmit about 90 percent of the light that glass will transmit. However, the more ultra-violet light and heat, the quicker most plastics deteriorate. If put on in late September, polyethylene will hold until the next June in locations from Kentucky on north.

VENTILATION

Ventilation has been shown to be very important. The usual method of ventilating greenhouses, is side vents and vents in the ridges and gable ends. The side vents often let cold air strike the plants. This, of course, is undesirable. Ridge ventilation largely eliminates the cold air problem and should be used in winter.

Side Ventilation. Ventilation in the spring or fall can be more effective if the plastic on the side is left loose at the bottom so it can be raised. It is fastened only at the top to the eave plate (usually a 2" x 4"). It hangs down and meets a piece of black plastic which extends about 2 or 3 inches above the soil line.

The dead-air space on the side wall is made by putting a 2-mil layer of plastic on the outside of the side framing or supports and a thin 3/4 mil layer on the inside of the framing. This dead-air space reduces heat loss. If these sheets of plastic are not too firmly attached to the sides or bottom, they may be rolled or pulled up to provide ventilation during very warm periods. A 1" x 1" or 2" piece is placed every 4 feet on the outside of the plastic to keep it from flopping. The piece is driven into the soil at the bottom and nailed at the top.

In cold weather the clear plastic is pinned to the black plastic, or soil can be placed along the edges to hold it. The plastic on the side must be long enough to extend 4 to 6 inches in the soil to insure good sealing. This is readily removed in late March after winter is over, and the sides can be raised as needed.

HEATING

A hot water heating system is best because it gives more uniform temperatures. The cost of the equipment is high and may require somewhat more care, although the operation can be made automatic. A steam system is also effective. It has about the same general layout as a hot water system, but the temperature is not as uniform as with hot water.

Most steam and hot water heat pipes in a non-bench house are run along the edges of the greenhouse. This is not the best arrangement to save heat, but it is the most convenient placement of pipes. Steam and hot water systems heat the house uniformly. Convection of the air gets heat to the ground level. In this process the warm air rises to the top and moves down to plants by convection or air movement. As a rule, the top of the house is the warmest part, sometimes being 20^{o} warmer than the air next to the soil.

Gas heaters are relatively simple to operate; they can be entirely automatic, and the equipment cost is comparatively low. Gas heaters may burn propane gas which usually costs somewhat more than natural gas. Propane gas, if combustion is complete, gives off only carbon dioxide and water. If the concentration of carbon dioxide is not too great, it favors plant growth. Few propane burners, however, give complete combustion. With incomplete combustion, harmful gases are given off. If natural gas is used, the burners should be carefully vented because some types of natural gas and their combustion products harm plants. Be sure to adjust burners so you have complete combustion.

Burners may be bought from the Bluegrass Butane Company, Lexington, Kentucky; the L. B. White Company, Onalaska, Wis. or the Modine Manufacturing Company, Racine, Wis.

A heat distribution system made of black polyethylene tubing is efficient and is much cheaper than pipe. With this system, tomatoes planted along the wall grew well even in sub-zero weather. Plain, clear plastic tubes can be used but do not work quite as well as black tubes and deteriorate more rapidly.

Heat Source - Any heater that warms air that can be drawn off by a fan can be used. The heater should not give off fumes. Steam or hot water coils can be used to warm air to be drawn off by a fan, but as a rule a direct hot air heater is more economical in both overhead and fuel costs.

Tube Installation - The polyethylene tube system is very simple to install. Connect a 6-inch or larger pipe in large houses to the heat source. Connect this pipe to a header (Fig. 1) of metal pipe with as many outlets as desired. Place the outlets so it will be convenient to run the polyethylene tubes between rows of plants (Fig. 2) or under benches. Black plastic tubes 4 inches in diameter and 3-mils

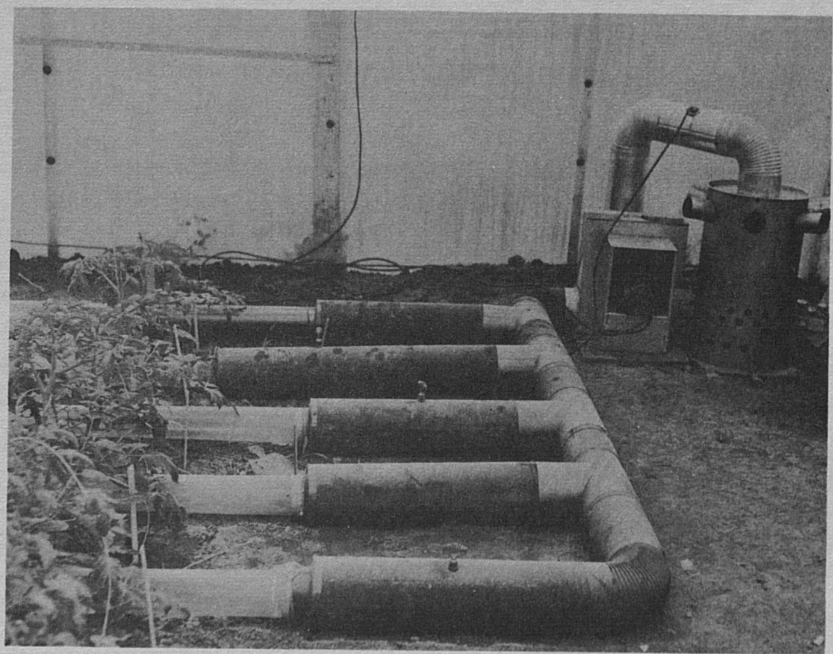

Fig. 1--Heating tube header distributes heat to rows. Tubes last longer when they are black polyethylene. The cover picture (bottom) shows plants that have just been set alongside the tubes.

Fig. 2--Black plastic tubes running through house from heating header. Partitions are for experimental tests.

thick may be used if the tubes are run between the rows. Six-inch tubes of the same material can be used if the tubes are placed under benches. In some cases, a small amount of metal pipe may be needed just beyond the header to prevent melting of the black plastic, for it melts at fairly high temperatures. Dampers may be needed in the headers to insure equal warm air flow through each tube. You can tell how evenly the heat is being distributed by watching the tubes as they inflate. If one tube inflates a lot faster than the others, it needs to be dampered down.

End of Tubes - It usually is best to run the tubes out of the house and have the heater inside the house draw air in. This keeps fresh air coming into the house at all times.

Be sure the division of air flow is uniform and that the heat tubes are long enough to utilize all the heat so that little goes to the outside. The end of the polyethylene tubes can be attached to a 4-inch metal pipe which extends outside to exhaust all possible fumes.

With this system, the heat is delivered along the row and warms the soil and air immediately around the plants. In this way, the temperature of the soil is higher than with other systems.

Handling Plastic Tubes - The plastic tubes need to be stapled in place about every 10 to 15 feet. These holders can be readily removed and the tubes rolled up out of the way when they are not needed or the house is to be reworked. The black plastic will last several years.

Trouble with Plastic Tubes - With long lengths of tubes expansion and contraction may cause the tubes to buckle when heat is on and the plastic expands. This is usually not noticeable except with lengths over 100 feet. Stapling the tubes helps correct this problem.

Sometimes moisture accumulates in the tube when gas heat is used and the tube is cold at the end. This condition is easily remedied by punching holes on the underside of the tube at the low points where water accumulates.

RESULTS OF TUBE HEAT ON TOMATOES

The tube heating system produced the best crop of tomatoes ever grown in the Kentucky Agricultural Experiment Station's greenhouses. The yield was 18 pounds per plant. The same variety (Michigan-Ohio Hybrid) grown in a glass greenhouse with steam heat yielded 15 pounds per plant. The plastic house tomatoes were also of somewhat better quality.

CIRCULATING FANS FOR VENTILATING PLASTIC HOUSES AND SAVING HEAT

Since plastic greenhouses are much tighter than glass greenhouses, it is important to have good ventilation and air movement. In cold weather ventilation is difficult without chilling the plants and losing too much heat. Any fan systems that keep the air circulating and mix the warm air from the top of the house with the rest of the air are helpful. It has been found that circulating fans set up as shown in Fig. 3 can save heat and provide good air movement with a minimum heat loss. The fans were installed according to the diagram.

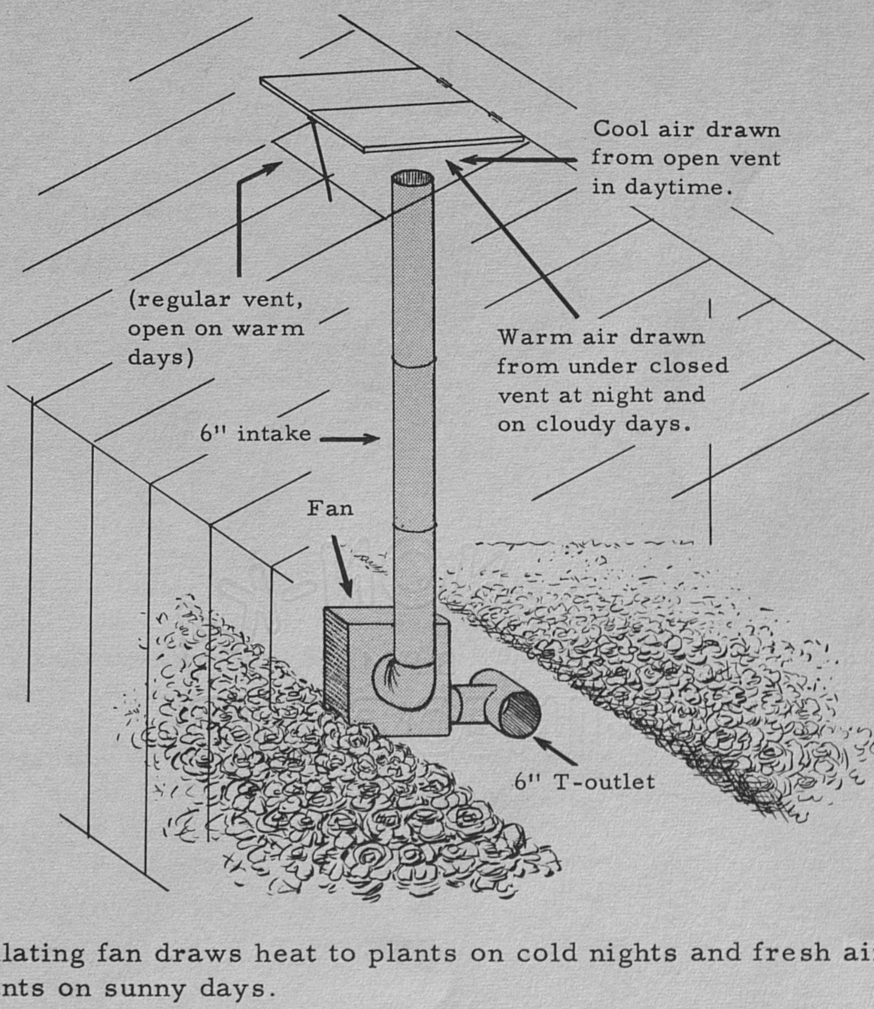

Fig. 3--Circulating fan draws heat to plants on cold nights and fresh air from vent to plants on sunny days.

A fan that circulates about 2,300 cubic feet of air per minute is large enough for a house about 40 to 60 feet long and 18 to 20 feet wide. The fan should be run regularly to get maximum benefit. On dark, cold days it should be run without opening the vents. On warm, sunny days it should draw outside air through the vents and disperse it in the house, thereby helping cool the house. On cold, sunny days the vent near the fan should be closed, but other vents can be opened. When the outside temperature is 50° or more on clear days, the vents over the fans should be opened so the fans will draw in fresh air. Of course, in cold weather there is some air exchange through small openings even when the vents are closed.

Temperature records have shown that the temperature at the floor level is up to 10° higher and the temperature in the peak is about 10° lower when the fans are going. This means warmer air surrounds even low plants, and air moves around the plants continuously.

CONSTRUCTION FEATURES

Foundation. A cement foundation can be used but is not necessary. Just the large posts need to be set in cement. In fact, unless the foundation is below the frostline, it is better to omit the cement wall and place the plastic in soil to a depth of about 6 inches. The one difficulty is that weeds grow between the two layers of plastic. This can be stopped with weed killers, but be sure the material is non-volatile and will not injure plants in the greenhouse.

Wood Preservation. All wood parts in the construction that are to be placed on or in the soil should be treated with a good wood preservative to prevent rotting. Houses made with treated wood will last much longer than those made with untreated wood. Treating ends of sash bars where they join the eave plates is good insurance against future trouble.

Roof Construction. Most plastic houses are not built as strong as commercial houses. Hence, extra precautions should be taken to prevent accumulation of snow on the roof during winter. One feature that helps solve the snow problem is a "steep" roof. It is suggested that the roof be built at a 40-degree angle instead of the usual 33-degree angle often used in glass houses.

FASTENING THE PLASTIC ON

It is usually best to apply the sheets of plastic the length of the house rather than over the house. The plastics are not extremely tough, and the best way to fasten them on is with laths. If the house is 84 feet long, roll out 85 feet of plastic around a pipe or stick about 12 inches longer than the width of the plastic. Tack one end of the plastic on the end sash bar next to the top of the roof. Roll out 6 or 8 feet over three or four sash bars, and pull it tight. Tack the lath on to within 8 inches of the lower edge. Continue this procedure until the entire lenght is attached. The next length is placed under the 8 inches so that there is a lap of about 4-6 inches, and tacked in the same way. If the lap is about 4-6 inches and the plastic is pulled tight, the laps do not need sealing and will stay together even in strong winds. The inside layer can be put up with metal disks and tacks since the wind does not get to it. Wide widths placed up and over the outside work quite well but are harder to put on and stretch tightly. Stapling the plastic helps to hold it in place until the laths are nailed on.

COST ESTIMATE ON A PLASTIC HOUSE

Since the project was started, the cost of plastic has dropped about 25 percent. To cover an 18'x84' house, the cost of plastic is only about $24 for the outside layer of 2-mil plastic and $15 for the inside layer of 1 1/2-mil plastic. A 3/4-mil liner costs only $7. 50 and last well for one season. These prices are based on large quantity wholesale prices. Plastic in small amounts costs more. The framework cost varies from $150 to $250. Heating units of the free-flame-type that burn propane cost about $100 per unit for 40 feet of house. This includes burner, thermostat, fan, and tubes.

A blueprint for an 18' x42' house is available from the Agricultural Engineering Department, University of Kentucky, Lexington, for 25 cents.

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