Development of Air Conditioned, Compartmented Greenhouse

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Progress in the development of new methods of plant breeding must, of course, be paralleled by the development of new tools and physical facilities geared to new requirements. As an example, the first hybrid corn seed was produced by laborious and costly hand detasseling; this task was soon taken over by machines developed for the purpose. The discovery and development of male-sterile inbred lines of corn made during the past six to eight years will undoubtedly retire the detasseling machines to obsolescence.

In the field of sugar beet breeding, transition from the use of mass selection techniques to the more detailed procedures involved with inbred lines and cytoplasmic male-sterility necessitates major changes in equipment and physical facilities; primarily the need changes from a relatively small number of large sized isolation plots to a large number of small ones. More precise control of pollination, particularly exclusion of "stray" pollen is imperative; stray pollen has little or no competition in the fertilization of cytoplasmic male-sterile plants or relatively sib-sterile inbred lines developed from self-incompatible breeding material; conversely, stray pollen in a group of "mass selected" plants where cross compatibility is the rule, has a minor chance of effecting fertilization. Further than this, plants produced by outpollination in heterogeneous populations are not readily identified since their influence on the total genic complex of the group is proportionately much smaller.

The above problems associated with changes in breeding techniques necessary to produce hybrid sugar beets, together with economic considerations, prompted the development of the first multi-compartmented greenhouse in the United States, specifically designed for such a purpose. Air conditioned chambers of various types have been used in Europe for a number of years;

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however, the requisites and climatic conditions which dictated the design differ markedly in a number of respects from those which prompted the structure described in the following paragraphs. Fortunately, progress in development of new plant breeding procedures has been paralleled by development of new, and perhaps more versatile, structural materials with which it has been possible to meet the needs of a changing program, and to do so at the lowest possible cost. Final design for this particular structure was arrived at after preliminary investigation and study over a period of several years; during this time, advancements in evaporative cooling methods moved rapidly. Engineering data collected by pilot type installations in existing greenhouses at The Great Western Sugar Company Experiment Station at Longmont, Colorado, proved useful in estimating air moving requirements, wet pad area, etc.

Presented here is a general description of the structure and some of the materials used. The glass house itself is of standard design and dimensions as manufactured by a nationally known commercial greenhouse manufacturer and measured over-all 25′3¼″ in width by 78′5⅛″ in length. All structural and glazing members are of extruded aluminum, with the exception of the exposed corners where galvanized iron angles have been used inside for greater strength. Standard, double-strength glass is used and glazed in the usual manner. Compartments inside the glass house are fabricated of extruded aluminum angle and polyethylene plastic film. Cooling is by water evaporation; negative air pressure through the wet pads is provided by vane-axial fans on each end of the subterranean main exhaust duct. Heating is by low pressure steam in aluminum "fin type" radiator with thermostatically controlled motorized valves.

A sketch of a typical cross section through two compartments is shown as Figure 1 with identification of the various parts as described herein.

A more detailed description of some of the features involved, together with specifications follows:

Compartments: A total of 15 compartments, each 10′2⅝″ x 5′2¼″ and 7′ high, are along each side of the center walk within the standard glass house. Sidewalls, fronts, and tops of these compartments are made by stretching .004″ thick polyethylene film on a frame of 1″ x 1″ x 3/16″ extruded aluminum angle. Cleats of flat ½″ x ⅛″ aluminum and aluminum stove bolts hold the film stretched in place. Front and sides rest upon rot-resistant redwood lumber, buried a few inches into the soil.

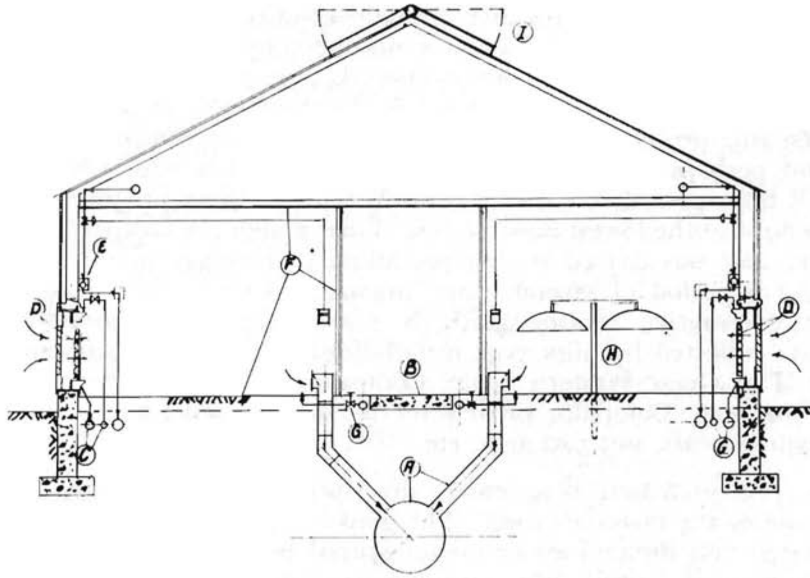

Figure 1.—Typical cross section of compartmented greenhouse—constructed 1959, Great Western Sugar Company.

A. 30.5″ diameter main exhaust duct and 6″ x 30″ rectangular risers to dampered register face in each of the 30 isolated compartments.

B. Cement walkway 36″ wide on building centerline.

C. Evaporative cooling system complete with sump, pump, automatic make-up, and gravity return.

D. Aspen cooling pad 34″ x 24″ x 2″ complete with 4″ gutter water distributor and collector, all made up in 30 wall frames complete with dust stop filters 20″ x 25″ x 1″. Frames become an integral part of concrete foundation wall.

E. 15 lb./0″ ga. steam heating, using 2″ aluminum fin tube x 4′ 0″ long per compartment, thermostatically controlling 3 compartments at one time.

F. 30 compartment partitions set from 1″ x 3/16″ tee and bar extruded aluminum and separated by .004″ polyethylene front, top and side walls. 10′ x 5′ x 7′ high.

G. Closed comparment irrigation system.

H. 18″ dome type reflectors for incandescent artificial light.

I. Ridge type ventilators.

J. Greenhouse structure 25′ x 78′ connected to a headhouse 12′ x 29′.

Heating system: Heat is supplied by low pressure steam (15psi max.); 2″ aluminum "fin type" radiation with one 4′ section in each compartment. Thermostatic control of motorized valves are arranged in such fashion that three compartments are controlled by one thermostat located in the center compartment.

Steam enters from above the first compartment in each set of three and condensate drains out underground from opposite end of each bank of three radiators.

Cold water supply to evaporative pads: Water is recirculated by means of a standard type 1/2 H.P. self-priming, centrifugal pump. Make-up water is automatically introduced into sump by means of a float valve. Drip from aspen pad evaporators is returned underground to sump. Inhibitory chemicals, obtainable from floral supply merchants, are used to prevent growth of algae and undesirable odors in cold water system. The aspen pads used are 34″ wide, 24″ high and 2″ thick.

Air ducts: A 30-inch diameter main exhaust duct is buried beneath the center walkway (Figure 1). Flat ducts, with adjustable louvers, leading from each small compartment to the main duct are 6 1/4″ x 2′6 1/4″. Air movement is accomplished by two vaneaxial fans, one at each end of the main duct which is discontinuous at the approximate center. Of the fifteen compartments on each side of the walkway, seven are ducted to one fan and eight to the opposite. Fan specifications are (a) 8230 CFM at 5000′ elevation and 70° temperature. (b) 1 1/4″ static pressure. Pollen in the entering air is screened by commercial type dust stop filters. size 20″ x 25″ x 1″, placed in the airstream ahead of the aspen evaporative cooler pad.

Irrigation of plants: When the compartments are closed and sealed at pollination time, the plants are irrigated in furrows from a spigot opening inside the compartment but operated from center walk area.

Supplemental light: Supplemental light within each compartment is supplied by two 150 watt incandescent bulbs in 18″ dome-type reflectors, on one central post, but arranged for vertical movement as plants increase in height. Power for lights is supplied from below ground by use of direct burial type cable. Control is from outside the compartment. Lights are completely removable from the compartment to facilitate soil preparation.

Operational: The standard greenhouse used has no side opening ventilators but does have full length ventilators at the ridge. Use of *exhaust* fans to provide air movement appears to reduce turbulence inside the compartment and promotes stratification of the air with respect to temperature. This phenomenon is considered advantageous for it reduces in size the mass of air to be cooled inside the compartment while simultaneously providing the desired climate in the space immediately surrounding the growing plants. Air temperatures taken vertically at

Table 1.—Air Temperature Gradient Vertically Inside Compartment

Height Above Surface	Outside Air Temperature	
	85° F.	94° F.
0	66	78°
2 ft.	70°	81°
4 ft.	72°	86°
5 ft.	78°	94°
6 ft.	96°	106°

two-foot intervals inside the compartment, with full midday sunlight and no shading of the greenhouse glass by whitewash or otherwise, are given in Table 1. Sugar beet plants were growing within the compartment at time of measurement.

It would appear that the portion of beet seed stalk that might grow beyond the 5′ height would be at such a stage of development that warmer temperatures at that level would not induce adverse effects. It appears entirely feasible, in the climate in northern Colorado at an altitude of 5000′, to utilize each compartment for growing at least two crops of breeders' seed per year, and to do so under very closely controlled and supervised conditions as opposed to space isolation with its inherent danger of loss of plants and greater cost.

Reference

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