AGRO-ENVIRONMENTAL TECHNOLOGY GRANT PROGRAM

FINAL REPORT

YEAR ROUND SALAD MIX PRODUCTION

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ABSTRACT

A plastic coated hoop style greenhouse, 17' x 96 ' (5m X 29 m), was constructed for growing salad mix on a year-round basis. The salad mix in this project is a blend of young and mature leaves of lettuce and greens. The greenhouse was sprayed with shading compound and mechanically ventilated for summer production. The soil beds were warmed by bottom heat supplied by buried water tubes for late fall, winter, and early spring production. Lighting was provided over a portion of the growing area during the winter. The production within this greenhouse was compared to an equivalent area in a nearby field as well as a conventionally heated greenhouse of the same size. The report presents details of construction and production techniques. An economic evaluation is included.

INTRODUCTION

There is a growing opportunity for small-scale farmers in Massachusetts to provide salad mix (Mesclun) to upscale restaurants. Salad mix consists of leaves of many lettuce varieties and other greens. Many restaurants are looking for a very fresh locally grown product year-round. This is a rapidly growing market that is being met by salad greens air-freighted in from California. In Massachusetts it is difficult to grow salad mix in the heat of the summer and costly to grow salad mix in greenhouses in the cold of winter. Restaurants need a steady consistent supply year-round in order to feature the salad on their regular menus. There is a need for a simple cost-effective means to grow salad mix year-round to maintain market share. From an environmental standpoint, when compared to growing head lettuce, salad mix growing requires virtually no pesticides/herbicides due to frequent harvest. Crops direct marketed to restaurants and consumers encourages small scale agriculture near urban centers where the open space preservation is needed.

Coonamessett Farm is a typical small scale farm that grows vegetables, small fruit, cutting flowers, herbs, bedding plants, etc. Products are sold at farmer's markets and directly to restaurants. One product offered to all markets is a salad mix made up of young as well as mature leaves of many varieties of lettuce and greens. This is a very profitable item during the good growing seasons of spring and fall. Techniques exist to grow the mix through the hot summer months but at a higher cost (ie, increased watering, continuous transplanting, hand cultivation, shade structures, etc.) . Harvest season can be extended into the fall using row covers, but the plants suffer leaf damage due to frost by October. It is a difficult process of covering/uncovering crops for harvest and time consuming to pick out frost-damaged leaves. A good crop can be grown in the greenhouse through most of the winter, but at a great expenditure of fuel making the operation marginal at best. The demand for the product is there but prices can not be raised due to competition with product air-freighted from California.

The main objective of this project was to produce salad mix cost-effectively on a year-round basis. The proposed production unit was to be a high-tunnel structure (29 m x 4 m) set over an insulated trench. The plan was changed to substitute a wider greenhouse (5 m wide) because the price was the same as the smaller unit. In addition, since electricity was needed for the lights and heating system, it was decided to add a ventilation fan. Heating was provided by a root-zone heating system. Two grow lights were tested and evaluated. During the summer the plastic structure was sprayed with liquid shading compound. Previous field trials of trench growing and liquid shade covered greenhouses successfully maintained production during summer months. While this project focused on the cost aspects of winter production, summer growing methods were incorporated into the production unit as well. The experimental production unit was compared to a conventional greenhouse and field operations.

The production unit was in commercial use for the length of the project. All components of the unit are commercially available off the shelf thus instantly adaptable by commercial farmers. The economic potential of this form of production is significant. One large restaurant can consume 30 pounds of salad mix per week during the off-season winter months on Cape Cod. Salad mix sells for $6.00/pound. It was anticipated that the experimental growing unit could produce this amount under the worst growing conditions based on our greenhouse growing experience. Multiplying the expected minimum production/sales rate (30 lbs/wk @ $6/lb) by a fifty week growing season yields an annual gross revenue of $9000 per production unit. Besides paying for the production unit, this approach should yield a profit in the first year. More importantly, this is one of few income producing food crops from November to May thus its significance can not be overstated. Farms closer to the large winter market of Boston will do exceptionally well with this product. For example, the summer demand for Coonamessett Farm's product in Falmouth alone exceeds production potential; one large restaurant can easily consume 100 pounds of salad mix per week.

EXPERIMENTAL DESIGN

The project was set up to accomplish a number of objectives as generally described in the preceding paragraphs. More specifically the project objectives were as follows:

a) To construct the greenhouse production unit as planned to determine the true fixed cost of the completed unit as well as any unanticipated design problems. Data collected primarily consisted of expenses.

b) To operate the production unit in a commercial mode through a summer and winter season to determine operating costs/income, production levels, and operational problems. Data collection included fall/winter production levels, fuel expense, and operating temperatures. Soil temperature in the production unit were obtained by a soil thermometer and a continuous temperature data logger.

c) To make some comparisons with alternative production methods. This was accomplished by simultaneously planting an equivalent area of a nearby field with the same transplants as the production unit at the beginning of the summer. Soil temperature and moisture data were collected from both areas. Comparisons were also made with a crop planted in a conventionally heated greenhouse but these were limited since the planting times were not the same due to delays in receiving the grant funds. However, fuel consumption comparisons during September through November were made between the two greenhouses.

Ideally, it would of been most appropriate, and it was our intention, to collect data on the daily harvest from each of the three areas being monitored. However, delays in getting the grant underway, coupled with the commercial need of getting production up early, required us to start the conventional greenhouse two months ahead of the experimental production unit. This made comparisons of limited value. In addition, each area was planted with a mix of lettuce and greens. In order to customize the salad product for each particular market, the harvesters had to move between each of the areas and selectively harvest what they needed to complete an order. This made it impossible to keep harvest records independently for each area. For example, an order would come in for 5 lbs of Asian mix. The harvester might pick the Tatsoi from the greenhouse, the mustards from the experimental unit, and the other greens from the field. During the fall, when the markets were reduced to just a few restaurants, it was easier to keep track of the harvest and records were kept. Comparisons are again limited during this period since we concentrated on harvesting the outside field crops first to save the protected crops for the winter. Thus the records to not clearly indicate the full production potential of the experimental unit.

PRODUCTION UNIT DESIGN AND CONSTRUCTION

We completed high tunnel specifications in April and opted to purchase a 5 m x 29 m (17' x 96') greenhouse frame in lieu of a 4 m (14') wide frame because the price was about the same. This would also allow for better comparisons with our conventionally heated similar 5 m (17') greenhouse. The greenhouse was ordered, received and erected on a prepared site. A twenty-four inch deep by 12' wide trench was dug inside the greenhouse frame and lined with one inch thick Styrofoam board. The trench was then filled with six inches of field loam. The Biotherm heating tubing was placed in the high-tunnel on top of the loam forming two beds; each three feet wide by ninety feet long. The tubing was covered with four inches of screened sandy loam. The final level of the loam surface was twelve inches below the outside grade. The planting area over each 3' wide tubing bed was actually about 4.5' wide leaving a 3' center walkway. A single layer of 4-mil plastic was placed on the high-tunnel frame and sprayed with two coats of Ezy-Off Kool-Ray White liquid shading compound.

Several changes had to be made to the original project plan in addition to the frame size change. The Biotherm system requires a separate structure to be erected to house the controls. We accommodated this requirement by making one of the end walls into a shed-type structure. We also decided to buy a LP gas fired water heater in lieu of an electric water heater as it should have a lower operating cost and be easier to monitor for fuel consumption.

At this point the north-south oriented high-tunnel had no end wall covering (other than the shed for the Biotherm system) and we found significant natural ventilation even without a breeze blowing. We decided to conduct the first phase without installing plastic film over the end walls and without operating the ventilation fan/shutter system. Watering was provided by overhead spray nozzles spaced ten feet apart with overlapping spray patterns.

In September, the end walls were covered with plastic film and a door installed. A second layer of plastic and inflation blower were installed on the frame to improve insulation and to protect from snow loads. The Biotherm heating system was turned on to maintain a soil temperature of 50 degrees F. In November, row cover was placed over the growing beds. Two 500 watt halogen lights ($10 @ Bradlees) were installed centered over the southern third of the greenhouse about 7' above the crop. The lights were placed on an enclosed outdoor type timer ($15 @ Radio shack) to go on at 0400-0600 and 1600-2000.

CROP PRODUCTION

Salad mix crops were established in the conventional greenhouse and under row cover in the field in April 1995. On June 27, 1995, 900 lettuce transplants (8 cultivars) were transplanted from 806 packs into the experimental unit. They were spaced in rows four across each bed and eight inches apart between rows. In addition 200 greens (Tat-soi, Mibuna, Hon Tsai Tai, Autumn Poem) were similarly planted.

Harvesting of individual leaves from the experimental production unit began on July 7, 1995. Peak production spanned a period of five weeks to August 15, 1995. Harvest after this point were minimal but included edible flowers from the greens. Six hundred new lettuce transplants and four hundred greens (Red Amaranth, Golden Purslane) were inter-planted between the old plants starting on August 15, 1995. During the five-week peak harvesting period an average of 45 pounds of product was harvested per week from the experimental unit and sold for $6.00/pound yielding $1,350.00 in gross income.

Summer Controls

During the production period from the experimental unit, two other growing areas were monitored as controls. The first area was a 48-foot long section of a greenhouse structure (similar to the high-tunnel but with double plastic) where lettuce and greens were being grown. The area was covered with shading compound and mechanically ventilated (thermostat setting at 75 degrees F). The crop in this area was planted several months earlier in four beds of similar planting density to the experimental unit. The crop was tilled in on July 21, 1995 and a second crop of greens only planted.

The second control area was a section of field planted at the same time as the experimental unit with the same lettuce cultivars at the same planting density. The experimental unit and this field section were monitored twice daily (morning and late afternoon) for soil temperature and moisture. Measurements were taken from three places in each planted area an averaged. Data collected from the field and the experimental unit are presented in Appendix A.

It became obvious very soon that there were major differences in the soil (primarily organic matter) that affected moisture retention. We tried to maintain some consistency in moisture levels within and between test sites. Equally, we could not maintain any control of existing nutrient levels in the soil. Some general observations were possible.

Production rates from the experimental unit and field site were about equal the first two weeks. After this point the field site was under severe weed pressure compared to the experimental unit. The lettuce bolted earlier in the field even though there was no significant difference in the soil temperature between the two sites at the reading times. However it certainly felt a lot hotter in the field during mid-day than in the experimental unit. While we monitored soil temperature it may be more appropriate, and more difficult, to have monitored air temperature at crop level. This would still not give an indication of radiant heating of the crop leaves by direct sunlight. Still, we can surmise that the earlier bolting of the crop in the field was not due to soil temperature. Also it would seem that shading the soil and depressing the growing bed in the experimental unit did not lower the soil temperature compared to the field.

The greenhouse site had problems with disease, slugs and aphids; the experimental unit did not. It is too early to conclude anything but this may be due in part to the higher amount of vegetative matter in the greenhouse site. In addition, this site has been in use for two years though well cleaned between crops. During the fall, the conventionally heated greenhouse used twice the propane as the experimental unit to retain air temperatures at 40 degrees F. The greenhouse was shut down in late November due to the high fuel consumption and low productivity.

<u>Fall/winter production</u>

During the cold weather growing period when the Biotherm heating system was in operation, from October 12, 1995 through February 29, 1996, data was collected daily from the experimental greenhouse (see Appendix B). An effort was made to take the readings at 0730 each morning before the sun had the chance to significantly impact the temperature. On a sunny morning, the greenhouse air temperature on the coldest days would be up to 60 degrees F by 0800. The "Hot out" and "cold in" readings indicate the temperature of the water leaving and returning to the hot water heater. The soil temperature readings in the Appendix B table were from a soil thermometer measuring 6-inches down. The thermometer was located in the center of one of the two heated beds about 15 feet from the south end. Before November 14, 1995, the thermometer was located six inches outside the bed (in the center walkway) and the temperature were about 8 degrees F cooler than in the center of the bed. The outside air temperature was from a protected thermometer located about five feet above the ground outside the greenhouse. The inside min/max readings were from a thermometer located at crop level in the greenhouse. The pressure reading is a measure of propane usage.

Several observations were made during the test period. If the temperature in the greenhouse fell below 28 degrees F, frost would form on the row cover. There was never any frost on the plants when covered, even on the coldest days. When uncovered the lettuce plants did suffer frost damage to the leaves below 28 degrees F, but no plants died due to the cold. On cold mornings there was almost always a fog in the greenhouse. The inner layer of plastic was untreated so dripping was common almost all the time. On the coldest days the drips came down as snow flakes. If the ventilation fan was placed on a timer to ventilate for five minutes each hour, these excess moisture problems would probably have been eliminated. Another problem was that the GFI circuit breaker located in the greenhouse outlet supplying power to the Biotherm circulating pump tripped on several occasions for unknown reasons. When this occurred there was a slow decline in soil temperature over the course of several days. This can be seen on the continuous temperature plot for Jan/Feb located in Appendix B.

The Biotherm system was capable of keeping the soil temperature within set limits. Differences between day and night soil temperatures usually were about 6-8 degrees F. The Biotherm system in the experimental unit kept the air temperature at crop level about six degrees warmer than outside minimum temperatures on average. On the coldest day, with outside temperatures at zero, the inside air temperature at crop level was 20 degrees F without row cover. The plants were frozen but recovered.

Harvests were monitored from September 1, 1995 to March 1, 1996. A total harvest of 390 pounds (Appendix C) sold for $2,343.00. During this period 372 gallons of propane were used costing $1.39/gal for a total cost of $517. It takes on average one hour to pick and process 5 lbs of salad mix. Labor cost for picking this quantity of product, at $7.00/hour was $546.00.

Plant growth between the first week of December and the last week of January is very limited by light. An attempt was made to augment plant growth using halogen lights during December and January. The blue light generated by metal halide or sodium vapor lamps is needed for the formative growth of crops like lettuce. One thousand watts of lighting were placed seven feet above the crop in one section of the greenhouse as described earlier. Visual observation did not notice enough of a difference in plant growth to justify the cost of electricity. On Cape Cod, electricity for a "seasonal operation" such as Coonamessett Farm now costs more than 17 cents per kilowatt.

ECONOMIC EVALUATION

Table One presents the cost of the production unit as $7,259.00. This cost is complete including connections to water and electricity. We did not plant the full width of the unit because of the experimental "sunken bed" and the limited width of the Biotherm coverage (6'). Based on the experimental results we would recommend not depressing the soil bed, increasing the space between Biotherm tubes to cover the full width of the greenhouse, placing the insulation board at the greenhouse perimeter, and planting the crop intensively in four beds. These changes would increase the growing area by 30%.

Our experience indicates the following production potential in pounds: January (0), February (60), March through May (120 per month), June through August (160 per month), September-October (120 per month), November (50), December (30). This totals to 1220 pounds of product at $6.00/lb yielding $7,320.00. To maintain this production requires intensive interplanting of new transplants between older plants. There would be about four complete changes of plants per year. A fully planted greenhouse would contain about 1500 plants thus 6000 transplants (125 48-plant flats) would be needed annually. We figure it costs us about $5.00 to produce a flat. About eight hours per week was spent in transplanting, weeding, and other crop maintenance duties. Fully planting the greenhouse might yield as much as $10,800 of product with added harvesting, crop maintenance and heating costs. A complete economic evaluation based on this discussion is provide in Table Two. The bottom line is that the experimental unit did not produce enough to be very profitable, but a fully planted unit would be economically feasible producing a good return.

We would recommend the substitution of oil heat for propane. Fuel oil is now available on Cape Cod for 69 cents per gallon. A fuel oil boiler for this size Biotherm system would cost about $750.00. All totaled, it might initially cost about $500 more to go with fuel oil heat (tank, pad, etc). However, at current prices the cost of heating with fuel oil will be about half of the cost of propane on Cape Cod.

CONCLUSION

The project was successful in that it demonstrated that salad mix can be grown profitably on a nearly year round basis in Southeastern Massachusetts. This is even with the high cost of fuel, electricity, and labor. The experimental production unit is capable of producing crops a full two months before and a month longer than our best field techniques. The protected enclosure of the greenhouse was also demonstrated to be a more controlled environment for reducing weed and insect pressure during the summer months. Bolting of the crops was also delayed in the shaded greenhouse production unit.

There were no significant problems though major improvements to the planting bed layout are suggested for maximizing production. The need to depress the growing beds for added cooling was not demonstrated thus space can be more fully utilized. Maintaining soil temperature at 50 degrees F and plant canopy temperatures above freezing required half the fuel when compared to a conventionally heated greenhouse maintained at 40 degrees F.

It is difficult to predict how this project's result will influence the agricultural industry. Many years ago New England had many glass hot houses and heated hot frames producing winter vegetables. These vanished when lower priced vegetables started coming in from California and southern producers. The new generation of efficient and low cost technology demonstrated by this project is only one part of the equation. The other part is the prices set by the California and southern producers of product. As long as they have cheap migrant labor, low cost electricity and water, inexpensive transportation, and lower environmental standards New England producers will be at a disadvantage. However, these factors are all in one way or another supported by government subsidy or neglect. This all may change and once again New England will be competitive.

TABLE ONE: Production Unit Cost

Site Preparation		
12- hours Bobcat time		$ 480
18- yards screened loam		$ 270
	Sub-total	$ 750
Structural		
1- 17' X 96' Inflation Buster (4' spacing)		$ 1026
38- Oki-pet base channel for poly lock		$ 157
38- Oki-pet spring insert for poly lock		$ 62
1- 6 mil, 28' x 100' 703 poly		$ 178
1- 4 mil, 28' x 100' 701 poly		$ 84
12- Perlin pipe 16' 2 1/2"		$ 192
2- Perlin hardware kits		$ 71
2- 20' double spline gable end		$ 118
28- 2' x 8' T&G styrofoam		$ 302
- lumber for baseboard and endwalls		$ 356
1- gal shading compound		$ 19
	Sub-total	$ 2565
Mechanical		
1- Biotherm root zone heating system		$ 1026
1- 40 gal LP gas hot water heater		$ 230
- misc heater vent pipe		$ 72
-additional piping/valves for biotherm system		$ 463
1- 3C615 36" Dayton ventilation fan		$ 303
1- 2C832 Dayton shutter motor		$ 67
2- 3C311 42" Dayton wall shutter		$ 212
1- 2E207 Dayton two-stage thermostat		$ 80
1- 4C440 Dayton blower w/mounting hdw		$ 75
	Sub-total	$ 2528
Irrigation		
1- 11 gpm Dosetron fertilizer injector		$ 270
- misc irrigation; ovhd sprinklers and piping		$ 84
	Sub-total	$ 354
Labor		
Greenhouse erection (farm staff)	60 hours	$ 480
Electrician (includes parts)		$ 462
LP gas hook-up (includes parts)		$ 120
	Sub-total	$ 1062
Total Production Unit Cost:		**$ 7259**

TABLE TWO: Economic Feasibility of Salad Mix Production

A. Production unit fixed cost:

Propane	$ 7259
Oil (not evaluated)	$ 7759

B. Income

Experimental unit: 1220 pounds @$6	$ 7320
Fully planted unit: 1800 pounds @$6	$10800

C. Production expenses of fully planted unit

Plants (125 flats @ $5.00)	$ 625
Propane (500 gal @ $1.40)	$ 700
Fertilizer (1 bag hydrosol)	$ 30
Labor	
crop maintenance (400 h @ $7)	$ 2800
harvest and process 1800 lbs	$ 2520
Electricity & water	$ 80
Misc (equipment, repairs)	$ 100
Subtotal variable expenses	$ 6855

D. Annual capital recovery- propane

10 year structure ($6913 @ 10%)	$ 1175
5 year plastic ($ 346 @ 10%)	$ 59
Total fixed and variable costs	$ 8089

E. Net returns (Income minus total costs)

fully planted propane fueled	$ 2711 or $1.51/lb

Photographic Legend

Sheet 1:

Three photos of the greenhouse under construction. The photos show the loam filled trench being lined with insulation board, the greenhouse posts with baseboards installed, and the frame installed on the posts.

Sheet 2:

1. A view from the west of the experimental greenhouse during January, 1996.
2. A close-up of the south wall showing the shed that houses the Biotherm system heater and controls.
3. A view inside of the shed showing the hot water heater, expansion tank, and circulating pump all covered with R-5 insulation. Note in the lower left the larger watertight enclosure that houses the temperature sensor control.
4. Another view from inside of the south wall.

Sheet 3:

1. The Biotherm tubing being covered by loam.
2. The north wall of the greenhouse and ventilation fan.
3. The tubing supply and return manifolds in the center of the structure left uncovered.
4. A view towards the north wall.

Sheet 4:

Four views of the greenhouse; two before planting and two showing the summer planting two weeks apart. Note overhead sprayers for irrigation.

Sheet 5:

1. Intense planting of greens in trays used for transplants.
2. Inside the greenhouse in January. Note hoops for row cover.
3. One of the lights tested with attached timer.
4. Same as 1, different plants.

Sheet 6:

1. Kyona/Mizuna
2. Hon Tsai Tai
3. Temperature probe next to a diseased lettuce plant.

Sheet 7:

1. Osaka purple mustard
2. Tatsoi
3. Red Russian kale
4. Hon Tsai Tai