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INSIGHTS INTO THE ECONOMIC VIABILITY OF A NEW CEA SYSTEM PRODUCING HYDROPONIC LETTUCE

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ABSTRACT

A new CEA (Controlled Environment Agriculture) system growing Boston lettuce, *Lactuca Sativa cv. 'Vivaldi'*, achieves the same quality and quantity of production every day of the year. The year-round constant quantity and quality production indicate potential for success. However, our research showed that out of nine selected U.S. locations with different climatic and economic conditions, the Northeast had 25.7 percent higher production costs for the same yield.

The analysis indicated that given current prices and costs, CEA hydroponic lettuce production in northern climates such as Ithaca in upstate New York and Chicago is marginal to negative in terms of economic viability. As a result, the question arises about the future viability of CEA in areas such as upstate New York and New England where electricity costs are high and the climate is relatively cold. Many such areas are struggling with the future viability of agriculture. Thus, this study provides alternative ways to increase the economic viability of this new technology in the Northeast. The importance of local production, state level promotion programs and other potential incentives, and metro farm alternatives are examined. The analysis is applicable to other agricultural products produced in the Northeast at higher cost than in other locations in the southern and western United States.

Key Words: Economic viability, Northeast, hydroponic lettuce, Controlled Environment Agriculture (CEA)

Insights into the Economic Viability of a New CEA System Producing Hydroponic Lettuce

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Introduction

The distinctive difference of this new CEA system is that accurate greenhouse climate control and integration of supplemental lighting provides consistent year-round rapid plant growth resulting in a higher yield than with any other existing systems. The CEA hydroponic system, when fully in production, yields a harvest of 945 heads of lettuce every day, seven days per week. It takes 35 days from seed to harvest 0.33 lb heads of lettuce.

The CEA hydroponic system provides an annual production level of 11.5 lbs/ft^2 which is considerably higher than any other existing hydroponic systems (Vestergaard, 1988; Lim, 1996; Jensen, 1999; Osvald et al., 1998).

In addition to higher yields and better quality production, the CEA hydroponic system has many other advantages, including a reduced need for disinfectants, decreased water consumption, more efficient use of nutrients, better control of plant development, qualitatively improved products, and more efficient use of labor. The CEA hydroponic operation is an environmentally friendly system since it eliminates the water and fertilizer runoff, and the produce is pesticide-free.

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Annual Operating and Production Expenses

A commercial-sized CEA demonstration greenhouse constructed in Ithaca, NY is used as a reference for input data. Primary and secondary data sources were utilized to determine the costs for eight other locations: Chicago, Denver, Los Angeles, Miami, Phoenix, Raleigh, Seattle, and St. Louis.

Direct input costs, except for fertilizer, oxygen, and water, were assumed to be provided by the same suppliers for all potential locations. Cost figures for fertilizer, oxygen, and water were calculated by using the economic engineering approach based on previous research results from the Cornell CEA research group and experience from the proto-type facility (see table 1).

Table 1. The Annual Production and Operating Costs of CEA System

	Chicago	Denver	Ithaca	L. A.	Miami	Phoenix	Raleigh	Seattle	St. Louis
Production (heads)	344,925	344,925	344,925	344,925	344,925	344,925	344,925	344,925	344,925
Shrinkage (3%)	10,348	10,348	10,348	10,348	10,348	10,348	10,348	10,348	10,348
Product Price [a]	0.74	0.71	0.81	0.65	0.82	0.69	0.81	0.75	0.78
Revenue	247,587	237,550	271,008	217,475	274,353	230,858	271,008	250,933	260,970
Brokerage Fee (8%)	19,807	19,004	21,681	17,398	21,948	18,469	21,681	20,075	20,878
Depreciation [b]	53,808	51,636	54,696	57,705	48,909	52,191	45,675	55,455	52,520
Interest [c]	15,296	14,465	15,429	16,423	13,943	14,596	13,008	15,618	14,770
Insurance	5,381	5,164	5,470	5,771	4,891	5,219	4,568	5,546	5,252
Property Tax	5,546	3,791	9,029	4,894	3,104	10,061	2,522	3,813	1,962
Repair & Maintenance (Equipment)	2,090	1,982	2,135	2,285	1,845	2,010	1,684	2,173	2,026
Repair & Maintenance (Greenhouse)	3,226	3,226	3,226	3,226	3,226	3,226	3,226	3,226	3,226
Miscellaneous	2,016	2,016	2,016	2,016	2,016	2,016	2,016	2,016	2,016
Total Annual Overhead Cost ($):	87,363	82,280	92,001	92,320	77,934	89,319	72,699	87,847	81,772
Seed	6,432	6,432	6,432	6,432	6,432	6,432	6,432	6,432	6,432
Fertilizer	2,628	2,628	2,628	2,628	2,628	2,628	2,628	2,628	2,628
Oxygen	1,980	1,980	1,980	1,980	1,980	1,980	1,980	1,980	1,980
Media, Rockwool	20,340	20,904	20,256	21,144	20,748	21,264	20,304	21,192	20,340
Plastic Package	8,676	8,676	8,676	8,676	8,676	8,676	8,676	8,676	8,676
Shipping Container	21,348	24,768	24,084	26,652	24,216	27,636	23,376	27,420	22,104
Annual Total Direct Variable Cost ($):	61,404	65,388	64,056	67,512	64,680	68,616	63,396	68,328	62,160
Utilities	46,704	35,467	65,162	27,005	18,039	27,941	36,475	26,998	29,678
Telephone	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800	1,800
Office Expenses	600	600	600	600	600	600	600	600	600
Labor	63,539	58,021	66,969	60,480	63,341	55,028	58,340	63,500	61,843
Total Annual Indirect Variable Cost ($):	112,643	95,888	134,531	89,885	83,780	85,369	97,215	92,898	93,921
Total Cost [d]	281,217	262,560	312,269	267,115	248,342	261,773	254,991	269,148	258,731
Per Head Lettuce Cost	0.84	0.78	0.93	0.80	0.74	0.78	0.76	0.80	0.77

[a] Product price is the most likely grower price estimated as the average of maximum and minimum product price. Revenue was calculated based on the most likely price

[b] Straight-line depreciation over 10 years

[c] Interest was estimated as the interest payment at 8.5% on the average value of the investment

[d] Total cost excluding local transportation cost

The major utilities, such as electricity for lighting and ventilating as well as heating requirements supplied by natural gas, were estimated by using the computer program “Liteduty” (Albright et al., 2000). The weather data of a “typical year” was used to estimate the parameters for all locations. Using hourly weather data of solar irradiance, the computer model calculated the monthly operating cost of the supplemental lighting system for CEA hydroponic greenhouses based on reaching a prescribed daily integral of PPF (17 mol/day).

The electricity demand and energy rates were received from the local providers of each location; however, special discount programs were not considered. The highest electric energy rate was in Phoenix, AZ location followed by Ithaca, NY and St. Louis, MO. The highest demand charge was the Chicago, IL location followed by Denver, CO and Ithaca, NY (see table 2).

Table 2. Total Annual Electricity Cost of CEA Hydroponic Lettuce Operation in Selected U.S. Locations

	Electric Rate ($/kWh) [a]	Demand charge ($/kW) [b]	Total Electricity Cost ($/yr)	Cost/ft^2 Floor Area ($) [c]	Per Head of Lettuce Cost ($) [d]
Chicago, IL	0.0440	12.69	35,230	4.37	0.10
Denver, CO	0.0165	12.55	24,248	3.01	0.07
Ithaca, NY	0.0718	11.35	47,120	5.84	0.14
L.A., CA	0.0293	10.53	21,466	2.66	0.06
Miami , FL	0.0261	6.25	16,481	2.04	0.05
Phoenix, AZ	0.1047	1.76	23,146	2.87	0.07
Raleigh, NC	0.0471	4.89	27,884	3.46	0.08
Seattle, WA	0.0347	1.60	19,376	2.40	0.06
St Louis, MO	0.0703	0.00	18,842	2.34	0.05

[a] Average of on-peak and off-peak electric rates provided by local power company
[b] Average of summer and winter demand charges provided by local power company
[b] The cost per ft^2 floor area was calculated as: cost per ft^2 greenhouse area = total annual electricity cost/8,064 ft^2
[c] The cost per head of lettuce was calculated as: cost per head of lettuce = total annual electricity cost /344,925

Northeast locations receive much less natural sunlight than southern and southwestern locations and, therefore, higher artificial light levels are needed to provide the same amount of light (17 mol/day). Higher need for supplemental lighting combined with higher energy and demand rates resulted in the highest electricity costs in Ithaca, NY. The total cost of electricity including basic and demand charges was $47,120 in

Ithaca, New York. The per head lettuce cost of electricity was approximately $0.14 at this location. On the other hand, the total cost of electricity was cheapest in Miami, FL, amounting to $16,481. The per head lettuce cost of electricity was approximately $0.05 in Miami (see table 2).

The highest per unit natural gas price and the highest total yearly heating requirement resulted in the highest total cost of heating in Ithaca, New York at $16,788. The per head lettuce cost of heating was approximately $0.049. On the other hand, the total cost of heating was cheapest in Miami, FL, amounting to only $510 (approximately $0.001 per head) (Ilaslan, 2000).

Daily tasks of seeding, transplanting, and harvesting is done by two full- time workers at each CEA hydroponic facility. The labor cost for two workers was calculated by hourly wage plus managerial salary and benefits (Ilaslan, 2000).

The average of the estimated annual total labor and management cost and labor and management cost per square greenhouse floor area for two workers for nine locations was $61,229 or $7.59 per ft^2. The highest total labor cost was determined to be in Ithaca, NY, with $66,969 or $8.31 per ft^2 while the lowest was in Phoenix, AZ with $55,028 or $6.82 per ft^2.

The production cost of per head of lettuce was calculated and reported (see table 1). Based on the results of this study it appears that southern and southwestern areas have a cost advantage in the production of CEA hydroponic lettuce. The cities of Miami, Raleigh, and St. Louis had the lowest per unit production costs because of higher natural light condition, relatively low heating requirements, and labor costs. Although similar quality and quantity of product is expected from different production locations provided by optimum control of environmental factors, the production cost varied 25.7% between the lowest cost producer (Miami, FL) and the highest cost producer (Ithaca, NY). This difference can be attributed almost solely to electricity and heating cost differences of the two locations.

Insights into the Economic Viability of the CEA System

The question that needs to be answered is what can be done to increase future viability of CEA in areas struggling with the future viability of agriculture such as upstate New York and New England where electricity costs are high and the climate is relatively cold.

Urban residents value the open space associated with agriculture and having a local supply of fresh produce. The Agriculture and Food Systems Economic Viability (AFSEV) Program at Cornell University is working with state, regional, and local development agencies to find ways to encourage such economic activity. State agencies have programs to lower utility rates to large industrial firms to encourage location in New York. Certain state and federal development programs and agencies provide guarantees for low interest loans for the construction of new facilities. Sometimes a firm is given property tax abatement for the first few years of operation. These programs have not usually been available to agricultural projects because the job creation potential of a single project is small since agriculture is generally a capital intensive, not a labor intensive industry. In the future, AFSEV needs to help articulate the case for encouraging agricultural development to attain benefits in addition to job creation for local communities.

The recommendations on how to increase the economic viability of the CEA hydroponic system are examined below.

Product Quality and Importance of Local Production

The product has to be sold at a premium price (Ilaslan et al., 2000) in all of the potential locations in order to achieve a successful investment of a CEA hydroponic lettuce system. In order to receive the price premium, a careful marketing strategy should be implemented to persuade that the consumers the extra price they pay for the product quality and safety (produced following the Hazard Analysis and Critical Control Point, HACCP, principles) is worth it. The benefits of local production should also be emphasized.

In choosing fresh produce, freshness, price, appearance, and convenience are more important to consumers than where the produce was grown (Lockeretz, 1986; Eastwood et al., 1987; Thompson and Kelvin, 1994). However, there are certain produce items consumers prefer when grown locally (Brooker et al., 1987; Eastwood et al., 1987). For example, tomatoes branded as “local” were priced up to 33% above the “imported” tomatoes without losing their market share, indicating that consumers perceived “locally” grown as a premium quality added to the product (Brooker et al., 1987). Pena (1985) reported that high quality tomatoes would sell at 100% markup or more of the field grown competitors if the field grown product was unattractive. With hydroponic lettuce, a 15 percent premium would be necessary to compete against produce shipped from the most competitive location, Raleigh (Ilaslan, 2000).

In order for consumers to have locally grown food available, nearby farmers must stay in year-round business. Thompson and Kelvin (1994) investigated consumer concerns about the viability of local farms in Pennsylvania. The results indicated that consumers, while agreeing farming created both on and off farm job opportunities, were concerned about the viability of farms in their local area.

Wilkins et al., (1996) reported that consumer support for local agriculture was impressive. Over 98% of the consumers surveyed agreed keeping farms viable in the Northeast was important and 80% would be willing to pay more for produce local farmers grew if doing so would help them stay in business. Consumers understood that buying local produce was an effective way to keep farms viable (Thompson and Kelvin, 1994; Wilkins et al., 1996).

It was reported that consumers wanted year-round availability of fresh tomatoes, lettuce, cucumbers, squash, broccoli, sweet corn, and strawberries. In the current situation, none of these items is available fresh from local sources in the Northeast throughout the year. In fact, the relatively short growing season is a major impediment in getting locally-grown produce into chain stores in the Northeast (Wilkins et al., 1996). However, in addition to lettuce, tomatoes, spinach and many more crops have the potential to be grown in a system such as CEA hydroponic operation (Albright and Langhans, 1996).

State Level Promotion Programs

It is anticipated that promotion of local produce may be used to support regional agricultural systems to preserve farm land and rural community economic viability, which could require less energy for transporting food. In addition, a strong brand image should be built to take advantage of local agriculture promotion programs.

Efforts at the state level to protect and promote local agricultural interests have existed more than 60 years. State governments have been involved in the advertising and promotion of agricultural products since the 1930s (Halloran and Martin, 1989).

State promotion programs that can be viewed as a type of "state of origin" labeling are initiated to protect local producers from interstate competition by capitalizing on consumers' loyalty to their state of residence. The popularity of these programs has been increasing with at least 23 states actively involved in promoting their own agricultural products, and several others considering the introduction of such a program. Budget commitments to agricultural promotion programs range between $80,000 to over $2.0 million (Williams, 1995).

State promotion programs can influence consumers' perception of local agricultural products by providing information about superior quality or freshness, or they may simply appeal to the parochial interests of consumers wishing to support local agricultural industries. The important assumption is that demand is not only a function of prices and income, but also depends upon consumer preferences and perceptions, which could vary across consumers, and which might be influenced by advertising. Advertising attempts to differentiate products by inducing consumers to build loyalties to particular brands, decreasing demand elasticity and possibly allowing the seller to receive a price premium over the non-differentiated product (Jekanowski et al., 2000).

The challenge for state promotion program is to provide local producers a vehicle for building consumer loyalty, so that purchase decisions may be based on attributes other than price and easily recognized quality differentials. This is especially important if the local producer faces a comparative disadvantage in production (Jekanowski et al., 2000) such as a CEA system producer.

CEA Hydroponic Operation as an Alternative Metro Farm

It is suggested that CEA hydroponic operation systems could be situated within Metropolitan Statistical Areas and would be an alternative metro farm. Metropolitan Statistical Areas (MSA) or metro areas constitute just 16% of U.S. farm land area, but they contain 29% of U.S. farms and account for 30% of farm sales (Heimlich and Brooks, 1989). Metro farms are generally smaller, more focused on high-value crop production, and produce more than two-thirds of vegetable and fruit sales and more than three-fourths of nursery and greenhouse crop sales.

The CEA hydroponic operation as a potential metro farm offers an alternative production system that could assist in the survival of agriculture in a rapidly changing environment, especially nearby large cities. Emerging trends in metro agriculture such as environmental awareness, concern for food quality and safety, and interest in farmland protection present new opportunities for systems such as CEA hydroponic operation. In addition, consumers' perceived differences in produce freshness and quality favor a return to locally-grown fruits and vegetables over transcontinental shipping and transseasonal storage. They are ready to embrace smaller, more environmentally sensitive, and locally oriented operations (Heimlich and Brooks, 1989).

If emerging environmental and consumer trends continue, metro farms will increasingly adopt high-value enterprises such as CEA hydroponic operation and innovative marketing strategies to meet the constraints and exploit the advantages of metro environment. Traditional farm type and production methods will probably decline in importance in metro areas as existing operations adapt and new alternative operations emerge (Heimlich and Brooks, 1989). This research by Heimlich and Brooks, provides a rationale for the role of CEA in an urbanizing region. Although the research by Heimlich and Brooks was done over 10 years ago, the case for hydroponic production may be even more relevant now.

In many areas of the US, the exit of farms due to urbanization pressures is notable. For example, the Northeast region loses farms at the rate of about 3,300 per year (USDA, Bureau of Census, 1992). With this loss of farms, the economic viability of rural communities continues to erode.

White et al., (1998a) compared the suitability of Central New York and Pennsylvania for a thriving food and agribusiness industry. The results indicated Pennsylvania has a statistically significant more favorable business climate than Central New York (CNY). White et al., (1998b) reported on a survey of 42 firms in CNY that energy costs were the largest single business cost weakness for the Central New York business climate. Another major disadvantage of Central New York is higher taxes including property tax, income tax, sales tax, and workmen's compensation (White et al., 1998a). While these data applied mainly to agribusiness or food firms, the same factors are important disadvantages for the agricultural production sector.

The northeast region, although at one time self-sufficient in fruits and vegetables, now imports more than 70% of its fruits and vegetables from all over the world (Wilkins, 1995). Increased reliance on food imports leads to the additional loss of processing, marketing, and other food system components from rural areas. (Bacon et al., 1989). It was concluded that new product development and new production technology are the only avenues to overcome the higher cost structure in Central New York (White et al., 1998a).

An adapted farm type suggested by Heimlich and Brooks was the alternative farm, which would be small but land, capital, and labor-intensive, and distinguished by the high value of output. This type of alternative farm has much in common with the CEA hydroponic system. The proximity of producers to large population centers could offer new opportunities, especially in marketing, with easier and larger access to markets. Another advantage of metro farming is that rising metro land values have increased metro farmers' equity. Higher land values due to the competition for land have resulted in less financial distress for metro farmers than those in the broader farm economy. The smaller average metro farm size has led to a higher share of farms operated by full owners than in non-metro areas. Owner operated farms tend to be more financially sound, because of the owner's potential for capital gains (Heimlich and Brooks, 1989).

Conclusions

The results of this study indicated that southern and southwestern areas have a cost advantage in the production of CEA hydroponic lettuce. The cities of Miami, Raleigh, and St. Louis had the lowest per unit production costs because of higher natural light condition, relatively low heating requirements, and labor costs.

In Ithaca, the highest electricity cost, heating cost, labor cost and the fixed costs resulted in the highest production cost of all locations examined.

If policy changes are made and cheaper electric rates are provided in NY State, the CEA hydroponic lettuce can be much more competitive with the other locations. For example, if the energy and demand rates were provided at 33% discounted rates, the total production cost can be reduced by five percent to $0.88 per head of lettuce. Such a reduction in the electricity rates could be possible if the industrial rate was available for CEA hydroponic system (see table 3).

Table 3. U.S. Electric Utility Average Cost per Kilowatt-hour to Ultimate Consumers by Sector, Census Division, and State (Cents/kWh)[a]

Census Division and State	Commercial	Industrial	Difference (Commercial - Industrial)
New England	8.7	7.3	1.4
Middle Atlantic	12.2	8.5	3.7
New York	11.3	4.8	6.5
East North Central	6.8	4.2	2.6
Illinois	6.1	4.0	2.1
West North Central	5.6	4.1	1.5
Missouri	5.0	3.8	1.2
South Atlantic	6.1	3.9	2.2
Florida	6.2	4.7	1.5
North Carolina	6.2	4.2	2.0
East South Central	6.1	3.6	2.5
West South Central	6.5	4.0	2.5
Mountain	6.1	3.9	2.2
Arizona	7.0	4.9	2.1
Colorado	5.5	4.3	1.2
Pacific Contiguous	7.3	4.4	2.9
California	8.3	5.3	3.0
Washington	5.2	3.1	2.1
U.S. Average	6.85	4.18	2.67

[a] Energy information administration, 2000

The highest difference in the US between commercial and industrial electricity average cost is observed in NY State and, therefore, the state would overall greatly benefit from widely availability of these cheaper electric rates.

While new employment would be modest, the CEA hydroponic operations would generate personal income and tax revenues. This would add to the viability of local communities which otherwise have few alternatives. Furthermore, the CEA systems would offer many new alternatives and opportunities for tomorrow's population by helping conservation and preservation of the environment rather than the exploitation of the land and water. Therefore, state and local governmental bodies could consider subsidizing CEA hydroponic operations for the benefit of the general public. This could dramatically affect the viability of the CEA system in a positive way.

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