EVALUATION OF A HIGH TUNNEL PRODUCTION SYSTEM AS A MEANS OF ENHANCING MARKET OPPORTUNITIES FOR ALABAMA GROWERS

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Phillip Roy Sanders

Certificate of Approval:

Wheeler G. Foshee III
Assistant Professor
Horticulture

Joseph M. Kemble, Chair
Associate Professor
Horticulture

Deacue Fields III
Assistant Professor
Agricultural Economics and Rural Sociology

Stephen L. McFarland
Dean
Graduate School

EVALUATION OF A HIGH TUNNEL PRODUCTION SYSTEM AS A MEANS OF ENHANCING MARKET OPPORTUNITIES FOR ALABAMA GROWERS

Phillip Roy Sanders

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EVALUATION OF A HIGH TUNNEL PRODUCTION SYSTEM AS A MEANS OF ENHANCING MARKET OPPORTUNITIES FOR ALABAMA GROWERS

Phillip Roy Sanders

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Signature of Author

____
Date of Graduation

VITA

Phillip Roy Sanders, son of Roy and Phyllis Sanders, was born August 11, 1979, in Fort Payne, Alabama. He graduated from Fort Payne High School in 1998. He entered Auburn University in the fall of 2001 and graduated with a Bachelor of Science degree in Horticulture in August 2003. In August 2003, he remained at Auburn University's Department of Horticulture in order to obtain a Master of Science degree. He married Miss Amanda Stone on August 27th, 2005 at Oak Bowery Plantation Home in Auburn, Alabama. They have two dogs, Ponder and Blu Sanders, and two cats, Possum and Sister Sanders.

THESIS ABSTRACT

EVALUATION OF A HIGH TUNNEL PRODUCTION SYSTEM AS A MEANS OF ENHANCING MARKET OPPORTUNITIES FOR ALABAMA GROWERS

Phillip Roy Sanders

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High tunnels (HT) can reduce negative environmental strains on crop production and have been shown to extend the growing season for many small fruits and vegetables. Because HT's require relatively low initial investment compared with standard greenhouse structures, they are particularly well suited for the small to mid-size grower. HT's provide a practical means of entry into intensive crop production for farmers who direct market their produce. By using HT's, direct market farmers may create a special marketing niche which set's them apart by offering locally grown vegetables, cut flowers, small fruits, and herbs earlier in the growing season and into the fall after frost.

This project examines (1) the potential use of HT's for the production of fresh-market tomatoes (*Lycopersicon esculentum* Mill.), strawberries (*Fragaria* spp.), and basil (*Ocymum* spp.) and (2) the seasonal market potential for these crops in Alabama. Viable

markets will be determined by conducting surveys at regional locations throughout Alabama, such as farmers markets, grocery stores, shopping centers, etc. Upscale restaurants will also be surveyed to determine the demand for locally grown herbs. These surveys will help determine target markets by asking demographic questions and determining spending habits. Justification for establishing a direct farmer-to-consumer market or a direct farmer to restaurant market for HT products will then be determined.

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I. INTRODUCTION AND LITERATURE REVIEW

Plasticulture is the use of plastics in Agriculture (Lamont, 2003). Plasticulture technology, such as a High Tunnel, can be used to extend the season of horticultural crops (Wells, 2000). High tunnels (HT's) are unheated structures that provide more protection compared with field production, but considerably less environmental control compared with greenhouse structures. HT's are passively ventilated via roll-up sidewalls and removable end walls and are well suited for the farmer with a small to mid-sized operation (Lamont *et al*., 2002). HT's have been used extensively in Asia and Europe, but only recently have they been used in the United States. Most of the research has been oriented around the northeastern United States (Lamont *et al*., 2002; Wells and Loy, 1993).

High tunnels reduce negative environmental strains on crop production. Compared to conventional field production, HT's utilize solar radiation more effectively (Lamont *et al*., 2002). Next to the amount of photosynthetic active radiation (PAR), the extent to which the available radiation is scattered or diffused is critical for plant production (Pollet *et al*., 2000). Solar radiation, when passing through plastic, diffuses and scatters. When plants are exposed to direct solar radiation in an open field environment the direct beam received by the plant's canopy can scorch the leaves because the canopy is receiving all of the sun's radiation. In contrast scattered radiation penetrates deeper into the plant's canopy, increasing the interception of PAR by the plants and consequently stimulating photosynthesis without as much solar stress (Edwards and Lake, 1965; Pollet *et al*., 2000).

High tunnels require relatively low initial investment compared to other high cost structures such as a greenhouse (Table 1). Since HT's are not necessarily permanent structures, however, they might require higher maintenance costs over the years (Spaw and Williams, 2004; Warren, 2003). For example, Jane Drake of Full Moon Farms (Riley County, Kansas) constructed two HT's on leased land. Since the land was leased, the HT structures had to be removable. The materials used, such as PVC pipe for the frame, made the structure more mobile and inexpensive to build (Spaw and Williams, 2004). Spaw and Williams (2004), however, indicated that because PVC was used initially it would likely need to be replaced more often compared to a more permanent frame fabricated from steel (Spaw and Williams, 2004).

Since the placement of a HT on a given site is dependent upon several factors, the installation of the structure might acquire hidden costs, depending on the site, such as retrieving water for the HT, electricity source (most HT's maintain an electrical source in the case of severe unpredicted weather), post harvest handling and equipment sheds, and access roads (Lamont *et al*., 2003; Spaw and Williams, 2004). Production efficiency should be maximized by placing the HT in close proximity of necessary resources used in everyday production practices (Spaw and Williams, 2004).

Other important factors to consider are wind, light interception, and structure. Wind is a two-sided coin (a paradox) in this case. Good ventilation is essential for plant growth and development (Kessler, 2001; Vassiliou, 2000). Since HT's are passively ventilated, orientation of the HT (Lamont *et al*., 2003; Wells, 2000), speed and direction of wind, and ambient temperature all influence ventilation (Kessler, 2001; Vassiliou, 2000). To optimize ventilation the structure should be oriented perpendicular to the prevailing wind (Vassiliou, 2000). If the structural materials of the HT are not of sufficient strength to resist strong winds this perpendicular orientation might increase maintenance costs due to the potential for increased damage (Spaw and Williams, 2004). Spaw and Williams (2004) reported severe wind damage to HT structures built from PVC bows. Also, strong desiccating winds are damaging to young seedlings and transplants (Spaw and Williams, 2004).

To optimize light interception, the long axis of structures constructed below latitude 401 N should be oriented north to south and those above latitude 401 N should be oriented east to west (Kessler, 2001; Nelson, 2003). Despite the need for sufficient structural framework in a HT, this framework is minimal compared to that of a conventional greenhouse structure (Table 1) (Spaw and Williams, 2004).

Because of low capital investment and potential high returns, high tunnels provide a practical means of entry into intensive crop production for farmers who direct market their produce (Wells and Loy, 1993). By using HT=s, farmers who direct market can create a special marketing niche (Adam *et al.*, 1999), e.g., they can offer locally grown vegetables, cut and edible flowers, small fruits, and herbs earlier in the growing season and into the fall after frost at a time when field grown produce is not available (Lamont, 2003; Lamont *et al.*, 2002; Spaw and Williams, 2004).

Direct marketing of agricultural products is rising at exponential rates around the United States (Adam *et al.*, 1999; Kambara and Shelley, 2002; Verhaegen and Huylenbroeck, 2001; Welsh, 1998). For example, Farmer's Markets have increased from less than 100 in 1960 to over 2,400 in 1996, and by almost 40 percent from 1994 to 1996 (Kirschenmann *et al.*, 2004). Although these direct markets deliver a small proportion of total food supplies, they represent an emerging trend with important implications for maintaining a diverse set of farms, ranches, and processing operations (Welsh, 1998).

Direct farmer-to-consumer marketing includes any method by which farmers sell their products directly to consumers (Adam *et al.*, 1999; Welsh, 1998). Justification for establishing a direct farmer-to-consumer marketing outlet is based primarily on the producer=s desire to increase his financial returns. This opportunity for increased returns stems from (1) opportunities to reduce marketing costs (and capture profits) attributed to intermediaries (middlemen) in the supply chain, and (2) the consumer's desire to buy (and willingness to perhaps pay a premium for) riper, fresher, higher-quality fruits and vegetables (Adam *et al.*, 1999; Welsh, 1998; Lamont, 2003). These two factors combined have often generated substantially higher net returns for producers (Adam *et al.*, 1999; Bachmann, 2005). Considering the cost of investment and maintenance of a HT, it is critical to the profitability of a HT grower to capture a premium on each sale (Bachmann, 2005; Lamont *et al.*, 2002; Lamont, 2003). In return for a higher premium, HT growers must supply higher quality produce (more aesthetically pleasing produce for example), crops produced in the off-season when competition is lessened, specialty or niche crops (crops not widely available on the market), or crops produced with decreased use of pesticides or which are certified organic (Bachmann, 2005; Lamont, 2003).

High quality is a prime requisite for sales to upscale and individually owned restaurants (Bachmann, 2005; Lamont *et al.*, 2002; Lamont, 2003). Specialty crops such as herbs, garlic (*Allium* spp.), mushrooms, salad greens, cut flowers, and edible flowers for restaurants can be grown on small parcels of land (Lamont *et al.*, 2002). One of the main requirements for selling to an upscale restaurant seems to be developing a good relationship with its chef (Adam *et al.*, 1999; Bachmann, 2005; Lamont, 2003). In some instances sales by local farmers to local institutions can be arranged. The Hartford Food Project developed a publication describing creation of such marketing channels (Adam *et al.*, 1999).

Another critical issue facing the small to mid-size farmer today is a lack of marketing knowledge and implementation (Kambara and Shelley, 2002; Klotz, 2002; Strohbehn and Gregoire, 2003; Verhaegen and Huylenbroeck, 2001). Many growers, especially new growers, are inclined to start production without giving a second thought to the business of marketing (Adam *et al.*, 1999; Bachmann, 2005; Welsh, 1998). Good marketing is an absolute must for a successful agricultural enterprise. Some would even argue that it ranks higher in importance than production itself-especially for farmers planning to diversify (Adam *et al.*, 1999). One method for determining whether season extension techniques can be a profitable addition to a farming operation is called partial budgeting (Bachmann, 2005; Ilic, 2004). A partial budget requires assessment of changes in income and expenses that would result from diversifying farm operations and practices. Partial budgeting means it is not necessary to calculate the expenses that would be the same for either practice (Bachmann, 2005).

Diversification out of traditional commodity crops, such as soybean (*Glycine max* (L.) Merr.), corn (*Zea mays* L.), and cotton (*Gossypium hirsutum* L.), may mean becoming familiar with, or even creating, new marketing systems (Strohbehn and Gregoire, 2003). Existing marketing channels often do not accommodate the non traditional producer especially producers with small operations (Adam *et al.*, 1999). Farmers with small operations and grassroots farm groups are the most likely groups to develop and use innovative marketing methods (Thompson, 1980). There are several marketing options for these operations such as direct and retail marketing, alternative and innovative marketing, and Community Supported Agriculture (CSA) farming (Lamont, 2003).

Direct and retail marketing is the direct sale of goods from the producer to the consumer at a retail cost (Adam *et al.*, 1999; Klotz, 2002; Verhaegen and Huylenbroeck, 2001; Welsh, 1998). This is a more profitable strategy for the smaller HT grower than the smaller grower attempting to compete with larger wholesale growers (Kambara and Shelley, 2002; Klotz, 2002; Verhaegen and Huylenbroeck, 2001). This marketing option will require the grower learning some processing and selling skills, rather than only knowing how to grow the crop (Lamont, 2003). These marketing skills include the grower defining the target market (Adam *et al.*, 1999; Lamont, 2003). In many cases demographic information such as location, age, income level, spending habits, and family composition can help to identify the target market for a grower's area. Also, psychographic information such as hobbies, beliefs, and lifestyles can further define market potential (Klotz, 2002; Verhaegen and Huylenbroeck, 2001; Lamont, 2003).

Plans for selling groceries on the World Wide Web are taking their place along with other forms of e-commerce. Ninety-two million potential customers frequent this innovative market place, with one-third of them making purchases (Klotz, 2002). Internet users tend to be older, with above-average educations and higher incomes. Interestingly, Internet users share these characteristics with direct market customers (Adam *et al.*, 1999).

Farms can do business on the Internet either by maintaining their own individual websites, or participating in a directory listing (Adam *et al.*, 1999; Klotz, 2002). Farms should examine Internet marketing as an opportunity to attract a new clientele, but must first determine whether existing customers are on the Internet (Adam *et al.*, 1999; Klotz, 2002; Verhaegen and Huylenbroeck, 2001). In addition, farmers must be aware of certain barriers to Internet buying: pricing, potential return hassles, credit card concerns of customers, privacy issues, and ease of site navigation are important aspects to consider (Adam *et al.*, 1999).

Community Supported Agriculture (CSA) is a system in which individuals and/or groups pledge support to a farming operation so that the farmland becomes the community's farm, with the growers and consumers providing mutual support and sharing the risks and benefits of food production (Sharp *et al*., 2002). Members or shareholders of the CSA pledge in advance to cover the anticipated costs of the farming operation and the farmer's salary. In return, they receive shares in the farm's bounty throughout the growing season, as well as satisfaction gained from reconnecting to the land. Members also share in risks, including poor harvest due to unfavorable weather or pests (Klotz, 2002; Sharp *et al*., 2002). For example, if the cost of production is estimated at $12,000 and the living wage is estimated to be $18,000, then a share in a CSA with 100 members would be $300. In return, each CSA member receives 1/100 of the year's production (Sharp *et a*l., 2002).

Community supported agriculture emerges as a particularly robust form of direct marketing (Adam, 2002; Kambara and Shelley, 2002; Sharp *et al*., 2002). In a recent survey from California a majority of CSA=s had yearly sales of over $100,000 and 67 percent had organic sales. CSA operators were younger on average than their more traditional counterparts (48 versus 55 years old) (Kambara and Shelley, 2002). CSA=s thrive where small farms can provide a diverse array of consumer-ready products such as vegetables, fruits, herbs, meats, honey, milk products, and eggs to large urban populations (the market) in close proximity to the farm (Adam, 2002). CSA=s are less adapted to sparsely populated regions characterized by large-scale commodity farming (Adam, 2002; Kambara and Shelley, 2002). CSA=s aim to provide consumers with healthy, locally grown food while at the same time revitalizing local food economies (Stigl and O=Hara, 2002). High tunnels might provide CSA's with more reliable harvests over an extended period and better quality produce.

Direct marketing can give the farmer a larger share of the food dollar and possibly a higher return on each unit sold (Adam *et al.*, 1999; Kambara and Shelley, 2002; Welsh, 1998), offset to some extent by loss of economies of scale (Kambara and Shelley, 2002). For some farmers, adding value or marketing some minimally processed farm products directly to the consumer is a way of enhancing financial viability (Adam *et al.*, 1999). Farmers who are unable to compete in, or are locked out of, distant markets can build a thriving local business (Adam *et al.*, 1999; Welsh, 1998). Finding the right niche and marketing directly to the public, however, is a hard and labor-intensive job requiring time and effort, creativity, ingenuity, sales expertise, and the ability to deal with people in a pleasant and positive manner (Adam *et al.*, 1999; Kambara and Shelley, 2002; Welsh, 1998). Agricultural producers must be absolutely certain that they are ready for the job (Adam *et al.*, 1999).

According to some reports, over 50% of the meals consumed in the U.S. are now eaten away from home (Stohbehn and Gregoire, 2003). This would appear to be a growing market for direct sales of produce, however, most high-volume meal servers (institutional food service and restaurant chains) require huge volumes of foods typically procured through centralized purchasing. Despite this, it is still possible to find an individually-operated restaurant buying some foods locally (Stohbehn and Gregoire, 2003; Verhaegen and Huylenbroeck, 2001).

In essence, food production, processing, marketing, and consumption have undergone a steady process of regional specialization in the past two centuries, resulting in a global food system characterized by long-distance transport from the field to the table (Kambara and Shelley, 2002; Welsh, 1998). Integral to this process has been the industrialization of the production process, resulting in a growing dependence of farmers on advanced technological inputs produced off the farm. These trends, made possible by massive infusion of low-cost fossil fuels, have resulted in a rate of productivity growth that has more than kept pace with global population growth (Borlaug, 2002; Kambara and Shelley, 2002). U.S. consumers have benefited greatly in terms of low cost food: the percentage of our net income spent on food has declined from 21 percent to 11 percent in the past 62 years (Kambara and Shelley, 2002).

The assumption that farmers must either "get big or get out", however, is being challenged by the emergence of alternatives (Adam *et al.*, 1999; Shand, 1997). It is possible for innovative farmers to stay small or medium-sized and make a comfortable and successful living from agriculture (Thompson, 1980). It is the excesses of the conventional marketing system that have forced the return of direct marketing. Consumers tired of tasteless supermarket produce want fresh food with flavor, as well as more control over their food supply, and these consumers are willing to pay a premium price for it (Adam *et al.*, 1999). Direct marketing, also called "shopping with a human face," promises "vine-ripened tomatoes that won't bounce if dropped and are full of the flavor you will remember" (Nothdurft, 1986).

II. OBJECTIVES

The scope of this project was to determine if the growing season for fresh-market tomatoes (*Lycopersicon esculentum* Mill.) and strawberries (*Fragaria x ananassa* Dusch.) were significantly affected using the high tunnel production system without the inputs required for greenhouse production and while establishing a viable market for this produce. In general, rendering crops at a time when the crop is normally out of season substantially increases the market value of the crop (Otten, 2003).

Use of the high tunnel production system in southern climates is applied by: extending the production season, increasing the quality of the product, minimizing the use of pesticides, and increasing cash flow during the off-season (Morris, 2004). With this system comes another side of sustainable agriculture that can be implemented. With a more stable and intimate environment, such as the environment created in a HT, integrated farming systems can be efficiently and commercially applied (Morris, 2004).

The University of New Hampshire and Pennsylvania State University both have on-going HT production research projects. The University of New Hampshire High Tunnel System involves roto-tilling the soil, using drip irrigation tape, covering the entire surface of the soil under the high tunnel with 6-mil thick black plastic and then planting the crop through the plastic next to the drip irrigation lines (Wells, 1996). The Penn State system allows access inside the tunnels for the utilization of tillage mechanization and allows for the use of a small tractor to form raised plastic-covered beds with drip irrigation tape (Lamont *et al*., 2002). The end walls have a larger hinged section and two smaller sections on each side of the larger section. The two smaller sections swing out and the larger section is lifted up and supported by two poles. Tillage equipment and other machinery use these portals. The average size of one of there HT's is 5.20 m by 10.97 m. (Lamont *et al*., 2002).

In 2001 University of Missouri at Bradford constructed four high tunnels each spaced 1.83 m apart with one purlin. Each unit was 6.10 m (width) by 2.74 m (height) by 10.97 m (length). The tunnels were oriented east to west in order to block the prevailing south by southwest wind. Each tunnel was covered with a single layer of 6-mil plastic (Jett and Reid, 2003).

<u>Results using High Tunnels</u>

All of the principles applied to sustainable agriculture are incorporated using the high tunnel system: crop rotation schemes, good soil preparation, maintenance of organic matter, fertilization, water management, IPM, multiple cropping, proper harvesting and post-harvest handling (Kirschenmann *et al.*, 2004).

Penn State University has grown a variety of vegetable crops in HT's, and has reported significantly earlier harvest dates for tomatoes (*L. esculentum*), summer squash (*Cucurbita pepo* L.) and cucumbers (*Cucumis sativus* L.). Improved yields and/or a higher crop quality were reported for peppers (*Capsicum annuum* L.), and leafy green crops such as broccoli (*Brassica oleracea* var. *italica* Plenck.), cabbage (*Brassica oleracea* var. *capitata* L.), cauliflower (*Brassica oleracea* var. *botrytis* L.), and kale (*Brassica oleracea* var. *acephala* DC.) (Lamont *et al.*, 2002).

The University of Missouri conducted a marketing experiment on tomatoes (*L. esculentum*) grown in high tunnels. Researchers found that there was a strong price premium for tomatoes harvested before 1 July (Jett and Read, 2003). They recorded wholesale tomato prices during 2002 at the Central Missouri Produce Auction and found wholesale prices for their tomatoes harvested beginning in April remained relatively high through June and began to decline thereafter as field supplies increased (Jett and Read, 2003). As a result, farmers with tomatoes available before June were able to obtain a premium price for their product because their product was available during the crop's off-season.

The Horticultural Research Institute in Icel, Turkey found that strawberries (*F. x ananassa*.) grown under a high tunnel production system reached maturity three to five months earlier than those produced in an open field system (Ozdemir and Kaska, 1997). Under tunnel culture, harvesting began in late November compared to March under open field production (Ozdemir and Kaska, 1997). In a previous study conducted on strawberries in Adana, Turkey, high tunnel culture induced early flowering but suffered frost damage (Kaska *et al*., 1986).

In Kentucky, Paul Wiediger of Au Naturel Farms, currently has five HT structures with a total of 789.68 m5 in production for 52 weeks a year. This is a considerable amount of production time for a farm operation which is made possible by the use of HT's. Marketing of his products is done via e-mail where once a week Wiediger sends out an e-mail to his customer base informing them what he will have available in the coming week. His customers respond back, basically making everything harvested pre-sold. Wiediger says this allows his customers to choose the produce that they want and allows him to do some extra marketing, such as informing his customers on how to use the product by providing recipes. According to Wiediger, this has increased weekly orders by 50 percent (Warren, 2003).

The High tunnel system of production is currently being evaluated for a wide array of horticultural crops. This system of production allows the farmer to increase production in several direct ways: it extends the production season, it increases the quality and shelf life of the product, it minimizes the use of pesticides, it allows a product to be produced even if the outside environment is unfavorable for conventional field production, and it allows production in less conventional settings such as urban areas (Lamont *et al*., 2003).

III. MATERIALS AND METHODS

High Tunnel Construction Materials

In Aug. 2003, one 7.0 m x 14.6 m High Tunnel (HT) was constructed at EV Smith Agricultural Research Station-Horticulture Unit in Shorter, Ala. Our tunnel design followed the Penn State HT design without any deviations (Figure 1a). The frame was fabricated from galvanized steel and covered with clear 6-mil polyethylene plastic. The sidewalls of the HT rolled up from the ground to a height of 1.5 m to allow ventilation (Figure 1b). The endwalls consisted of one large wall at each end which turned up and were covered with corrugated plastic (Figure 1b and 2). For more information on this HT design and construction see the High Tunnel Production Manual (Lamont, 2003)

A 21 hp New Holland Diesel tractor was used to prepare the area and to form raised beds. The bedder formed 0.5 m wide beds on 0.9 m centers (Figure 2). Beds were covered with 1.25 mm black polyethylene mulch in the fall of 2003 and 2004 and spring of 2004 and 2005 for the tomato and strawberry crops, respectively (Figure 2). In the summer of 2004, 1.25 mm white polyethylene mulch was installed for the basil crop. The bedder installed the polyethylene mulch and drip irrigation tape in the same pass. In each of the following experiments, RoDrip irrigation tape was used (Roberts Irrigation Products, Inc., San Marcos, Calif.) that was 0.254 mm thick, 16 mm inside diameter, 30 cm emitter spacing, and had a flow rate of 300 L per hour per 100 m at 0.55 bars. With 0.9 m bed centers, five raised, mulch covered beds fit under the HT.

Fall 2003 Tomatoes and Strawberries: Preparations

During the first week of Aug., 2003 four varieties of fresh-market tomatoes (*Lycopersicon esculentum* Mill.), 'Sunbeam', 'SunLeaper', 'FL 91', and 'BHN 640', were selected to be transplanted into the HT. These varieties were chosen because they were four readily available commercial varieties commonly used in Alabama. During the second week of Aug., 2003 seeds were sown into 606 cell flats (outer dimensions of flats: 266.7 mm width x 533.4 mm length x 57.2 mm height) at Plants Sciences and Research Greenhouses (Auburn, Ala.). Individual cells measured 66.7 mm wide x 84.6 mm long x 57.2 mm high. Seed were sown into Fafard Germinating Mix (Conrad Fafard Inc., Agawam, Mass.) and grown under normal greenhouse conditions until three days before transplanting. Following emergence, transplants were fertilized twice weekly for four weeks with 100 mg N/liter from 20N-4.3P-16.6K Peters General Purpose fertilizer (The Scotts Co., Marysville, Ohio). On 10 Sept. 2003 the transplants were removed from the greenhouse and placed outside for hardening off. To harden the tomato plants, they were allowed to wilt, but not to their permanent wilting point, and then given water. The transplants went through this cycle each day for three days prior to transplanting into the field.

In Sept. 2003 potassium (0N-0P-49.8K) derived from muriate of potash and ammonium nitrate (34N-0P-0K) were broadcasted at a rate of 150 $kg{\cdot}ha^{-1}$ and 197 $kg{\cdot}ha^{-1}$, respectively, over the entire HT tier. Tillam was broadcasted for pre-emergence control of broadleaf weeds and grasses at a rate of 6.2 $liters{\cdot}ha^{-1}$. Both fertilizers, lime (as based on soil test recommendation), and the Tillam were incorporated into the entire HT tier. At transplanting, Treflan was applied as a post-bed treatment to each row at a rate of

1.2 liters·ha^{-1} for pre-emergence control of annual grasses and some broadleaf weeds. It is believed that this treatment caused severe plant stunting during the first fall planting of tomatoes in 2003 which resulted in no reportable yields.

Beginning one week after transplanting and continuing through the final harvest, additional N was applied via the drip irrigation system at a rate of 6.7 kg per ha per week alternately from potassium nitrate (13N-0P-36.5K) and calcium nitrate (15.5N-0P-0K). Water was applied as needed via the drip irrigation system to provide at least 2.5 cm of water per week.

On 13 Sept. 2003 the four varieties of fresh-market tomato were transplanted into the upper 2/3 (68.1 m^2) of the HT within the same rows as the strawberries (Figure 3). These transplants were approximately six-weeks-old. Transplants were spaced 0.9 m apart on row centers and 45.7 cm apart within each row. On 13 Sept. 2003 the tomato transplants received a soil drench of Terrachlor® applied at a rate of 6 g of Terrachlor® per liter of water with each plant receiving about 0.24 L of the solution.

On 13 Oct. 2003 six-week-old strawberry plants (*Fragaria x ananassa*) were transplanted into the later 1/3 (34.1 m^2) of the HT within the same rows as the tomatoes (Figure 3). Strawberry plants between rows were spaced 0.9 m on center. Strawberry plants within rows were in staggered double rows and spaced 30.5 cm on center. Both bare root and plug type transplants were used for the varieties ‘Camarosa’ and ‘Chandler’ making a total of four treatments. All transplants were ordered from a grower in North Carolina. The same fertility and herbicide regime described above for the tomatoes was used for the strawberries.

Fall 2003 Tomatoes and Strawberries: Experimental Design

Due to a temperature and soil compaction gradient located at the HT site, a randomized complete block design (RCBD) was used for each of the experiments described above. The replications were laid out perpendicular to the long axis of the HT. The long axis of the HT was oriented east to west. The tomato treatments were replicated five times with five plants per treatment in each plot (3.4 m^2) totaling 20 plants per replication. The strawberry treatments were replicated five times with seven plants per treatment in each plot (1.7 m^2) totaling 28 plants per replication.

Fall 2003 Tomatoes and Strawberries: Harvesting and Grading

No harvestable fruit were produced from the fall 2003 tomato crop due to the herbicide (e.g Treflan) and cold damage described above. These tomato plants were removed from the HT on 12 Jan. 2004.

Strawberries were harvested starting on 16 Feb. 2004 and ending on 20 Apr. 2004 for a total of 14 harvests. Fruit were graded into either marketable or non-marketable fruits according to USDA standards (USDA, 1965). All yields are reported as g/m^2 and separated into early season (all fruit harvested prior to 1 Apr.), which marks the normal beginning of the harvest season in central Alabama) and late season (all fruit harvested after 1 Apr.). Data were analyzed using SAS (SAS Inst., Cary, NC). Mean separation was used to determine differences among the four treatments and among treatments at each harvest date.

Spring 2004 Tomatoes: Preparations

In the third week of Jan., 2004 tomato transplants were produced using the same transplant production methods as described above for the fall 2003. The same fertigation rates and methods were used in the spring 2004 tomato crop as described in the fall 2003 planting; however, there was no Tillam and Treflan application. Transplants were approximately six-weeks-old when they were set out in the HT on 13 Feb. 2004. Transplants were set out into the same polyethylene mulch used in the fall 2003 tomato planting. The same with-in row and between-row spacings were used as previously described for the fall 2003 tomato experiment.

Spring 2004 Tomatoes: Experimental Design

As with the fall 2004 experiments, a RCBD was used for the experiment described above due to a temperature and soil compaction gradient located at the HT site. The replications were laid out perpendicular to the long axis of the HT. The long axis of the HT was oriented east to west. The tomato treatments were replicated five times with five plants per treatment in each plot (3.4 m^2) totaling 20 plants per replication.

Spring 2004 Tomatoes: Harvesting and Grading

Tomatoes were harvested starting on 19 May 2004 and ending on 21 June 2004 for a total of 11 harvests. Tomato fruit were harvested at the breaker stage or riper and then graded into U.S. Combination (highest quality), U.S. #3 (some cosmetic defects) and culls (non-marketable) (USDA, 1991). U.S. Combination grade fruit were size-separated according to diameter: jumbo (>88 mm), extra large (73 to 88 mm), large (64 to 72 mm), and medium (58 to 63 mm) (USDA, 1991). Data were analyzed using SAS (SAS Inst., Cary, NC). Mean separation was used to determine differences among the four varieties, differences among varieties at each grade, and differences among varieties at each harvest date. All yields are reported as g/m^2 and separated into early season (all fruit harvested prior to 1 June, which marks the normal beginning of the harvest season in central Alabama) and late season (all fruit harvested after 1 June).

Fall 2004 Tomatoes and Strawberries: Preparations

In the fall 2004 it was decided that the planting date for the tomatoes would be moved to the first week of Sept. in an effort to begin harvesting before Thanksgiving. In anticipation of this, seed were sown on 11 Aug. and transplants were produced as described above. This date was missed, however, due to extensive structural damage done to the HT from Hurricane Ivan. As a result, seven-week-old tomato plants were transplanted on 13 Sept. 2004. The same varieties, in-row and between-row spacing, cultural practices, and experimental design described above were used for this experiment. The same materials and methods used in the fall 2003 were used with the exception of the Treflan application. Beds were re-worked then new black polyethylene mulch and drip irrigation tape were installed throughout the HT

On 11 Oct. 2004 six-week-old strawberry plants were transplanted into the later 1/3 (34.1 m^2) of the HT within the same rows as the tomatoes (Figure 3). Strawberry plants between rows were spaced 0.9 m on center. Strawberry plants within rows were in staggered double rows and spaced 30.5 cm on center. Both bare root and plug type transplants were used for the varieties ‘Camarosa’ and ‘Chandler’ making a total of four treatments. All transplants were ordered from a grower in North Carolina. The same fertility and herbicide regime described above for the tomatoes was used for the strawberries.

Fall 2004 Tomatoes and Strawberries: Experimental Design

A RCBD was used for each of the experiments described above due to a temperature and soil compaction gradient located at the HT site. The replications were laid out perpendicular to the long axis of the HT. The long axis of the HT was oriented east to west. The tomato treatments were replicated five times with five plants per treatment in each plot (3.4 m^2) totaling 20 plants per replication. The strawberry treatments were replicated five times with seven plants per treatment in each plot (1.7 m^2) totaling 28 plants per replication.

Fall 2004 Tomatoes and Strawberries: Harvesting and Grading

No harvestable fruit were produced from the fall 2004 tomato crop due to cold damage to the developing tomato plants. Average soils temperatures and ambient temperatures were below 60° F during initial flowering and fruit set. This is believed to be the cause of the immature green fruits never ripening. Tomato plant growth and development begins to slow considerably when temperatures drop below 60° F and nutrients uptake is inhibited at temperatures below 50° F (Sanders, 2005). These tomato plants were removed from the HT on 27 Dec. 2004

Strawberries were harvested starting on 12 Dec. 2004 and ending on 13 May 2005 for a total of 34 harvests. Fruit were harvested and graded into either marketable or non-marketable fruits according to USDA standards (USDA, 1965). Data were analyzed using SAS (SAS Inst., Cary, NC). Mean separation was used to determine differences among the four treatments and among treatments at each harvest date. All yields are reported as g/m^2 and separated into early season (all fruit harvested prior to 1 Apr., which marks the normal beginning of the harvest season in central Alabama) and late season (all fruit harvested after 1 Apr.).

<u>Spring 2005 Tomatoes: Preparations</u>

In the third week of Jan., 2005 tomato transplants were started using the same transplant production methods as described above for the spring 2004 with the exception of the transplant date. The same HT bed preparations were used as in spring 2004 except that the polyethylene mulch was removed from the fall 2004 tomato rows (row sections with strawberries were left in place), the soil re-worked, and new beds made. New black polyethylene mulch and drip irrigation tape was installed as previously described. The same fertigation rates and methods were used in the spring 2005 tomato crop as described in the spring 2004 planting; however, there was no application of Tillam and Treflan. Transplants were approximately five-weeks-old when they were set out in the field on 26 Feb. 2005. The same with-in row and between-row spacings were used as previously described for the spring 2004 tomato experiment.

<u>Spring 2005 Tomatoes: Experimental Design</u>

As with the spring 2004 experiments, a RCBD was used for the experiment described above due to a temperature and soil compaction gradient located at the HT site. The replications were laid out perpendicular to the long axis of the HT. The long axis of the HT was oriented east to west. The tomato treatments were replicated five times with five plants per treatment in each plot (3.4 m^2) totaling 20 plants per replication.

<u>Spring 2005 Tomatoes: Harvesting and Grading</u>

Tomatoes were harvested starting on 23 May 2005 and ending on 3 June 2005 for a total of five harvests. Tomato fruit were harvested, graded, and the data analyzed as described in the spring 2004 tomato harvesting and handling. All yields are reported as g/m^2 and separated into early season (all fruit harvested prior to 1 June, which marks the normal beginning of the harvest season in central Alabama) and late season (all fruit harvested after 1 June). Data were analyzed using SAS (SAS Inst., Cary, NC). Mean separation was used to determine differences among the four varieties, differences among varieties at each grade, and differences among varieties at each harvest date.

Summer 2004 Basil: Preparations

In the summer 2004 basil transplants were grown at Patterson Greenhouse Complex at Auburn University (Auburn, Ala.). Four varieties were used in which three were culinary varieties, ‘Italian Large Leaf’, ‘Lime’, and ‘Magical Michael’. The fourth variety, ‘Holy Red’, was a horticultural variety. Seeds were sown into 606 cell flats (266.7 mm width x 533.4 mm length x 57.2 height) the second week of June 2004. Individual cells measured 66.7 mm wide x 84.6 mm long x 57.2 mm high. Seed of each variety were sown into Fafard Germinating Mix (Conrad Fafard. Inc., Agawam, MA) and grown under normal greenhouse conditions until three days before transplanting. Following emergence, transplants were fertilized twice weekly for four weeks with 100 mg N/liter from 20N-4.3P-16.6K Peters General Purpose fertilizer (The Scotts Co., Marysville, OH).

New beds were prepared using the same materials and methods described in the spring tomato experiments; however, white polyethylene mulch was used for the basil planting. N, P, and K were applied as recommended by soil test from Auburn University Soil Testing Laboratory (Auburn, Ala.). Additional nutrients and water were supplied via the drip irrigation tubing. All four varieties were transplanted during the second week of

July into the HT and into a field adjacent to the HT. Basil plants between rows were spaced 0.9 m. Basil plants within rows were in staggered double rows with plants spaced 0.46 m apart. The same four varieties and experimental design (RCBD) were used both inside the HT and in an open-field planting adjacent to the HT in order to determine the influence of the HT on growth and yield of these selected basil varieties.

Summer 2004 Basil: Experimental Design

A RCBD was used for the HT and open-field experiments described above due to a temperature and soil compaction gradient located at the HT site. The replications were laid out perpendicular to the long axis of the HT. The long axis of the HT was oriented east to west. The basil treatments were replicated six times with seven plants per treatment in each plot (2.6 m^2) totaling 28 plants per replication both in the HT as well as in the open field. The open field experiment was immediately adjacent to the HT.

Summer 2004 Basil: Harvesting and Grading

Using a hand-pruner the top four to six inches (the tender tips) of the basil were harvested and yields recorded as g per m^2. Harvests inside the HT began on 28 July 2004 and continued until 3 Sept. 2004 for a total of five harvests. Harvests outside the HT occurred during the same time period as in the HT, however, there were only four harvests outside. The interval between harvests was dependent upon re-growth rate of the basil plants. Data were analyzed using SAS (SAS Inst., Cary, NC). Mean separation was used to determine differences among yields between the four varieties and to determine differences between inside the HT and outside the HT. Project was terminated on 3 Sept. 2004 (last harvest date).

Consumer Preference Survey

Direct farmer-to-consumer marketing includes any method by which farmers sell their products directly to consumers (Adam, 1999; Welsh, 1998). Justification for establishing a direct farmer-to-consumer marketing outlet is based primarily on the producer's desire to increase his financial returns from farm production. This opportunity for increased returns stems from (1) opportunities to reduce marketing costs (and capture profits) attributed to intermediaries (middlemen) in the supply chain, and (2) opportunities to enhance the consumer's desire to buy (and willingness to perhaps pay a premium for) riper, fresher, higher-quality fruits and vegetables. These two factors combined have often generated substantially higher net returns for producers (Adam, 1999). Considering the cost of investment and maintenance of a HT, it is critical to the profitability of a HT grower to capture a premium on sales (White, 2003; Lamont *et al*., 2002). In return for a premium price, HT growers must supply higher quality produce (more aesthetically pleasing produce, for example), crops produced in the off-season when competition is lessened, specialty or niche crops (crops not widely available on the market), crops produced with the decreased use of pesticides, or certified organic crops (White, 2003).

In order for a grower, who chooses to direct market his produce, to make a profit, a target market must be defined and then established. Considering the potential early season production of HT tomatoes and strawberries and the large market window HT production can create, a grower has the opportunity to establish his business early in the season if he knows who and where to sell his product.

In the summer 2004, 423 consumers who purchased vegetable products were asked to take surveys in order to determine whether or not there was a viable market for locally grown (grown in Alabama) tomatoes made available in the early season. Each survey was exactly the same and consisted of 20 questions (See Appendix 1). These surveys were conducted over a three-month period.

The survey consisted of twelve questions about the consumer's preferences for fresh-market tomatoes and eight questions related to demographics. These surveys were given in a face-to-face manner and were categorized according to where the consumer took this survey. Respondents were approached and asked to complete a survey either at a grocery store (53.4%, 226 respondents) or market (i.e. farmer's market) (46.6%, 197 respondents). All regions of Alabama were represented in this survey. Several Alabama farmer's markets were surveyed including Pepper Place Market in Birmingham and Government Street Market in Mobile. Shoppers at grocery stores in Auburn, Montgomery, Birmingham, and Fort Payne were surveyed. The other locations were Jasper and Cullman. These places were intentionally selected in attempt to obtain an accurate representation of the typical Alabama tomato consumer. Each survey location was selected based on its region location in Alabama. Urban and rural locations were also selected in an attempt to sample both urban and rural populations.

Each person who walked within a reasonable talking distance from our table set-up was approached and asked to complete a survey regardless of race (91% white, 386 respondents; 4% African, 16 respondents; 5% other, 21 respondents), gender (61% female, 257 respondents; 39% male, 166 respondents), or age (unless the person was obviously not of a care taker age, i.e. a young child).

The first 12 questions were designed to determine the willingness of the Alabama vegetable consumer to pay more for better quality produce. In doing this, we hoped to provide the small to mid-size HT farmer in Alabama an exact market target. Knowing your target market means not only knowing the shopping preferences of the consumer but also knowing how much the consumers spend and where they tend to spend it. By identifying potential target markets, growers will become more efficient and therefore more cost effective in their operations because they will know who their customer is, what they are going to buy, and how much they are willing to spend for a quality product. These surveys will help growers with small to mid-sized operations understand where consumers purchase produce, who buys the produce, and how much they are willing to spend for a high quality product in the state of Alabama.

Thirty-three percent (139 respondents) of respondents lived in rural areas, 34% (145 respondents) lived in urban areas, and 33% (139 respondents) lived in suburban areas. Six percent (27 respondents) of respondents had less than a high school education, 25% (104 respondents) had only a high school education, 25% (106 respondents) had some college education, 24% (103 respondents) had an undergraduate college degree, and 20% (83 respondents) had a graduate level degree. Eight percent (33 respondents) of those surveyed made less than $20,000/year, 26% (110 respondents) made between $20,000 and $40,000/year, 25% (106 respondents) made between $40,000 and $60,000/year, 13% (53 respondents) made between $60,000 and $80,000/year, 10% (43 respondents) made between $80,000 and $100,000/year, 18% (78 respondents) made over $100,000/year. The average respondent was Caucasian, 51 years old, and made $66,000 per year.

Data from the surveys were analyzed using the econometric software LimDep (Econometric Software, Inc, Plainview, NY). Data from these surveys were used to determine the market potential for fresh-market tomatoes produced in the HT. A Binary Probit Model was used to predict the probability relationship of the dependent variable and independent variables. This leads to the joint probability of the variables (Greene, 2000). For example, in our study, consumers were asked if they would pay more for early-season locally grown tomatoes. This question serves as our dependent variable and the independent variables predict how likely a consumer is to purchase early-season locally grown tomatoes based on their answer of the independent variables.

IV. RESULTS AND DISCUSSION

Introduction

As the produce market expands it becomes more and more competitive (Adam, 2002; Kambara and Shelley, 2002). Competitiveness drives growers to become more innovative with production practices and marketing techniques (Adam *et al.*, 1999; Kambara and Shelley, 2002). One way to become more competitive is to have a product outside of its normal marketing season (Ilic, 2004; Lamont, 2003). This allows the grower to set a higher than normal price since they have a product when few others have it. Season extension is especially profitable when a grower direct markets their produce (Lamont, 2003). This allows them to capture a premium for the product by cutting out the "middle-man" (Adam, 2002; Ilic, 2004; Kambara and Shelley, 2002; Klotz, 2002.

2003 Fall Tomatoes

On 13 Sept. 2003 tomatoes were transplanted into two thirds (68.1 m^2) of the HT tier. At transplant time Treflan was applied as a soil drench around the root zone of each tomato transplant for pre-emergence control of broadleaves and grasses. It is believed that the interaction of decreasing temperatures and the residual activity of the Treflan may have caused severe stunting of the entire tomato crop. Temperature data and physical evidence supports this in that clubbing of the tomato roots was observed which is typical of trifluralin damage. It is also believed that due to this clubbing and cold temperatures (<50°F) phosphorus uptake was inhibited. Due to this stunting, no yield data was recorded for the fall 2003 tomato crop.

2004 Fall Tomatoes

In late Aug., 2004 tomato transplants were ready to be planted into the HT. The planting date was moved back to the end of Aug. in order to begin harvesting fruit before mid to late Nov. In Sept. 2004 Hurricane Ivan brought rain and wind to most parts of the southeast. Rain inhibited planting until the third week of Sept. and wind gusts of 75 mph ripped the plastic covering from the HT causing structural damage to both endwalls of the HT. Due to rain and damage to the HT, the tomatoes were not transplanted as scheduled but were delayed until 13 Sept. Despite this delay in transplanting, the vines grew and produced tomato fruits as normal; however, this fruit remained at the immature green stage never maturing. Flowering and fruit set began in mid-Nov. when at the same time average daily soil and ambient air temperatures within the HT fell below 60 F (data not shown). These low temperatures caused symptomatic chilling injury to the developing fruit (Willis *et al.*, 1998). Delaying or inhibiting the maturation of fruit is a common symptom of chilling injury (Willis *et al.*, 1998). No harvestable fruit were produced from the fall 2004 tomato crop due to this chilling injury.

2004 & 2005 Spring Tomatoes

In spring 2004 the HT tomato crop harvest season began on 19 May and continued until 21 June for a total of 11 harvests. These harvests were sorted into early season harvest (fruit harvested prior to 1 June) and late season harvest (fruit harvested after 1 June). The normal beginning of the tomato production season for central Alabama is 1 June. The date of the first harvest of tomatoes in the HT was three weeks earlier than the typical first harvest of field-grown tomatoes in central Alabama. Three weeks is a significant early season window in which a grower could command a premium price for his product. In spring 2005, the HT tomato crop harvest was also approximately three weeks earlier beginning on 23 May and continuing until 6 June for a total of five harvests. This was due to the fact that the field-grown tomato crop for the whole state of Alabama was behind an average of two weeks in 2005 due to inclement weather.

<u>2004 & 2005 Spring Tomatoes:</u> *Analysis of Yield Data*

In the preliminary statistical analysis of the yield data, both years (spring 2004 and 2005) were combined. An analysis of variance procedure was used to determine if there were differences in yield among the treatments between the two years based on treatment, harvest date, or from interactions between these variables. There were no significant interactions between treatments (i.e., the four varieties) and year for total yield, total marketable yield, total non-marketable yield, or any of the individual grades based on fruit size. In addition, there were no significant differences between any of the treatments (varieties). Based on this analysis data from both years were analyzed together and yields are reported as averages over the two years among the four varieties.

Total yield in 2004 was significantly higher as compared to that in 2005 (0.68 kg per m^2 vs. 0.24 kg per m^2, respectively) ($p=0.05$). Total yield of the late season harvested fruit was significantly higher as compared to that of the early season harvested fruit (0.82 kg per m^2 vs. 0.41 kg per m^2, respectively) ($p=0.05$).

Total marketable yield in 2004 was significantly higher as compared to that in 2005 (0.50 kg per m^2 vs. 0.18 kg per m^2, respectively) ($p=0.05$). Total marketable yield of the late season harvested fruit was significantly higher as compared to that of the early season harvested fruit (0.62 kg per m^2 vs. 0.30 kg per m^2, respectively) ($p=0.05$).

Total non-marketable yield in 2004 was significantly higher than in 2005 (0.18 kg per m^2 vs. 0.06 kg per m^2, respectively) ($p=0.05$). Total non-marketable yield of the late season harvested fruit was significantly higher as compared to that of the early season harvested fruit (0.20 kg per m^2 vs. 0.11 kg per m^2, respectively) ($p=0.05$).

Individual Fruit Grades

There were no significant differences between 2004 and 2005 or between early and late season harvests for extra-large sized fruit ($p=0.05$). Yield of extra large fruit averaged 0.12 kg per m^2 across years and harvest seasons. Yield of large sized fruit were significantly higher in 2004 as compared to 2005 (0.18 kg per m^2 vs. 0.06 kg per m^2, respectively). In addition, yield of large sized fruit harvested in the late season were significantly higher than of those harvested in the early season (0.24 kg per m^2 vs. 0.1 kg per m^2, respectively) ($p=0.05$). Yield of medium sized fruit were significantly higher in 2004 as compared to 2005 (0.32 kg per m^2 vs. 0.11 kg per m^2, respectively) ($p=0.05$). In addition, yield of medium sized fruit harvested in the late season were significantly higher than of those harvested in the early season (0.38 kg per m^2 vs. 0.20 kg per m^2, respectively) ($p=0.05$). .

Non-marketable Fruit

Yield of cat-faced fruit was significantly higher in 2004 as compared to 2005 (0.02 kg per m^2 vs. 0.003 kg per m^2, respectively) ($p=0.05$); however, there was not a significant difference in the amount of cat-faced fruit produced in the early season and late season (data not shown).

The incidence of fruit damaged by disease was significantly higher in 2004 as compared to that in 2005 (0.005 kg per m^2 vs. 0.0 kg per m^2, respectively) ($p=0.05$). This incidence was also higher in the late season harvested fruit as compared to that harvested in the early season (0.008 kg per m^2 vs. 0.002 kg per m^2, respectively) ($p=0.05$). Early blight, buckeye rot, and disease associated with insect damage, such as fusarium, were observed on fruits damaged by disease.

There were significantly more insect–damaged fruit in 2004 as compared to 2005 (0.02 kg per m^2 vs. 0.001 kg per m^2, respectively) ($p=0.05$); however, there was not a significant difference in the amount of insect-damaged fruit produced between early season and late season (data not shown). All insect damage was observed on the fruit (i.e. piercing sucking insects).

Yield of all other culls (off-shaped, radial cracking, concentric cracking, under sized, etc) were significantly higher in 2004 as compared to 2005 (0.13 kg per m^2 vs. 0.05 kg per m^2, respectively) ($p=0.05$). In addition, there where more culls produced in the late season as compared to the early season (0.17 kg per m^2 vs. 0.08 kg per m^2 , respectively) ($p=0.05$).

Significant differences between years can likely be attributed to the fact that the 2004 planting date was earlier than in 2005 (e.g. transplant date was 13 Feb. in 2004 vs. 26 Feb. in 2005) and production lasted longer into the season (e.g. last harvest was 21 June in 2004 vs. 6 June in 2005) therefore produced more over all yields. The increased yield in 2004 naturally produces increased yields from each grade. Significant differences between early season vs. late season can be attributed to the longer production season of 2004 in which production lasted longer into the season (e.g. 21 June vs. 6 June), as well as beginning earlier, because of less disease pressure. The 2005 season was much wetter compared to the 2004 season and is believed to be the reason for higher disease pressure late in the season. Higher disease pressure in 2005 cut the production season short compared to 2004. This argument may not make sense given that the high tunnel protects crops from rain and other inclement weather, however, our HT site was on a hard pan which allowed water to run in from underneath the structure and stand in between rows. Standing water likely increased humidity inside the HT and therefore increased disease pressure. Higher yields in the late season can also be attributed to the increase of temperature as the season progressed regardless of years.

There were no differences among treatments (e.g. varieties), therefore, nothing can be extrapolated in terms of which is best for early season production. The fact that there were fruits being harvested earlier in the season compared to what’s normal is important for a grower looking to establish a market earlier in the season regardless of the variety used.

2004 and 2005 Strawberries

The harvesting of the first ripe strawberries marks the beginning of the annual harvest season for fruit producers in Alabama. It is the only true spring season fruit produced statewide. About three hundred fifty acres of strawberries are grown commercially (mostly on black polyethylene mulch) all over Alabama. The harvest season begins in March along the Gulf Coast and ends in early June in northern Alabama (Struempler and Powell, 1998).

2004 Strawberries: *Harvest*

In spring 2004 the HT strawberry crop harvest began on 16 Feb. and continued until 20 Apr. for a total of 14 harvests. These harvests were sorted into early season harvest (fruit harvested prior to 1 Apr.) and late season harvest (fruit harvested after 1 Apr.). The normal beginning of the strawberry production season for central Alabama is 1 Apr. (Himelrick *et al.*, 1996). The date of the first harvest of strawberries in the HT was six weeks earlier than the typical first harvest of field-grown strawberries in central Alabama. Six weeks is a significant early season window in which a grower could command a premium price for his product.

2004 Strawberries: *Analysis of Yield Data*

In the preliminary statistical analysis of the yield data, both years were combined. An analysis of variance procedure was used to determine if there were differences in yield among the treatments across the two years of this study based on treatment, harvest date, or from interactions between these variables. There was a significant interaction between the four treatments ('Camarosa' plugs and bareroot transplants and 'Chandler' plugs and bareroot transplants) and year for total yield ($p=0.0001$), total marketable yield ($p=0.0001$), and total non-marketable yield ($p=0.005$). Since the response of each treatment was dependent upon year, the statistical analysis was performed by year.

Data from the first nine harvests were combined constituting the early season harvest (all fruit harvested prior to 1 Apr.). Data from the remaining five harvests were combined constituting the late season harvest (all fruit harvested after 1 Apr.). Mean separation was used to determine treatment differences in total yield, total marketable yield, and total non-marketable yield for the early season fruit harvest and late season fruit harvest.

In 2004, total yield in the late season was significantly higher than that in the early season (33.88 g per m^2 vs. 9.92 g per m^2, respectively) ($p=0.05$). Among all of the treatments, the average marketable yield in the late season harvest (fruit harvested after 1 Apr.) was significantly higher as compared to that in the early season fruit harvest (53.24 g per m^2 vs. 19.21 g per m^2, respectively) ($p=0.05$).

Even though fruit production was higher in the late season compared to the early season in 2004 the HT was still producing fruits six weeks earlier compared to the normal production season. This is a large marketing window created by the use of a HT. A larger marketing window is important because this will allow the grower to become established early while still producing later. This also allows the grower the opportunity to supplement his other operation(s).

2004 Strawberries: *Treatments*

In 2004, the total yield was significantly influenced by treatment ($p=0.0001$) and harvest date (early season harvest vs. late season harvest) ($p=0.0001$). There was also a significant interaction between the treatments and harvest dates ($p=0.0001$), therefore, pairwise tests of least square means were used to determine differences between each treatment at the two harvest dates.

The total yield of the 'Chandler' bareroot treatment in the late season harvest (93.93 g per m^2) was significantly higher than the total yields of all other treatments both in the early and late seasons ($p=0.0001$) (Table 2a). In addition, the total yield of the 'Camarosa' bareroot treatment in the late season harvest was significantly higher compared to all other treatments in the early and late seasons (with the exception of 'Chandler' bareroot in the late season) ($p=0.0014$) (Table 2a). All other treatments were statistically similar (Table 2a).

Marketable Yield

Marketable yield of the 'Chandler' bareroot treatment in the late season harvest (79.78 g per m^2) was significantly higher than the marketable yields of all other treatments in the early and late seasons with the exception of the 'Camarosa' bareroot treatment in the late harvest season (58.27 g per m^2) ($p=0.0001$) (Table 2a). The marketable yield of the 'Camarosa' bareroot treatment in the late season was significantly higher compared to all treatments in the early and late seasons with the exception of the 'Chandler' bareroot treatment in the late harvest season ($p=0.0001$) (Table 2a). The marketable yield of the 'Chandler' plug and 'Camarosa' plug treatments in the late harvest season (42.65 g per m^2 and 44.67 g per m^2, respectively) were statistically similar but were significantly higher than the marketable yields of the treatments in the early season ($p=0.0173$) (Table 2a). All other treatments were statistically similar (Table 2a).

Non-marketable Yield

The non-marketable yield of the 'Chandler' bareroot treatment in the late harvest season was significantly higher as compared to the non-marketable yield of the 'Camarosa' plug treatment in the late season ($p=0.0164$) (Table 2a). All other treatments were statistically similar (Table 2a).

2005 Strawberries: *Harvest*

For the spring 2005 strawberry crop, the HT strawberry crop harvest season began on 12 Dec. 2004 which is approximately14 weeks ahead of the normal beginning (1 Apr.)

of the Alabama strawberry harvest season. Fourteen weeks is a significant early season window in which a grower could command a premium price for his product and help him to establish a market earlier in the season. There were a total of 34 harvests with the first 24 harvests occurring in the early season (fruit harvested prior to 1 Apr.). As in the spring 2004 strawberry crop, these harvests were sorted into early season harvest and late season harvest (fruit harvested after 1 Apr. from the remaining 10 harvest). The final harvest was on 13 May.

In 2005, total yield among all of the treatments in the late season was significantly higher than that in the early season (33.87 g per m^2 vs. 19.9 g per m^2, respectively) ($p=0.05$). Among all of the treatments, the average marketable yield in the late season harvest (fruit harvested after 1 Apr.) was statistically similar as compared to that in the early season fruit harvest (21.17 g per m^2 vs. 15.2 g per m^2, respectively) ($p=0.05$).

Even though fruit production was higher in the late season compared to the early season yields were still statistically similar. The HT was also producing fruits 14 weeks earlier compared to the normal production season. This is a large marketing window created by the use of a HT. A larger marketing window is important because this will allow the grower to become established early while still producing later. This also allows the grower the opportunity to supplement his other operation(s).

<u>2005 Strawberries:</u> *Analysis of Yield Data*

In 2005, mean separation was used to determine differences in total marketable yield between the early season harvest and late season harvest. Across all treatments, the total marketable yield in the late season fruit harvest was significantly higher as compared to the total marketable yield of the early season fruit harvest (20.78 g per m^2 vs. 15.19 g per m^2, respectively) ($p=0.05$).

2005 Strawberries: *Treatments*

The total yield of the ‘Camarosa’ bareroot treatment in the late season (59.94 g per m^2) was significantly higher compared to that of the total yields of all other treatments in the early and late seasons ($p=0.0043$) (Table 2b). The total yield of the ‘Camarosa’ plug treatment in the late season was significantly higher as compared to that of the ‘Chandler’ bareroot treatment in the early season and that of the ‘Camarosa’ plug treatment in the early season ($p=0.0147$) (Table 2b). The total yield of the ‘Camarosa’ plug treatment in the early season was significantly higher as compared to that of the ‘Chandler’ plug treatment in the early season ($p=0.0078$) (Table 2b). All other treatments were statistically similar (Table 2b).

Marketable Yield

Marketable yield of the ‘Camarosa’ bareroot treatment in the late season (37.47 g per m^2) was significantly higher as compared to all other treatments in the early and late seasons with the exception of the ‘Camarosa’ plug treatment in the late season (25.18 g per m^2) ($p=0.0137$) (Table 2b). The marketable yield of the ‘Camarosa’ plug treatment in the late season (25.18 g per m^2) was significantly higher as compared to that of the ‘Camarosa’ plug treatment in the early season (9.56 g per m^2) and that of the ‘Chandler’ bareroot treatment in the late season (8.24 g per m^2) ($p=0.0347$) (Table 2b). All other treatments were statistically similar (Table 2b).

Non-marketable Yield

Non-marketable yield of the ‘Camarosa’ bareroot treatment in the late season (22.47 g per m^2) was significantly higher as compared to all other treatments in the early and late seasons (p=0.0008) (Table 2b). The non-marketable yield of the ‘Chandler’ plug treatment in the late season (10.82 g per m^2) was significantly higher as compared to that of the ‘Camarosa’ plug treatment in the early season (3.01 g per m^2) (p=0.0196) (Table 2b).

In both 2004 and in 2005 the bareroot treatments in the early season were statistically similar to the plug treatments in the early season. This is important given the price of the bareroot treatments were substantially less expensive therefore a grower could use the bareroot type transplant and reduce cost without sacrificing yields. The lack of difference between the yields among the two types may be due to increased ambient temperatures inside the HT compared to outside. The increased temperatures may have allowed for earlier establishment without much of a shock to the transplant.

There is not much to be extrapolated from the yield data of the varieties since varieties did not perform the same among the two years except in the early season where they were statistically similar among the two years.

Summer 2004, Basil

Four varieties of basil were selected for the summer 2004 HT study. Three culinary types, ‘Italian Large Leaf’, ‘Lime’, and ‘Magic Michael’ were selected. One horticultural type, ‘Holy Red’, was selected. The study consisted of both HT production and normal field production so that yields from the HT could be compared to yields from the field. There were a total of five harvests inside the HT and a total of four harvests outside the HT. All harvests took place between 28 July and 3 Sept. of 2004. The data presented is from one year only.

Yield Analysis

An analysis of variance procedure was used to determine if there were differences in yield among the treatments across the two locations of this study. There was a significant difference between locations (p=0.0001) with plants inside the HT yielding 533.46 grams per m^2 and plants outside the HT yielding 266.56 grams per m^2. 'Italian Large Leaf', 'Lime', and 'Magical Micheal' (i.e. the culinary varieties) had significantly higher yields inside the HT compared to outside of the HT (684.93 grams per m^2 vs. 414.48 grams per m^2, 773.39 grams per m^2 vs. 284.42 grams per m^2, and 518.2 grams per m^2 vs. 239.09 grams per m^2 respectively) (p=0.0001). 'Holy Red' (i.e. the horticultural variety) was statistically similar across both locations.

All culinary varieties grown inside the HT produced statistically higher yields than the same varieties grown in the field. In visually observing the two locations, basil grown inside was of better quality than the basil grown outside. This assumption is based on lushness of the plants and growth rate between harvests.

Evaluation of Consumer Surveys to Determine the Direct Marketing Potential for Alabama Growers

Introduction

Direct farmer-to-consumer marketing includes any method by which farmers sell their products directly to consumers (Adam, 1999; Welsh, 1998). Justification for establishing a direct farmer-to-consumer marketing outlet is based primarily on the producer=s desire to increase the financial returns from farm production. This opportunity for increased returns stems from (1) opportunities to reduce marketing costs (and capture profits) attributed to intermediaries (middlemen) in the supply chain, and (2) consumer desire to buy (and willingness to perhaps pay a premium for) riper, fresher, higher-quality fruits and vegetables. These two factors combined have often generated substantially higher net returns for producers (Adam, 1999). Considering the cost of investment and maintenance of a HT, it is critical to the profitability of a HT grower to capture a premium on the sale (White, 2003; Lamont *et al*., 2002). In return for a higher premium HT growers must supply higher quality produce (aesthetically pleasing produce for example), crops produced in the off-season when competition is lessened, specialty or niche crops (crops not widely available on the market), or crops produced with decreased use of pesticides or certified organic production (White, 2003).

In order for a grower who chooses to direct market their produce to make a profit a target market must be defined and then established. Considering the early season production of HT tomatoes and strawberries and the large market window HT production can create a grower has the opportunity to establish his business early in the season if the grower knows who and where to sale the product.

Surveys were administered over a three month period during the summer season around the state of Alabama to help define this target market. The surveys were conducted in a face-to-face manner from a table set-up outside the farmers market (46.6%, 197 respondents) or grocery store (53.4%, 226 respondents) where the surveys were given out. Each person that walked within a reasonable talking distance from our table set-up was approached and asked to complete one of our surveys regardless of race (91% white, 386 respondents; 4% African, 16 respondents; 5% other, 21 respondents), occupation, religion, gender (61% female, 257 respondents; 39% male, 166 respondents), or age (unless the person was obviously not of a care taker age, i.e. a young child).

Each survey consisted of 20 questions, 12 questions asking about their personal consumer preferences of tomato and eight asking about their personal demographics (see Appendix 1). The first 12 questions were designed to determine the willingness of the normal Alabama vegetable consumer to pay more for better quality produce. In doing this we hope to provide the small to mid-size farmer in Alabama an exact market target. Knowing your market target means not only knowing the shopping preferences of the consumer but also knowing how much the consumer spends and where they spend it. The bottom-line is growers will become more efficient and therefore more cost effective with their operations because they know who their customer is, what their going to buy, and how much their willing to spend for a quality product.

Thirty-three percent (139 respondents) of surveyors live in rural areas, 34% (145 respondents) live in urban areas, and 33% (139 respondents) live in suburban areas. Six percent (27 respondents) of surveyors have less than a high school education, 25% (104 respondents) have only a high school education, 25% (106 respondents) have some college education, 24% (103 respondents) have an undergraduate college degree, and 20% (83 respondents) have a graduate level degree. Eight percent (33 respondents) of those surveyed make less than $20,000/year, 26% (110 respondents) make between $20,000 and $40,000/year, 25% (106 respondents) make between $40,000 and $60,000/year, 13% (53 respondents) make between $60,000 and $80,000/year, 10% (43 respondents) make between $80,000 and $100,000/year, 18% (78 respondents) make over $100,000/year.

Out of almost 500 people surveyed, 93% of those indicated they would pay more for early season vine-ripened tomatoes produced by local growers (growers in Alabama). Over 50% of those surveyed indicated they would pay from 50 cents to one dollar more per pound of tomato. Eighty-four percent (357 respondents) of those surveyed indicated they buy tomatoes because they or their family like the taste of tomato. Ten percent (41 respondents) of those surveyed indicated they buy tomato because of the health benefits associated with eating tomatoes.

A Binary Probit Model was used to predict the probability relationship of the dependent variable and independent variables. This leads to the joint probability of the variables. For example, in our study, consumers were asked if they would pay more for early season locally grown tomatoes. This question serves as our dependent variable and the independent variables predict how likely a consumer is to purchase early season locally grown tomatoes based on their answer of the independent variables (Table 3). This model was highly effective in correctly predicting whether or not a consumer would pay more for early season locally grown tomatoes (i.e. dependent variable) based on their answers of the independent variables (Table 4). When consumers were asked if they would pay more for locally grown early season tomatoes, the model predicted that they would 92% of the time. The model correctly predicted this answer 98.6% of the time.

Consumers who would pay more for vine ripened tomatoes (VINE) (Table 5) are also more likely to pay more for locally grown tomatoes (Table 3). VINE (Table 5) increases the probability that they would pay more for early season locally grown tomatoes (Table 3). Consumers earning more than $60,000 per year (Income 2) (Table 5) are more likely to pay more for early season locally grown tomatoes (Table 3).

Consumers who indicated they would pay between $0.25 and $1.50 (Pay 1) (Table 5) more per pound for early season locally grown tomatoes are more likely to pay more for early season locally grown tomatoes (Table 3). Consumers with less than a high school education (EDU 1) (Table 5) are more likely to pay more for early season locally grown tomatoes (Table 3). Consumers who are Caucasian (Ethnic 2) (Table 5) are more likely to pay more for early season locally grown tomatoes (Table 3).

Consumers earning more than $60,000 per year (Income 2) (Table 5) increase the probability that they would pay more for early season locally grown tomatoes by 30.5% (Table 3). Consumers with less than a high school education (EDU 1) (Table 5) increase the probability that they would pay more for early season locally grown tomatoes by 58% (Table 3). Consumers who are Caucasian (Ethnic 2) (Table 5) increase the probability that they would pay more for early season locally grown tomatoes by 48% (Table 3). Consumers who indicated they would pay more for vine ripened tomatoes increase the probability that they would pay more for early season locally grown tomatoes by 43% (Table 3). Consumers who indicated they would pay between $0.25 and $1.50 more per pound (Pay 1) (Table 5), compared to regular season prices, for early season locally grown tomatoes increase the probability that consumers would pay more for these early season locally grown tomatoes by 39.5% (Table 3).

Table 1: HT and Greenhouse Construction Cost Comparison

High Tunnel Construction	cost/m^2	Greenhouse Construction	cost/m^2
Frame	$6.18	Frame	$5.21
Lumber	$1.86	Glazing	$2.10
Hardware	$3.69	End Walls	$12.70
Plastic Coverings	$2.49	Heating	$2.69
		Floor	$1.68
		Utility	$1.98
		Benches	$4.19
		Cooling	$7.66
total	$14.22	total	$38.21

Table 2a: 2004 Total, Marketable, and Non-marketable Strawberry Yield by Season

season	treatment	total		marketable		non-marketable	
early	Chandler br	30.66	c	22.35	c	8.31	ab
early	Chandler p	28.24	c	19.12	c	9.12	ab
early	Camarosa br	32.43	c	21.76	c	10.66	ab
early	Camarosa p	29.26	c	19.19	c	10.07	ab
late	Chandler br	93.33	a	79.78	a	14.15	a
late	Chandler p	47.61	bc	42.65	b	4.96	ab
late	Camarosa br	62.32	b	58.27	ab	4.04	ab
late	Camarosa p	46.32	bc	44.67	b	1.65	b

Table 2b: 2005 Total, Marketable, and Non-marketable Strawberry Yield by Season

season	treatment	total		marketable		non-marketable	
early	Chandler br	15.82	c	11.51	bc	4.31	c
early	Chandler p	28.01	b	21.91	b	6.1	b
early	Camarosa br	23.26	bc	17.8	b	5.47	b
early	Camarosa p	12.57	c	9.56	c	3.01	c
late	Chandler br	17.53	bc	8.24	c	9.29	b
late	Chandler p	23.06	bc	12.23	bc	10.82	b
late	Camarosa br	59.94	a	39.04	a	22.47	a
late	Camarosa p	34.94	b	25.18	ab	9.76	b

Table 3: Binomial Probit Model

Variable	Coefficient	P[|Z|>z]	Marginal Effect
Constant	1.6969	0.0034***	-0.1042
Grocer	-0.1884	0.5169	-0.1157
Pay 1	0.6425	0.0347**	0.3946
Vine	0.7008	0.0102**	0.4304
Early	-0.8991	0.7509	-0.5522
Organic	0.6126	0.1174	0.3762
Born	0.2602	0.0044***	0.1598
Edu 1	0.9508	0.0021***	0.584
Income 2	0.4964	0.0583**	0.3049
Ethnic 2	0.7761	0.0475**	0.4767
Log Likelihood	-69.907		
Restricted Log Likelihood	-94.61		
Chi-Squared	49.405	0.0000	

Table 4: Predicted Model

Actual	0	1	total
0	1	25	26
1	4	347	351
total	5	372	377

Table 5: List of survey variables

Variable	Definition
Local 1	dependent variable, if would pay more for early season, locally grown produce
Grocer	purchase tomato most often in grocery store - 1 if yes, 0 otherwise
Pay 1	would pay between $0.25 and $1.50 more per pound - 1 if yes, 0 otherwise
Vine	pay more for vine ripened - 1 if yes, 0 otherwise
Early	pay more for early season - 1 if yes, 0 otherwise
Organic	pay more for organic - 1 if yes, 0 otherwise
Born	age
Edu 1	education level of less than college degree
Income 2	income of $60,000 or more
Ethnic 2	caucasian

Figure 1a: HT design viewed from the west facing wall.

Figure 1b: HT viewed from south facing side with sides rolled up.

Figure 2: HT view of polyethylene mulch covered raised beds with endwalls and sidewalls up.

Figure 3: HT view of tomatoes and strawberries planted within the same rows.

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APPENDIX

Auburn University, Horticulture Department
Survey of Consumer Preferences on Tomato

I. Purchase Information

1. Have you purchased tomato in the past 12 months?
___yes (If yes, skip question 2 and go on to question 3) ___no

2. If not, why? (Check one, and skip to question 11)
___don't like taste/texture ___too expensive
___allergies or other medical reasons ___grow your own
___other (Please specify) __________

3. Approximately, how many times each month do you purchase tomato? (Write number of times per month on each line)

___Jan	___Apr	___July	___Oct
___Feb	___May	___Aug	___Nov
___March	___June	___Sept	___Dec

4. Would you pay more for early season (Nov-May), vine ripened tomatoes produced by a local grower (i.e. grown in Alabama)? ___yes ___no

5. If so, how much more would you pay per pound (1 lb. equals approx. 3-4 tomatoes and may cost $1.00 to $2.00)? (Check all that apply)

___$0.25	___$1.50	___$3.00
___$0.50	___$2.00	___$3.50
___$1.00	___$2.50	___$4.00

6. Would you pay more for any of the following types of tomatoes? (Check all that apply)___locally grown ___vine ripened ___early season (Nov-May) ___organic

7. If so, how much more would you pay per pound (1 lb. equals approx. 3-4 tomatoes and may cost $1.00 to $2.00)? (Check all that apply)

___$0.25	___$1.50	___$3.00
___$0.50	___$2.00	___$3.50
___$1.00	___$2.50	___$4.00

8. What is the most important reason you purchase tomato? (Check one)

___health benefits ___price compared to other fruits/vegetables
___family likes it ___flavor/taste
___party/special occasion ___other (Please specify) ________

9. Where do you most often buy tomato? (Check one)
___grocery store ___roadside stand ___farmers' market

10. Which would you be most willing to purchase? (Rank them in order)
___Alabama grown tomatoes ___Southern grown tomatoes
___U.S grown tomatoes ___imported tomatoes ___no preference

11. Do you know why organically produced vegetables and sustainable produce may be more expensive than produce grown using conventional methods? (Conventional methods may involve the use of synthetic fertilizers and pesticides)
___yes ___no

12. Would you be interested in knowing more about the differences between organic and conventional produce? ___yes ___no

II. Demographic Information

13. In what year were you born? _______

14. What is your gender? ___male ___female

15. What is your ethnic group? (Check one)
___African American ___Asian ___Caucasian
___Hispanic ___Native American ___Other (Please specify) ________

16. What level of education have you completed? (Check one)
___less than high school ___completed four-year college degree
___high school graduate ___completed graduate degree
___some college or technical school

17. Counting yourself, how many people in each age category live in your household?
___15 year's old or younger ___30-44 year's old ___60-74 year's old
___16-29 year's old ___45-59 year's old ___75 year's or older

18. Where is your home located?
___suburban (city perimeter) ___urban (city/town) ___rural (country)

19. What was your approximate household income in 2003 before taxes? (Check one)

___less than $20,000 per year	___$60,000 to 79,999 per year
___$20,000 to 39,999 per year	___$80,000 to 99,999 per year
___$40,000 to 59,999 per year	___more than $100,000 per year

20. Please indicate the date you took the survey? __________