12-2009

Heirloom and Hybrid Tomato Yield and Quality in Organic and Conventional Production Systems

Diana J. Edlin
Western Kentucky University, diana.garland@wku.edu

HEIRLOOM AND HYBRID TOMATO YIELD AND QUALITY IN ORGANIC AND CONVENTIONAL PRODUCTION SYSTEMS

A Thesis
Presented to
The Faculty of the Department of Agriculture
Western Kentucky University
Bowling Green, Kentucky

In Partial Fulfillment
Of the Requirements for the Degree
Master of Science

By

Diana J. Edlin

December 2009

HEIRLOOM AND HYBRID TOMATO YIELD AND QUALITY IN ORGANIC AND CONVENTIONAL PRODUCTION SYSTEMS

Date Recommended___12/9/09___________

_Martin Stone_________________________
Director of Thesis

_Linda Gonzales_______________________

_Elmer Gray___________________________

_Nathan Howell_______________________

____
Dean, Graduate Studies and Research Date

Acknowledgements

Many thanks to the following people:

My parents, Roger and Lisa Garland, for always supporting and encouraging me in all life decisions, for teaching me to think and allowing me to pursue my interests, and for listening to all the details and difficulties of tomatoes

Chris Edlin, for believing I could do this even when I wasn't sure, for listening, enduring, cheering, and eating copious amounts of homemade spaghetti sauce

Dr. Martin Stone, for all of the time, training, editing, planning, green hands, advice and odiferous grading

Dr. Elmer Gray, for his supreme example, wonderful insight and always having time to discuss a new idea, or an old one

Nathan Howell, without your expertise we would have been lost, without your humor at times we would have been depressed

Stephen Flomo, for all of your hard work and generosity with information, without you this would not have been completed

Mr. Wang, Tara, Crystal, and the Sustainability class (Fall 2009) without all of your hard work we would have despaired of picking tomatoes long before we were finished

The Department of Agriculture for giving me the opportunity complete this project and for being so enthusiastic about taking home our extra tomatoes

Table of Contents

Chapter Page #

I. Objectives 3

II. History of the Tomato, its Discovery, Spread, Acceptance and Development.......4

III. Specific Literature Review...33

IV. Materials and Methods 38

V. Results...48

VI. Discussion and Conclusions..51

VII. Appendix 61

VIII. Literature Cited...65

List of Tables

Title Page #

1. Soil test analysis for 2008 and 2009 for organic and conventional production system plots...41

2. Comparison of organic and conventional management techniques for weight, size, grade, and fruit number in three tomato cultivars for the 2008 season..................44

3. Comparison of organic and conventional management techniques for weight, size, grade and fruit number in three tomato cultivars for the 2009 season...................45

4. Comparison of three tomato cultivars for weight, size, grade and fruit number grown using organic and conventional management techniques for the 2008 season 47

5. Comparison of three tomato cultivars for weight, size, grade, and fruit number grown using organic and conventional management techniques for the 2009 season 48

6. Precipitation, temperature and humidity for the 2008 and 2009 seasons.............51

HEIRLOOM AND HYBRID TOMATO YIELD AND QUALITY IN ORGANIC AND CONVENTIONAL PRODUCTOIN SYSTEMS

Diana J. Edlin | December 2009 | 67 Pages

Directed by: Dr. M.J. Stone

Department of Agriculture | Western Kentucky University

Due to the recent changes in the economy of Kentucky tobacco production, some producers are seeking an alternative crop that will provide similar economic gains to tobacco without needing more acreage. Tomatoes are an existing crop in Kentucky that have been declining in acreage over the last five years. There is evidence to suggest that, through niche and local marketing, tomatoes may be able to fill the void left by tobacco. However, there is concern among producers that they will lose yield and/or quality if they switch to one of these niche production systems or cultivars.

A two year study at Western Kentucky University compared the yield and quality of three tomato cultivars, two heirlooms and one hybrid, under organic and conventional management techniques to see if producers concerns are valid. The heirloom cultivars used were 'Cherokee Purple' (CP) and 'Mr. Stripey', (MS) the hybrid cultivar was 'Crista' (CR). The study was a split block design, with four randomized replications within each block. Plants were grown under black plastic mulch, with drip irrigation under the mulch. Plants were harvested weekly throughout the season and data were collected on individual fruit weight, size, grade and the number of fruit produced per plant. Production and quality were compared between management techniques for each

cultivar, and the cultivars were compared to each other under individual management techniques.

When comparing organic and conventional management practices, CP produced significantly ($p<.05$) larger, heavier, and higher quality fruit under organic practices and showed no significant differences in fruit number in 2008. MS and CR showed no significant differences between production systems for fruit weight or size, CR produced significantly higher quality fruit under conventional treatment and MS produced significantly more fruit per plant in 2008. In 2009, CP did not produce enough fruit under organic management to allow statistical comparison between management systems. MS however did not show any significant differences between management systems for any of the traits studied. CR produced significantly larger fruit under organic management, but no other differences were observed.

When comparing cultivars in 2008, CP and CR produced fruit of similar weight but significantly heavier than MS under both production systems. CP produced the largest fruit under organic management, with CR following and MS producing the smallest fruit. Under conventional management, CP and CR produced fruit of similar size and both were larger than MS. MS produced the highest quality fruit under organic management, and CR produced the nicest grade under conventional management. No differences were seen for number of fruit per plant between cultivars under organic management, while MS produced the most fruit per plant under conventional management. In 2009 CP did not produce enough fruit to be statistically compared to the other cultivars under organic management. MS and CR produced fruit of similar weight under both organic and conventional management, while CP produced the greatest weight under conventional management. CR produced larger fruit than MS under organic management, while under conventional management CP and CR were of similar size as were CR and MS, but CP was significantly larger than MS. No significant differences were found between cultivars for fruit grade or number of fruit per plant under either management system in 2009.

CHAPTER ONE

Objectives

The objectives of this study are to research ways that have potential to enhance producer's profits and see if they are viable options. The main targets for this benefit would be former tobacco producers looking for an alternative crop, but this information should be beneficial to any vegetable producer. Heirloom varieties, local production and marketing, and organic production systems are all potential ways to add value to produce, but concerns exist that a grower will lose productivity if they convert to organic cultural practices or heirloom vegetables. There is also concern whether a significant enough local market exists to support a grower and his/her family. In this study these concerns are explored by comparing the yield of tomatoes grown with conventional practices and those grown under organic practices. The yield of heirloom tomatoes will be compared to that of hybrid tomatoes. Some research performed by others to confirm existing demand for local and organic produce in our region will be examined and its relevance elucidated.

CHAPTER TWO

History of the Tomato, its Discovery, Spread, Acceptance and Development

From their earliest introduction into Western society, tomatoes, *Lycopersicon esculentum* Mill., have caused a stir. Not only did they come from the mysterious new world (the Americas), they had suspiciously bright fruit and were related to the dreaded and highly poisonous nightshades. Soon after their introduction to Europe there were many concerns about their edibility due to their familial relationship; others suggested they might be an aphrodisiac. Suspicion of their safety remained even after their acceptance into cuisine. Today the questions revolve around what their true name should be, whether they are fruit or vegetable and, more recently, if they are the newest weapon against the formidable enemy cancer. A fruit that has caused so much debate surely demands closer review.

When exploring the history of any plant, it is crucial to discover its geographic center of origin. It is generally assumed that plants growing at their center of origin should be in relatively the same form and genetic diversity as when the crop evolved. Vavilov, the renowned Russian scientist, theorized that domesticated plants will only represent a portion of the genetic diversity available to that species, genus or family in its wild or original state (Rice et al., 2006). Therefore, to find the center of origin one must find the area with the most natural genetic diversity of that plant (Cox, 2000; Rice et al., 2006).

For the tomato, the center of origin is a narrow strip along the Pacific coast of South America, majorly centered in the mountainous area of modern day Peru and the Galapagos Islands (Bassett, 1986; Cox, 2000; Cutler, 1997; Heuvelink, 2005; Jones, 1999; Male, 1999). It is here that one finds the maximum diversity of the genus *Lycopersicon,* a total of eight wild species (Male, 1999; Gould, 1983).

While *Lycopersicon* is the most diverse in this area, it seems the potential of using it as a food crop was not recognized until it reached Central America and Mexico (Ucko and Dimbleby, 1996). There is no conclusive evidence regarding how the tomato reached Central America but two probable possibilities present themselves. The first route speculates that during the trading of major crop seeds among tribes, some of these tasty, wild fruit were traded. This option seems less likely since the native Peruvians did not appear to recognize the tomato in their cuisine. It is more likely the tomato traveled along in these trades as a weed of the more useful crops squash, beans and maize and later adapted to the conditions of the crops it grew alongside (Ucko and Dimbleby, 1996).

The strongest cultural and genetic information points to domestication and cultivation originating in Central America and Mexico. The pre-Columbian cultures of Peru, such as the Inca, tended to decorate pottery and textiles with images of crops and figures that were important to their well-being and day-to-day life, this also appears to be how they documented their history. If the tomato had been domesticated and commonly cultivated in this culture one would expect to find evidence on these articles, but none has been unearthed to date (Smart and Simmonds, 1976). Additionally, even though the tomato is in common cultivation throughout Peru today, it appears to be a recent addition to the native Indian diets in that region (Bassett, 1986). Conversely, the tomato is deeply rooted in the cuisine and culture of Central American and Mexican people; with its presence even found in early Aztec recipes (Cutler, 1986).

A study of linguistics also supports the theory of Central American domestication. The Aztecs called the tomato 'xitomatl' (Gould, 1983) while the word 'tomato' itself seems to be a Spanish adaptation of the word 'tomatl' from the native Mexican tribe of the Nahuatl (Bassett, 1986; Lovelock, 1972). Peruvian writings, however, fail to mention a tomato-like fruit and do not have a native word that represents the tomato (Cox, 2000).

Finally, modern genetic analysis points to domestication and initial cultivation in Central America. Direct descendants from the original tomatoes were imported to Spain and several of the oldest tomato varieties known to Europe have been analyzed to determine their most recent ancestor. They have been shown to be most closely related to a cultivar which was widely cultivated in Mexico during the time of the Spanish exploration and can still be found in a semi-wild state across Mexico and Central America. The variety has subsequently been named *Lycopersicon esculentum* var. *cerasiforme* (*'cerasi'* referring to cherry and *'forme'* translating directly into form, thus indicating this species has a cherry fruit) and is now considered the direct ancestor of modern cultivated tomatoes (Amer. Hort. Soc., 1976; Gould, 1983; Heuvelink, 2005; Smart and Simmonds, 1976).

Since *L. e.* var. *cerasiforme* seems to be most widely distributed throughout Mexico and Central America, and conspicuously lacking in Peru, it is safe to assume that the native cherry tomatoes underwent several changes during their migration to the north and subsequent domestication. The first of these changes was toward greater edibility. Of the eight species found throughout Peru and Central America only two, *L. e.* var.

cerasiforme and *L. pimpinellifolium*, appear to be edible (Male, 1999). Obviously this change was necessary before cultivation by man could take place. With the change from inedible to edible also came the change of color from green to yellow (Male, 1999). This change seems to have taken place for more mammal dissemination of seed since as Male (1999) points out that not only are the other six species inedible, at least one of them has to go through the digestive systems of a turtle before it will germinate.

Probably the most significant change was reproductive in nature. The majority of wild tomato species are self-incompatible, meaning that they must outcross to make viable seed. With long-protruding stigmas and somewhat fanned stamens, the wild species are well suited to cross-pollination. At some point in their evolution, however, two of these species took a different path. *L. e.* var. *cerasiforme* and *L. pimpinellifolium* became self-compatible, though *L. e.* var. *cerasiforme* seems to be more consistent in this trait than *L. pimpinellifolium.* Physical changes that took place in order for this to be possible included significant shortening of the stigma and the stamens moving closer to one another and the stigma, thereby reducing dependence on animal and insect pollinators. This physical change made self-pollination a more plausible option than it had been previously. This trend continued as the tomato migrated north and entered cultivation. As a result, the varieties found in Central America and Mexico are similar to each other and significantly different than those in Peru. Breeders continued this pattern of encouraging self-fertilization and shortening stigma length as the tomato spread throughout the Old World. It is not surprising then that almost all Old World varieties (along with all 'heirloom' varieties) are completely self-pollinated and self-fertilized, and that their stigmas have been shortened to the point that they are almost enclosed by the stamens. Complete enclosure did not occur until 1955-65, however, as a by-product of some crosses in California (Bassett, 1986; Smart and Simmonds, 1976).

While the tomato found by the conquistadors was still very different than the one found on your sandwich, the species was set on the path that would take it there. The conquistadors were first introduced to the tomato when they began exploring Mexico and the surrounding areas. Cortez conquered Tenochtitlan, later to be named Mexico city, in 1521, and the tomato appears to have returned to Spain with the conquistadors shortly thereafter as spoils of war. From there tomatoes spread quickly throughout the Mediterranean region (Gould, 1983).

We have records of the tomato being eaten in Italy as early as 1544 which speak of the *pomi d'oro* (golden apple) being eaten "with oil, salt and pepper" (Gould, 1983). We also have a written account of the tomato by the Italian herbalist Pier Andrea Mattioli (Bassett, 1986). Between these two accounts we can surmise that the tomatoes first introduced into the Old World were yellow in variety and initially introduced in the Mediterranean region. It is also apparent from several accounts that the Spanish and Italians were quick to embrace the tomato as edible and to add it into their cuisine. They were the only ones to embrace it so readily (Bassett, 1986; Gould, 1983; Heuvelink, 2005; Lovelock, 1972; Smart and Simmonds, 1976).

During its spread throughout Europe the tomato met curious suspicion. As people did not wish to appear uncultured, tomatoes were usually accepted as ornamental plants but not eaten. It was feared due to its dubious relation to the deadly nightshade (*Solanum dulcamara*) and its strikingly similar appearance. It was even classified by Linnaeus in 1753 as *Solanum lycopersicon,* one of the nightshades (Heuvelink, 2005). It is surprisingly difficult to elucidate a translation for the word *Solanum* or its Latin origin. It is commonly assumed in the literature that it is from the Latin verb *solari,* which means to soothe, or the Latin noun *solamen,* which means a comfort or a relief (Jepson, 1911). Both of these would presumably refer to the narcotic qualities of the family and genus. Some sources relate it to another meaning of the Latin root *sol,* which is the source of our word solar, relating it to the sun or moon. These sources indicate that this could be where the family got the common name of nightshade (Personal communication, Lawrence Alice, Western Kentucky University Profsessor, 2009; Cox, 2000). Regardless, this word directly relates the tomato with the deadly qualities of nightshades. *Lycopersicon* is not difficult to define, however. *Lyco-* refers to wolf and *-persicon* refers to peach, bringing to mind the current superstition of the day which related tomatoes to German werewolf legends (Jones, 1999; Cox, 2000). Recognizing the mistaken implications of the name and the tomato's differences from the nightshade, Philip Miller (Heuvelink, 2005) renamed the tomato, fifteen years after Linnaeus' title, as *Lycopersicon esculentum*. *Esculentum* translates into 'edible'. Thus, after this correction, the tomato became the edible wolf peach (Heuvelink, 2005; Jones, 1999).

The scientific name of tomatoes is still debated. Many botanists contend the name first coined by Linnaeus should be reinstated because of its precedence and because this name may be the more taxonomically correct placement. While *Solanum lycopersicon* has been recently reintroduced, *Lycopersicon esculentum* is still valid and the most commonly used (Heuvelink, 2005).

Change appears to be associated with the tomato throughout its history; it underwent multiple name changes, changes in public opinion, and physical changes.

Early in its time in Europe the tomato was known variously as *Peruvian apple* (in Spain), *pommi d' oro* (meaning 'golden apple' in Italy), *pommes d' or* (meaning 'golden apple' in France), and *goldapfel* (meaning 'golden apple' in Germany) (Lovelock, 1972). While many refute the validity of the name 'love apple' it is mentioned in enough places that it deserves examination here. Some believe that the name was a simple distortion of the Spanish name *pome dei Moro* ('Moor's apple') into the French name *pomme d'amour* ('love apple') (Cox, 2000). Others, however, point to the fact that it was not only called 'love apple' in France but also in Germany, along with the names of *mad apple* or *rage apple* during a time when these words carried overtones of wanton or amorous ambition (Lovelock, 1972). These names came from the belief in its aphrodisiac qualities. *Wolf peach,* as mentioned above, hinted at yet another suspicion collected along the tomato's trail which came from old German folklore; witches used nightshades to evoke werewolves. Due to its connection with nightshades, the tomato was also implicated in other cases of witchcraft activity (Cox, 2000; Cutler, 1997).

Regardless of these names and the various negative connotations associated with the safety of eating tomatoes, their acceptance slowly spread throughout Europe. By 1623 four forms appear to be recognized: red, yellow, orange and golden, though the distinction between yellow and golden are subtle and emphasized by Gould (1983). The first cookbook to contain tomatoes appeared in Naples in 1692 (Cutler, 1998). Seven different types are mentioned in one article by 1700 (Gould, 1983) and by 1752 cooks in England were using tomatoes sparingly to flavor soups and sauces (Cutler, 1998). The earliest records show the tomato fruit being marketed to eat during the early 1800's (Gould, 1983).

During its early time in Europe, the tomato experienced significant changes to its morphology and utilization. Although not well documented, historians assume that the tomatoes first introduced were relatively small fruited in comparison to the fruit common today since they were direct descendants of the cherry type *L. e.* var. *cerasiforme.* Writings about breeding to improve their size indicate that they were smaller than desired. Additionally, emphasis on breeding for smoother skin indicates that these early cultivars had rough or bumpy-skin (Gould, 1998). Finally, as mentioned above, there were continued changes to the reproductive structures, with shortening of the stigma, enclosure of the stigma by the stamens and definite selection for self-fertile plants. These reproductive changes were especially important as tomatoes moved indoors, into orangeries and other early greenhouse structures with other ornamental and edible plants of the time, and away from pollinators such as wind and insects (Smart and Simmonds, 1976).

As Europeans embarked for the new world in the mid 1600's, tomatoes came with them (as did most of the other foods we know and enjoy); unfortunately most of their suspicions came along as well. As with most of Europe during this time, newly immigrated Americans viewed tomatoes mostly as an ornamental plant, though some were using them sparingly for the medical purpose of removing pustules (ewww...) (Simpson and Ogorzaly, 1986). The first documented record of the tomato in America was in 1710. Apparently even though some colonists brought the tomato and appear to have been consuming it the persistent view was that they were unhealthy at best and poisonous at worst (Bassett, 1986).

Although Thomas Jefferson brought the tomato to his table in 1781, it still did not really grow in popularity until the 1830's (Bassett, 1986). During the intervening time, attempts to market tomato fruit met with little success. Gould (1983) relates the story of a painter who had difficulty even convincing people to taste the fruit he was trying to sell in 1802 Massachusetts. By 1812 evidence suggests that people in New Orleans were incorporating the tomato into their cuisine and acceptance was widening throughout the country, but many were still dubious (Gould, 1983). Supposedly Colonel Robert Gibbon Johnson laid all doubt to rest in 1820 when he declared he would eat a whole bushel of tomatoes in front of the Boston courthouse. Hundreds of spectators gathered to watch the poor man meet his death and were shocked when he survived the ordeal none the worse for wear (Cutler, 1997; Simpson and Ogorzaly, 1986; Smith, 1994). Unfortunately according to Andrew Smith, this story has no basis in fact despite its infamous and recurring position in the tomato's history (1994).

Fortunately the tomato's acceptance continued to spread without the help of Colonel Johnson. Tomatoes began appearing in cookbooks such as *The Cook's Own Book* by 1832, and in gardening books such as the *Shaker Gardener's Manual* by 1843 and *The Gardener's Text-Book* in 1851 (Cutler, 1997). In 1835 tomatoes were sold by the dozen in Boston's Quincy Market and in 1847 four varieties were listed in Thomas Bridgeman's seed catalogue: Cherry, Pear, Large Yellow and Large Squash (Cox, 2000). By the end of the Civil War tomatoes were fairly common in American gardens; so much so that the first *Fanny Farmer Cookbook,* which came out in the 1890's, included tomatoes in soups, salads and sauces without the usual words of caution (Cutler, 1997).

A few pockets of resistance existed even into the 20th century. In an attempt to improve his Alabama neighbors' woefully nutrient deficient diets, George Washington Carver encouraged them to include tomatoes in their gardens and cuisine (Jones, 2008). To that end he is quoted saying "Every normal person should make the tomato a very prominent part of their weekly diet" (Jones, 2008). He met with limited success despite the moderately widespread acceptance of tomatoes at this point (Cox, 2000).

Selecting for improvement came quickly on the heels of acceptance and marketing. Early improvements were accomplished mostly through natural selection, that is when growers would see an improvement or desirable change they would save seed from that fruit for future crops. Through this method of continuous improvement a plethora of new varieties were produced. These desirable changes occurred through various methods. One method was mutation of the stock as it spread throughout the world. When these mutations were beneficial they were saved and propagated in future generations. A second method was the occasional outcross which could happen through insect pollination. When these crosses occurred they added vigor and new genetic material to existing lines (Male,1999).

A final method that may have been used is deliberate crosses between two of a grower’s finest plants. This method is not the same as modern hybridizing. When creating a hybrid today we use two parents that we know consistently make a favorable fruit when they are crossed. But since this offspring is not homozygous in its genetic makeup we will not get the same fruit from it next year if we were to save the seed. Therefore, the same two parents must be used every year to obtain seed that will produce plants with the traits we desire. The crosses to which we refer would eventually become homogenized through the saving and selecting of seed over several generations. Once a plant has a homogenous genetic makeup it will 'come true' in its seed; when seed is saved, the resulting plant will be identical to the parent plant it was obtained from (Cutler, 1997).

While it seems improbable that today's diversity could have been derived from a handful of plants and seed brought to Europe by some soldiers, an amazing variety was well established throughout Europe and the Americas by the 1880's. A study conducted at Michigan Agriculture College in the late 1880's showed that some of this variety may have been false. Of the 171 named cultivars examined in their study only 61 truly different lines existed (Gould,1983). Despite this fact, the sheer volume of cultivars is a strong indication of how established tomatoes now were in Western culture and of the high demand for new strains.

Due to their ability to self-pollinate and maintain homogenous gene pools, these early varieties have not greatly changed over the last hundred years. Many have been handed down in families and communities for generations, thus earning them the name heirlooms.

An investigation of heirlooms tomatoes

It is difficult to identify an exact definition for heirloom vegetables in general. Some heirloom growers assert that heirlooms are a treasured variety that has personal value, no matter how old it is or where it came from. Other growers insist that in order to be an heirloom it must have been cultivated before 1940. They use this date because in the 1930's many seed companies had begun introducing hybrids on the public market, a revolution that changed the way we produce and look at tomatoes. Some producers take this a step further by insisting that in order to be an heirloom the variety must have been handed down in the same family, or extended family, for several generations (Male, 1999). Still others invested in heirlooms set an age limit on what can be defined as an heirloom. Even those in this camp cannot agree, however, since some insist on 50 years while others say 100. Some growers are simply satisfied to apply the name heirloom to any plant that has a background or formation story (Coulter, 2006).

If these options do not make the matter confusing enough, there are also people who recognize the problem and try to resolve it by breaking heirlooms into different classifications. Craig LeHoullier suggested the first three categories, commercial heirlooms, family heirlooms, and deliberately created heirlooms (Male, 1999). Male added a forth category called ‘mystery group’ for those that do not fit well into any of the above (Male, 1999).

'Commercial heirlooms' are tomatoes that were introduced to the public by seed companies before 1940. Historians assume that most of these were derived from family stock, naturally occurring mutations, and natural selection. Many of our modern hybrids are progeny of these popular older varieties. Male (1999) lists examples of this group and their dates of commercial introduction, including: ‘Trophy’ (1870) (the first modern looking, red, smooth-skinned tomato), ‘Paragon’ (1870), ‘Favorite’ (1883), ‘Beauty’ (1885), ‘Optimus’ (1885), ‘Magnus’ (1900), and ‘Alpha Pink’ (1915). This is just a small selection of the hundreds of varieties available in this period. Even with the large number that have been lost, these and many others can still be found through places like Seed Savers Exchange and the USDA seed bank (Male, 1999; Stickland, 1998).

'Family heirlooms' are what most people think of when they ponder an heirloom. These are plants that have been handed down through generations. Many were treasured heirlooms brought with new settlers in the late 1800’s and early 1900’s. These tomatoes were originally selected for positive traits and stabilized to an open pollinated form by observant farmers and home gardeners. These varieties are still coming into this country with new settlers today such as ‘Sandul Moldovan’ which came with a family newly emigrated from Moldova. Other examples of imported heirlooms include ‘Eva Purple Ball’ from the Black Forest in Germany, ‘Soldacki’ from Poland, and ‘Myona’ from Italy. Family heirlooms have also been developed and preserved in our country. Some of these include ‘Cherokee Purple’, ‘Red Brandywine’, ‘Mortgage Lifter’, and ‘Kellogg’s Breakfast’. While these may or may not have well documented histories, claims of the families with which they are associated puts them in this category. This category has no an age limit, so while many of these varieties may have been around since the 1800’s, many have also been established in the last twenty years. Again, Seed Savers Exchange is an excellent source for 'Family Heirlooms' as they have encouraged families to share their treasures with others as a way to preserve these lines (Male, 1999).

The third category named by LeHoullier is 'created heirlooms'. These are established by deliberately crossing two heirlooms or an heirloom and a hybrid. The resulting offspring must be saved, selected and grown out for several years in order to stabilize the genetic makeup and return it to its open-pollinated state. The number of years required to dehybridize the new cross varies depending on the traits sought but typically spans between three and ten years. Although many insist that these cannot be true heirlooms, they have admittedly introduced some different variations into tomato selection. Some examples of these include ‘Green Grape’, ‘Green Zebra’ and ‘Snowstorm’ (Male, 1999).

The final category, which Male added to this group, is aptly dubbed the ‘Mystery Group’ (1999). These are heirlooms that resulted from natural cross-pollination, usually between heirlooms. Although most of our current heirlooms were formed in this way, along with spontaneous mutation, the distinction here is that they are being selected for modern times. These heirlooms are not truly family heirlooms (they have not been around long enough) although their parents might have been. Neither are they created heirlooms since the cross was not deliberate. Male (1999) gives the example of ‘OTV (Off The Vine) Brandywine’, which is now available through Seed Saver’s Exchange (SSE). ‘OTV Brandywine’ was the result of an unknown cross between a ‘Yellow Brandywine’ and an unknown large red tomato. The offspring was a large, red, beefsteak type tomato with orange undertones at the shoulders. After five years of purifying and selecting for the desirable traits first seen in that offspring ‘OTV Brandywine’ was released to others through SSE (Male, 1999).

No matter which definition one chooses to adhere to, there is one major quality that all heirlooms must share, open pollination. Domesticated tomatoes (*Lycopersicon esculentum*) are naturally self-pollinating. Since they do not outcross very often, strains quickly become homogenous and produce ‘true to seed’. 'True to seed' means that seed saved from one tomato will produce fruit identical to the parent plant. Open pollination promotes continual small changes in the plant's production and immunities, which explain the local adaptation witnessed in most heirloom cultivars. The only interference needed from humans to continue these lines is a place to grow and, isolation from other cultivars for strains that are particularly prone to out crossing. Because of this trait heirloom tomatoes are also known as 'Open Pollinated'.

A defining characteristic of heirlooms as a whole is the sheer variety available. Colors of heirlooms range from yellow, red, orange, purple, white, green, and bicolor combinations of them all. There is also wide variety in their shapes and sizes. One can find tiny cherries and huge two-pounders in the same garden, along with globe, flattened, oblong, pumpkin, egg, pear, and pepper shaped fruits. This wide variety in color and shape is reflected as well in a wide variety of flavors. With fruit that can be very sweet to highly acidic, an heirloom tomato can be found to suit any palate or need. Variety can also be seen within cultivars of the same name or origin, this variety is a result of the small changes that lead to local adaptations. Because of local adaptation 'Cherokee Purple' that has been grown in one climate for several generations may taste different than 'Cherokee Purple' grown in another climate (Coulter, 2006; Cutler, 1997; Male, 1999; Stickland, 1998).

The wide variety available in heirlooms is one of many reasons why heirlooms have made a come back in produce lately. Consumers have tired of the cookie-cutter tomatoes found in the super market and are willing to seek out these unique fruit. Mr. Bill Best a farmer's market producer of Madison county, Kentucky, has customers that regularly drive an hour or more to his farmer's market to buy his heirloom beans and tomatoes, which easily cost two to three times more than store vegetables (Personal communication, Bill Best, Retired Berea College Professor, 2007). When consumers are asked why they are willing to pay such exorbitant prices, they answer in a variety of phrases such as, "it reminds me of what tomatoes tasted like when I was a kid", "they have so much more flavor than store tomatoes", "they aren't mealy like tomatoes at the store". Put bluntly, people seem to think they just taste better (Personal communication, Bill Best, Retired Berea College Professor, 2007).

Heirlooms, or 'old standard varieties', are found in peoples home gardens more often than modern hybrids because of taste and personal preference (Jones, 2008). Another reason some people grow an heirloom, however, is because it was developed in their area and is therefore locally adapted to their soils and climate (Male, 1999). This is most often the case in the 'Family Heirloom' category mentioned above.

Most heirlooms have colorful histories as well as colorful fruit. The story of 'Mortgage Lifter', or 'Radiator Charlie's Mortgage Lifter', is most beloved and oft repeated. According to Stickland (1998), this tomato was developed by M.C. Byles, who was known as "Radiator Charlie" for his repair shop at the bottom of a steep hill where trucks frequently overheated. In the 1930's he crossed four of the largest tomatoes he could find: 'German Johnson', an old beefsteak, an Italian and an English tomato. He went through a specific pollination and selection process for six years, at the end of which he was selling tomato plants for a dollar each during the 1940's; a steep price for the period. The legend says he was able to pay off his six thousand dollar mortgage in six years, mainly through tomato sales. Allegedly one plant could feed a whole family and people would come from up to two hundred miles away to get a few plants (Stickland, 1998). While the story has changed some over the years, it has remained relatively consistent and represents the rich heritage associated with some heirloom tomatoes.

'Brandywine' is an Amish heirloom that dates back before 1885. It was preserved, along with hundreds of other varieties, by Ben Quisenbury of New England. This large, reddish-pink, thin-skinned tomato was one of his favorites. Supposedly he obtained it from Mrs. Suddith who claimed it had been in her family for over 100 years. When Mr. Quinsenbury died at age 95, 'Brandywine' was among hundreds of varieties he passed to the Seed Savers Exchange as part of his legacy (Male, 1999; Stickland, 1998).

More recently, heirloom tomatoes, and other heirloom vegetables, have been garnering interest for more than just their superb flavor and unusual colors and shapes. With the advent of genetically modified organisms and recent concerns over the shrinking gene pool of many of our major crops, a new move to collect and preserve all possible varieties has begun in force. There has constantly been people interested in preserving this expansive genetic variety, namely the Seed Saver Exchange founded in 1975, but until now these were relatively small groups that were individually funded and run mostly by passionate volunteers. Since government officials have begun to understand the urgency of saving these genetics, many countries worldwide have set up gene banks where they store seeds (Stickland, 1998).

Vavilov and his colleagues established one of the first and most important of these genetic diversity collections. Because of their tours to collect plant diversity specimens in the 1920' and 30's, Vavilov later identified the centers of diversity for our crops. While Vavilov and many of his counterparts died as martyrs for their scientific beliefs during the communist régime in Russia, their work lives on in The Vavilov Institute of Plant Industry in St. Petersburg, Russia, where more than 360,000 seed samples from around the world are saved (Stickland, 1998). Many other countries have now set up gene banks, their contents range from predominantly local to global collections of many crops to global collections of only a few. For example, the Nordic gene bank in Sweden maintains a wide variety of plants but mostly from the Scandinavian region, while the United Kingdom gene bank has worldwide collections of only radishes, onions, carrots and several cultivated brassicas. In the United States, the National Seed Storage Laboratory houses seed only from North America, the collection includes nearly 400,000 seed samples from wild, old and new varieties of all the main crops in North America. The bank in Svälbard, within the Arctic circle, is one of the newer additions to this list (Stickland, 1998).

These establishments are expensive to maintain and require intensive labor every year to grow out these seeds and resave the new stock, one may be led to question the motivation behind such investment. One supporting reason to maintain these collections is the fear of repeating previous mistakes. The need for genetic diversity in our crops has been demonstrated several times throughout history but never more poignantly than the Irish Potato Famine. A lack of genetic diversity left the whole country susceptible to the fungus that struck and destroyed their main food source. The hope is that should such a disaster occur again, there would be enough genetic resources available to replace that crop with one more suited to the situation. A second reason to maintain these facilities is in case of some global disaster in which much of our crops and their diversity is destroyed. While many mock this concern, humans have shown themselves more than capable of mass destruction. Our new forays into bio-engineering are the final reason to support these stores. We do not yet know the potential of this new science and so do not want to lose any genetic information that could prove useful in the future.

While Stickland (1998) acknowledges that these facilities are vital, she also emphasizes that grassroots systems of maintaining vegetable varieties should not be abandoned. She points out that these programs are precariously dependent on government funding and that when grown in laboratories plants do not gain enhancement from their natural local adaptations or gain new disease and pest exposure or resistance (Stickland, 1998).

Regardless, the existence of all these facilities reinforces the idea that maintaining old (or in some cases not-so-old) heirloom varieties preserves vital genetic diversity.

An investigation of hybrid tomatoes

While these early cultivars offered a plethora of variety, breeders were still searching for yet more improvements to fruit size, plant productivity, and disease resistance. Help soon came to these breeders in the form of government funded research institutes which were founded to support breeding for improved traits. Because of the way funding was appropriated these programs supported breeding processes that were deemed more scientific, and as such changed the face of tomato breeders from farmers and home gardeners to scientists. This new process quickly produced the desired results, and in 1946 the first hybrid cultivar, 'Single Cross', was released (Heuvelink, 2005).

Because hybrids combine the best characters from both parents and produce a phenomenon called 'hybrid vigor', 'Single Cross' was superior in production, fruit size and appearance than anything on the market up to that point. Hybrids are the result of breeding two stable, genetically homogenous lines (using one specifically as the mother and the other as the father) to get a superior offspring. This offspring is called the F1 generation by breeders, geneticists and growers. Saving seed from an F1 and growing it out the next season would produce the F2 generation. If a producer were expecting the same fruit as last year, however, he would be disappointed. The F2 generation is also referred to as the segregation generation because when grown out it will separate back into its original parts, the two parent cultivars used to make the original cross, and produce some interesting, but not usually good, crosses as well. Because of this segregation generation home growers and large producers alike are not able to save seed from F1 hybrids. Inability to save seed is advantageous to seed manufacturers and marketers since their clients must buy new seed each year to get consistent produce (Heuvelink, 2005; Cutler, 1997). Hybrid tomatoes quickly dominated the seed market due to their advantages and continuous improvement. Cross breeding with wild cultivars from Central America not only added greatly needed genetic diversity but also disease resistance, which up to this point had almost reached its limit in older varieties (Heuvelink, 2005). Cornell University established Tomato Genetics Cooperative in 1951, as hybridizing with wild cultivars became more profitable. The goal of this organization was to collect and disseminate useful germplasm for future breeding projects (Gould, 1983).

Intensive breeding programs for traits such as plant productivity, fruit size, consistent yield and disease resistance have produced ongoing success toward their goals and changed the face of tomato production systems. In the course of about twenty years tomatoes went from being an exclusively hand-harvested product to completely compatible with machine-harvesters. This conversion did not happen in isolation, it took the imagination and cooperation of several disciplines in order to accomplish such a renovation. The first machine-harvestable tomato was developed at University of California Davis by G.C. Hanna and involved restructuring the tomato with smaller vines, more concentrated fruit set timing, firmer fruit to endure machine harvest, and high disease resistance for concentrated growing conditions. This completely changed production of the tomato, since producers were now able to grow hundreds of acres, harvest them all in just a few days, and ship them intact to wherever demand was highest. Add to these new cultivars extra input in the form of synthetic fertilizers and pesticides (availability of which boomed after WWII) and yield per hectare of processed tomatoes increased fourfold in California since 1940 (Cox, 2000). These cultivars and management practices have since become the overarching standard for tomato production in both fresh and processed markets. Currently they are referred to as conventional production systems.

Tomato breeders have more recently turned to biotechnology to resolve some of their production challenges. Ripe tomatoes are traditionally very soft and often bruise easily during harvest and shipping. The only way to resolve this issue until recently has been to pick tomatoes while still mostly green and allow them to ripen at their destination. Consumers often complain that this practice is detrimental to the tomato's flavor and texture. Calgene Fresh Inc. undertook the challenge to please both the consumer and the producers by inactivating the genes responsible for fruit softening during ripening. Through this process tomatoes were able to be left on the vine until they turned red, supposedly improving flavor, but stayed hard indefinitely to preserve quality during shipping and handling. The resulting cultivar, 'Flavr Savr', was introduced in 1993, and, to the surprise of many, was loudly rejected. Apparently industry executives and developers alike extremely underestimated consumers concern over such a risky, new development being applied to their food, even though there is no evidence to support their fear. Needless to say 'Flar Savr' was soon removed from shelves and has not been reintroduced since (Cox, 2000).

Seed banks, elaborated on previously, were indirectly encouraged after the advent of hybrids. When hybrids became increasingly popular, many families stopped preserving their family heirlooms and many communities abandoned the tradition of saving seed. Approximately 97% of the varieties offered in this country in 1903 have been lost due to neglect in preserving their lines, with more disappearing every day (Veteto, 2007). Groups like the Seed Savers Exchange were developed to curb this trend and to try and preserve the variety that still exists.

Hybrids are also partly responsible for the renewed interest in heirloom tomatoes recently. Due to the dissatisfaction with the flavor of hybrid tomatoes in the stores, many consumers have either begun to grow their own tomatoes or to seek them out in different venues such as farmer's markets. A recent article in Common Ground (2008) stated that producers in the North Carolina region may ask for as much as two to three times the going price of conventional hybrids for their heirloom tomatoes and still easily attract buyers due to the superior flavor, texture and variety of their cultivars.

Regardless of this debate over flavor, hybrids have proved themselves indispensible in the large production systems that commonly provide tomatoes, processed and fresh, to our grocery stores today (Heuvelink, 2005).

An investigation of organic production

As organic agriculture has grown in popularity, tomatoes are experiencing yet another change, not only in how they are grown but also in marketing. When looking at the organic food industry today it is hard to believe the movement began in 1969 People's Park in Berkley, California. Political and social radicals took the already existing ideas of organic agriculture, along with feminism and environmentalism, and elaborated upon them in an effort to reform what they saw as the social ills of the time. This period marked the beginning of the 'counterculture' movement and unknowingly the 'greening' of our culture as well (Pollan, 2006).

The definition of organic agriculture during the late 1960's and 1970's, as with many other ideas contemporary to it, carried much more weight and complexity with it than is currently associated with the concept. When one supported "Organic", they were simultaneously protesting the use of DDT and rejecting the Vietnam war, since the same companies who produced synthetic agricultural chemicals were direct descendants of the companies that produced chemicals for WWII and the chemicals used in that time against Southeast Asia. Supporting "Organic' was also seen as "Acting on the ecological premise that everything's connected to everything else, the early organic movement sought to establish not just an alternative mode of production (the chemical-free farms), but an alternative system of distribution (the anti-capitalist food co-ops), and even an alternate mode of consumption (the 'counter-cuisine'). These were the three struts on which organic's revolutionary program stood; since ecology taught 'you can never do only one thing,' what you ate was inseparable from how it was grown and how it reached your table" (Pollan, 2006).

Most of these early farmers were generally lacking hands-on experience. As such early communes served as *de facto* organic research stations for what worked and what failed. The first few years of development were rough, but these innovators stuck with it, some were able to ride through the changes that soon came and went on to be hugely successful (Pollan, 2006).

Since its inception, the original ideas of organic agriculture have faced opposition from many detractors. Conventional farmers were offended at the perceived slight inferred upon their products, politicians were concerned about the consequences of this counter-culture movement, marketers were seeking a way to get in on potential profits, the USDA was actively hostile toward organic agriculture until recently, and the general public wanted the benefits without the commitment to the ideology and other lifestyle changes. Consumers were the ultimate cause for the degeneration of this wealth of meaning surrounding "organic" (Pollan, 2006).

Since organically produced food was perceived as safer and more nutritious, there were many people who wanted food raised according to organic standards. Most of these people did not want to commit to the rest of the ideology however and were content to see the original three struts of organic agriculture (alternative production, alternative distribution and alternative consumption) reduced to the one perceived to have the most impact on health, alternative production in the form of "chemical-free farms" (Pollan, 2006).

In order to survive, many of those original commune farmers succumbed to this compromise, leaving the local co-op systems and making food the way consumers were demanding - processed. A famous (or infamous) example of one such farmer who is now extremely successful is Gene Khan, founder of Cascadian Farm. He began working on one of several communes and grew from there. He became a good organic farmer but bit by bit began to mimic the marketing and shipping system he originally tried to escape. He eventually succumb to pressure to become a big business in 1990 when he nearly lost everything because of a social scare. While some people lament over the compromise of Cascadian Farm, Khan points out that while the original ideas of organic were sacred to the founders, for most people this is "Just lunch" (Pollan, 2006).

The same year Khan sold a majority of his company also marked the beginning of federal recognition of organic agriculture. In 1990 Congress passed the Organic Food and Production Act (OFPA), which instructed the USDA to establish uniform national standards for organic food and farming. This directive turned out to be more difficult than anticipated. Initially the USDA complied with the requests of those in large agribusiness who wanted organic to be defined as loosely as possible. These groups desired a loose definition in part because they wished to enter the organic market as easily as possible, but also because they had very valid concerns that anything not labeled organic, such as genetically modified foods, would henceforth carry a negative stigma on the market, whether deserved or not. This early, weak definition was furiously rejected by organic producers, many of which still held firmly to the early movement ideals of organic production (Pollan, 2006). Finally, in 1994 the United States Department of Agriculture (USDA), via the NOSB (National Organic Standards Board), defined organic agriculture as " -an ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity. It is based on minimal use of off-farm inputs and on management practices that restore, maintain and enhance ecological harmony" (Gold, 2009).

While this definition was satisfactory, big producers, little producers, marketers, consumers, and the USDA continue to struggle with and debate different aspects and standards of organic agriculture. Some of these issues have been rehashed time and time again, others have come up more recently as they have emerged (Pollan, 2006).

Vegetables, including tomatoes, were and continue to be impacted by the USDA rules. Since vegetables are still grown in the ground and need sunlight and water, the general way to produce tomatoes has not changed since they were introduced to Spain several centuries ago. The advent of synthetic fertilizers and pesticides has been the biggest change to production, which the author would argue has been an even bigger change than the wide spread use of hybrids. These products have in many ways simplified the lives of producers. Instead of incorporating green manures along with crop rotation and animal manure to increase fertility, producers simply spread a premixed synthetic fertilizer over their fields and feed a little extra of the same through irrigation. In place of using netting, crop rotation, predatory insects or hand removal to take care of pests such as horn worms, they spray every week with a pesticide to kill harmful and beneficial organisms alike. Also with the various sprays and chemicals now available, any advent of disease, whether from planting too high a density or using the same field over and over, can be eliminated quickly and efficiently with just a few applications (Coleman, 1989).

Organic production of tomatoes in its simplest form means going back to the production methods farmers used before the advent of synthetic chemicals. Rather the use of knowledge that if a plant is being attacked by a disease, it is likely not healthy. The true solution, it may be argued, is that something is missing from the plant's make-up; either it is just not hardy enough to survive and it needs to be culled or the plant is not getting the nutrition it needs (Coleman, 1989; Pollan, 2006). This type of knowledge was overlooked during the advent of large scale production, but is slowly being rediscovered through trial and error. As mentioned in the USDA's definition, soil health is a critical factor in organic production systems. Most organic producers will insist when converting ground into organic production the first and most important step is building the soil's fertility, organic matter, and biodiversity. Soil health, they believe, will prevent most problems. These producers also recommend not reaching for the few approved sprays available for pests and diseases the first time they appear, but to look at those diseases or pest as vital signs for the crop, and try to discern what the plant needs to defend itself (Coleman, 1989; Pollan, 2006).

With the extra time and effort required, one may well wonder why any producers would commit to such a change. The answer for most producers is price. The produce section at Kroger or other grocers reveal the extreme price difference between a regular tomato and an organic tomato. While most of this price increase is to compensate producers for the extra effort put into production, some of this increase is due to the price that consumers are willing to pay for a product they believe is better for their health. Unlike other products, almost all of the price increase has trickled down to the farmers, enabling many of them, who were not earning enough to survive in conventional production, to remain in the profession they love (Pollan, 2006).

An investigation of tomato for medical purposes

The first time tomato extracts were encapsulated in 1837, they were touted as being able to cure ills from digestive problems, diseases of the liver, the common cold, and even syphilis (Smith, 1994). Smith (1994) documents that Archibald Miles seems to have been the major player in the rapid rise to fame of 'Extract of Tomato Pills', though he was not the first to encapsulate the tomato. He named the substance, Hepitine, supposedly the naturally occurring compound he extracted from tomatoes (Smith, 1994). While 'Extract of Tomato Pills' were eventually discarded from common medical usage, another tomato compound has recently been identified that may change the face of the medical industry, lycopene. Lycopene is the major carotenoid found in tomatoes and is responsible for their deep red color. While lycopene may not achieve all the miraculous cures claimed for Hepitine, it is a powerful antioxidant and several studies have shown that people who consume increased amounts of tomato products experience marked reductions in cancer risk (Giovannucci, 1999). This research has spurred many breeders to produce tomatoes with high lycopene concentrations. Through this search breeders found that *L. esculentum*'s wild cousin *L. pimpinellifolium* produces tiny fruit that have over 40 times more lycopene that domesticated tomatoes. Since these two are able to hybridize *L. pimpinellifolium* will prove indispensible in future programs aimed at increasing the lycopene content of tomato fruit (Cox, 2000). A University of California Davis survey recently ranked the tomato as "the single most important fruit or vegetable of western diets in terms of overall source of vitamins and minerals" (Cox, 2000). All of these promised benefits have once again spurred marketers to encapsulate part of the tomato, lycopene.

Conclusion of investigations into tomato history

Tomatoes have become established since their introduction to western culture. As recently as 2004, the United States ranks second in total world production, behind China and ahead of Turkey, and the U.S. per capita consumption is 88.9 pounds when the amounts of fresh and canned are combined (Maynard and Hochmuth, 2007). From the humble position of a weed seed to 'most popular "vegetable" grown today,' tomatoes have made a huge impact on western society (Amer. Hort. Soc., 1976; Cox, 2000; Coulter, 2006; Cutler, 1997; Stickland, 1998). Tomatoes are now the most widely grown fruit in American home gardens, they have worked their way into much of our cuisine and have repeatedly been shown to be beneficial to our health (Male, 1999). There can be no doubt that tomatoes have become an integral part of the United States' cuisine and gardens

CHAPTER THREE

Specific Literature Review

Demand for Local and Organic and Heirlooms

The first concern to address is the issue of the demand for local tomato production, organic production, and the production of heirloom varieties. The Spring 2008 edition of Common Ground, published and distributed by Southern Region SARE (Sustainable Agriculture Research and Education Program), addresses the issues of demand for local food and heirlooms vegetables (SARE, 2008).

The first article addressed demand for locally produced food, summarizing a survey conducted by ASAP (Appalachian Sustainable Agriculture Project). ASAP conducted twenty separate surveys of buyers for grocery stores, hospitals, schools, summer camps and other such institutions across 23 counties in Western North Carolina. From this 325-page report it can be seen that current spending on local food totals at around 14 million dollars, but there is a desire for nearly 452 million dollars worth of food in those counties alone. Many barriers would need to be overcome to make this much marketing possible, such as substantial investment in slaughter houses and some farm-friendly policy changes that would make it easier for farmers to sell meat, dairy, and processed foods. However, there is roughly 36.5 million dollars worth of potential annual demand in fresh produce sales available now that would not need the accommodations stated above (SARE, 2008). In addition to confirming the potential market for local foods, this study also reported that 75 percent of consumers surveyed said they would be willing to pay more for local food and 82 percent said they would increase their purchases of local food if it was labeled. These results confront the myth that only consumers in big cities would be willing to pay more for local food; since the only sizable city included in the survey was Ashville the majority of respondents were from small towns or rural areas (SARE, 2008).

This survey is most relevant for producers within the southern Appalachian area but could also apply to those across the nation as those at SARE and ASAP speculate this trend would prove consistent no matter where you are located.

Yue and Tong (2009) explored how much more consumers are willing to pay for local and organic products in Minnesota. Through their study they found that the average consumer was willing to pay $1.18 for 1 lb. of conventional tomatoes. If the consumer purchased organic tomatoes, they were willing to pay a premium of $0.72, and if they chose local they were willing to pay a premium of ≈$0.73. The premium consumers were willing to pay for tomatoes with both organic and local qualities was $1.16. Yue and Tong (2009) also found the current price premiums found in most markets for organic, local, and organic plus local tomatoes were $0.67, $0.67, and $1.06 respectively. This study would be useful to producers in determining what premium to place on their produce.

Another confirmation of the increasing popularity of local food is the word 'locavore', the 2007 Oxford Dictionary word of the year (Oxford University Press, 2009). Pollan (2006) also testifies that consumption of local food is on the rise through his documentation of the customers who visit Joel Salatin's farm for meat and produce. Finally, the 13 percent increase in the number of farmers markets, as documented by the USDA, over the last ten years stands as evidence that more people are seeking out local food through the most obvious means they can think of (USDA, 2009).

Increased demand and willingness to pay more for heirloom produce has been written about and supported through SARE (2008) and ATTRA (Appropriate Technology Transfer for Rural Areas) (2002). Other evidences of increased interest include the recent influx of information available on heirloom vegetables in general and tomatoes in particular. For the last thirteen years thousands of people have gather at the Kendall-Jackson Winery in Santa Rosa, California, for their annual Heirloom Tomato Festival (Kendell-Jackson, 2009). For the price of 55 dollars a ticket attendees experienced "food of gourmet food purveyors, a Food & Wine magazine Best New Chefs Challenge, Bruschetta Boulevard, wine and garden education seminars, a tomato growing contest, garden tours and live entertainment. All paired with Kendall-Jackson wines"; in addition to tasting more than 170 heirloom tomato varieties (Kendall-Jackson, 2009).

According to USDA data, since 1990 organic food production and consumption have annually increased an average of 20 percent each year (Dimitri and Greene, 2002). Thus they were a major focus at the 2000 meeting of the FAO (Food and Agriculture Organization of the United Nations). The meeting was focused on the safety and quality of organic foods, specifically the establishment of uniform international standards and understanding the public's opinion of organic food (FAO, 2000). It was concluded that "There is a growing demand for organic foods driven primarily by consumers' perceptions of the quality and safety of these foods to the positive environmental impact of organic agriculture practices. This growth in demand is expected to continue in the foreseeable future" (FAO, 2000). Rivard (2006) reinforced these statements with his assessment that the market for locally produced food, organically produced foods, and heirloom vegetables was on the rise. From these statistics it can safely be assumed that there is a growing demand for organic food which has yet to be saturated.

Yield comparisons of heirlooms and hybrids

Due to a deficiency of paired comparisons, there is limited literature on the productivity of heirloom and hybrid vegetables in general, and tomatoes specifically. A singular example of direct comparisons reported that from a grower's perspective (i.e. looking at yield, disease resistance, drought resistance) there was no distinct pattern of advantage or disadvantage with either hybrids or heirlooms because of the extreme variability among varieties (Grunzke, Baumbauer and Dougher, 2006).

The common assumption is that hybrid tomatoes produce higher yields, more consistent fruit quality, and better pest resistance since that is how most of them have been specifically bred (Heuvelink, 2005; Jones, 2008). However, some locally adapted heirloom cultivars have been found to perform better in their area of adaptation than most hybrids (Coulter, 2006; Cutler, 1997; Male, 1999).

Yield comparisons of organic and conventional production systems

Although most growers like the idea of more profit from their produce, they are discouraged from converting to organic production systems because they are concerned the potential monetary gains will not compensate for the anticipated loss in productivity. Contrary to these concerns Rivard (2006) found that there were no significant differences in yield of tomatoes between organic production systems and conventional production systems in tests conducted in North Carolina.

CHAPTER FOUR

Materials and Methods

This study was conducted at the Western Kentucky University Research Farm (Lat. 36.93˚; Lon. -86.47˚) at Bowling Green, Ky. 42104.

In May 6th of 2008 pre-finished plants of 'Crista' (commercial hybrid standard), 'Cherokee Purple' (a dark beefsteak type heirloom), and 'Mr. Stripy' (a yellow heirloom) were obtained from Mammoth Cave Transplants (Appendix). In 2009 plants were started from seed in the campus greenhouse at WKU due to a mechanical malfunction at Mammoth Cave Transplants.

The study included sixteen plot rows which were five feet apart with the plants eighteen inches apart. Plants were grown under plastic mulch, with drip tape under the mulch to provide water and fertilizer. Plastic mulch, drip tape, and the equipment to lay it down were provided by Nathan Howell, vegetable extension associate, University of Kentucky. The plants were grown under black plastic mulch since this is the current production standard. Plant were given 1-acre inch water per week through the irrigation system. The same amount of water was provided regardless of the weather conditions. The study was a split block trial with one block (eight rows) treated with organic cultural practices and the other block (eight rows) with conventional cultural practices. There was a 20-foot buffer between the two blocks and the same experimental area was used both years. Plants were staked and tied up with twine as needed, using the Florida weave staking method. Varieties were randomized within each row.

During both seasons the conventionally managed portion was fertilized through the irrigation system weekly with 10-20-20, 20-20-20 and Calcium nitrate 15.5-0-0 depending upon the determined needs of the plants (Chemical information in Appendix). The fungicides 'Quadris', Dithane DF (Mancozeb), Copper (kocide 300) and Bravo Weatherstik (chlorothalonil) were used during both seasons to treat fusarium wilt and bacterial canker that were observed to prevent additional disease and fungal problems (Appendix). The insecticide 'Capture' and 'Endosulfan' were applied regularly as preventatives (Appendix). In both seasons weeds were controlled between the rows with Sandea 75 DF herbicide on the conventionally managed portion (Appendix).

The organically managed portion was difficult to fertilize because most available products were not readily water soluble. In 2008 one application of 'Earth Juice' (2-1-1) and one application of Drammatic "ONE" (4-4-0.5) each was applied through the irrigation system, one application of organic Miracle Grow (6-4-5) was applied around the base of the plants in a slurry form, and two applications of Organic fish powder (9-1-1) were applied through the irrigation system after soaking in water over night (Appendix). In 2009 fertilization form of soaking Organic fish powder (9-1-1) in water was applied through the irrigation system was continued (Appendix). Kocide 300 (Copper), JMS Stylist-oil, and Green Light (neem oil) were used in both 2008 and 2009 to control insect and fungus problems (Appendix). All materials used on the organic half were OMRI (Organic Materials Review Institute) approved and listed. Weeds were controlled between the rows with leaf litter mulch (supplied by the University) and mechanical control.

Soil tests show a 2.3% organic matter on the organically managed portion of the study in 2008 and 1.5% organic matter on the conventionally managed portion (Table 1). In 2009 the soil organic matter content increased to 4.4% on the organic portion (likely due to the leaf mulch between the rows) and the conventional portion remained relatively steady at 1.7%.

Plants were transplanted May 30, 2008 and June 29, 2009; respectively. Harvests began on July 30, 2008 and September 18, 2009; respectively, and continued weekly until frost in 2008 and disease ended harvest in 2009. Stage for harvest was also based largely on the USDA standards which indicate significant color should be showing on the fruit. Heirlooms were allowed to ripen further than the hybrid since they did not ripen well off the vine. Data were collected on number of fruit per plant, individual fruit weight, individual fruit size, and individual fruit grade. Fruit size and grade were based on USDA standards.

Fruits were graded on a scale of 1-3 with #1 being a fruit with no blemishes, bruises or discoloration; #2 was a fruit with blemishes that prevent it from being #1 but would not prevent it from being marketed or consumed; #3 was a cull, it had weeping wounds, rotting places or blemishes that would otherwise prevent it from being marketed or consumed. Weight was taken in pounds. In analyzing size, 1 represents an extra small (XS) and 5 represents an extra, extra large (XXL).

Seven harvests were taken in 2008 and four in 2009. 2009 was a wet cool summer compared to 2008 (Table 6). In 2009 the plants took longer than usual to set fruit, and that fruit took longer to ripen as well. These weather conditions were favorable

Table 1. Soil test analysis for 2008 and 2009 for organic and conventional production system plots.

	2008		2009	
Soil Property	Organic	Conventional	Organic	Conventional
Soil pH	7.5	7.0	7.5	7.4
Cation Exchange Capacity (CEC)	15.5	8.2	16.9	8.3
Pound per Acre Suggested				
Phosphorous (P)	216	208	204	78
Potassium (K)	484	408	424	194
Calcium (Ca)	6676	3078	7450	3348
Magnesium (Mg)	440	396	448	368
Organic Matter Content	2.3	1.5	4.4	1.7

Soil test performed by A&L Analytical Laboratories, Inc. 2790 Whitten Rd. Memphis, TN 38133.

for disease which attacked earlier than usual and stopped the harvest before frost. In addition, a mechanical failure at Mammoth Cave Transplants delayed the project a month in planting. Poor weather, disease, and late planting resulted in fewer harvests in 2009.

Data were analyzed using SAS software (SAS institute, inc. 1998). Significance was analyzed at the 0.05 level of probability. When F values were significant, means were separated with the Duncan's Multiple Range test.

CHAPTER FIVE

Results

When compared to the conventional management, 'Cherokee Purple' produced significantly heavier and larger individual fruit under the organic setting in 2008 (Table 2). In analyzing performance by grade, the smaller number is optimal since only the highest quality fruit receive a grade of 1. 'Cherokee Purple' produced higher quality fruit under the organic setting than the conventional setting. There was no significant difference between production system for number of fruit per plant. For 'Mr. Stripey' there were no significant differences between production systems for individual fruit weight, individual fruit size, or individual fruit grade in 2008. However, 'Mr. Stripey' produced significantly more fruit per plant under organic cultural practices in 2008. For 'Crista' there were no significant differences between production systems for individual fruit weight, individual fruit size, or number of fruit per plant in 2008. 'Crista' did however produce significantly higher quality of fruit under the conventional production system than the organic production system in 2008.

The production season of 2009 was very different on several levels (Table 3). 'Cherokee Purple' did not produce enough fruit on the organically managed portion of the study to allow statistical analysis. For 'Mr. Stripey' there were no statistical differences between organically and conventionally managed production systems for any of the traits. 'Crista' did not show any statistical differences in individual fruit weight, individual fruit grade, or number of fruit per plant between the two production systems in. It did have a

Table 2: Comparison of organic and conventional management techniques for weight, size, grade, and fruit number in three tomato cultivars for the 2008 season.

Cultivar	Weight (lb.)		Size[2]		Grade[3]		Fruit Number per Plant	
	Organic	Conventional	Organic	Conventional	Organic	Conventional	Organic	Conventional
Cherokee Purple	0.67 **[1]	0.57 **	4.77 **	4.31 **	2.22 *	2.40 *	2.58 n.s.	2.47n.s.
Mr. Stripey	0.32 n.s.	0.28 n.s.	3.14 n.s.	3.15 n.s.	2.32 n.s.	2.33 n.s.	4.09 *	3.46 *
Crista	0.61 n.s.	0.59 n.s.	4.25 n.s.	4.19 n.s.	1.89 **	1.61 **	2.55 n.s.	2.15 n.s.

[1]Comparisons are within rows and under the trait (Weight, Size, Grade or Fruit Number) being measured. (**) means were statistically different at the 0.01 level; (*) means were statistically different at the 0.05 level; (n.s.) means were not statistically different. [2]Scale for size: 1= extra small, 5= extra, extra large. [3]Scale for Grade: 1= highest quality, 3= cull.

Table 3. Comparison of organic and conventional management techniques for weight, size, grade, and fruit number in three tomato cultivars for the 2009 season.

Cultivar	Weight (lb.)		Size[2]		Grade[3]		Fruit Number per Plant	
	Organic	Conventional	Organic	Conventional	Organic	Conventional	Organic	Conventional
Cherokee Purple	--	0.93	--	4.75	--	2.25	--	1.25
Mr. Stripey	0.25 n.s.[1]	0.32 n.s.	3.15 n.s.	3.00 n.s.	2.65 n.s.	3.00 n.s.	3.75 n.s.	1.00 n.s.
Crista	0.48 n.s.	0.47 n.s.	4.67 *	3.50 *	2.67 n.s.	3.00 n.s.	1.44 n.s.	1.25 n.s.

[1]Comparisons are within rows and under each trait (Weight, Size, Grade, or Fruit Number) being measured. (**) means were statistically different at the 0.01 level; (*) means were statistically different at the 0.05 level; (n.s.) means were not statistically different. [2]Scale for size: 1= extra small, 5= extra, extra large. [3]Scale for Grade: 1= highest quality, 3= cull.

significant increase in size under the organic setting as compared to the conventional setting in 2009 (Table 3).

In 2008, 'Cherokee Purple' and 'Crista' produced significantly heavier fruit than 'Mr. Stripey' under both the organic and conventional production systems (Table 4). Under organic production conditions 'Cherokee Purple' produced the largest fruit, with 'Crista' significantly smaller than 'Cherokee Purple' but significantly larger than 'Mr. Stripey'. Under the conventional setting 'Cherokee Purple' and 'Crista' were similar in size and both were significantly larger than 'Mr. Stripey'. In 2008 'Crista' produced the highest quality fruit under organic conditions as compared to 'Cherokee Purple' and 'Mr. Stripey'. Under the conventional setting, 'Crista' produced significantly higher quality fruit than either 'Cherokee Purple' or 'Mr. Stripey'. No significant differences were found among the varieties for number of fruit produced per plant under organic production practices in 2008. Under conventional production practices, however, 'Mr. Stripey' produced significantly more fruit per plant than either 'Cherokee Purple' or 'Crista'.

In 2009, 'Cherokee Purple' did not produce enough fruit under organic production system to allow statistical analysis (Table 5). No significant differences were found between cultivars for weight under organic production systems (Table 5). Under conventional production systems 'Cherokee Purple' yielded significantly heavier fruit than the other two cultivars. 'Crista' produced significantly larger fruit than 'Mr. Stripey' under organic conditions in 2009. Under conventional system, fruit size of 'Cherokee Purple' and 'Crista' were similar, 'Crista' and 'Mr. Stripey' also had similar fruit size, but the fruit size of 'Cherokee Purple' was significantly larger than 'Mr. Stripey'. All of the

Table 4. Comparison of three tomato cultivars for weight, size, grade and fruit number grown using organic and conventional management techniques for the 2008 season.

Cultivars	Weight (lb.)		Size[2]		Grade[3]		Fruit Number per Plant	
	Organic	Conventional	Organic	Conventional	Organic	Conventional	Organic	Conventional
Cherokee Purple	0.67 a[1]	0.57 a	4.77 a	4.31 a	2.22 b	2.40 b	2.58 a	2.47 b
Mr. Stripey	0.32 b	0.28 b	3.14 c	3.15 b	2.32 b	2.33 b	4.09 a	3.46 a
Crista	0.61 a	0.59 a	4.25 b	4.19 a	1.89 a	1.61 a	2.55 a	2.15 b

[1]Comparisons are within columns and between cultivars. Different letters represent significant differences found at the 0.05 level.
[2]Scale for size: 1= extra small, 5= extra, extra large. [3]Scale for Grade: 1= highest quality, 3= cull.

Table 5. Comparison of three tomato cultivars for weight, size, grade and fruit number grown using organic and conventional management techniques for the 2009 season.

Cultivars	Weight (lb.)		Size[2]		Grade[3]		Fruit Number per Plant	
	Organic	Conventional	Organic	Conventional	Organic	Conventional	Organic	Conventional
Cherokee Purple	--	0.93 a[1]	--	4.75 ab	--	2.25 a	--	1.25 a
Mr. Stripey	0.25 a	0.32 b	3.15 b	3.00 c	2.65 a	3.00 a	3.75 a	1.00 a
Crista	0.48 a	0.47 b	4.67 a	3.50 bc	2.67 a	3.00 a	1.44 a	1.25 a

[1]Comparisons are within columns and between cultivars. Different letters represent significant differences found at the 0.05 level.
[2]Scale for size: 1= extra small, 5= extra, extra large. [3]Scale for Grade: 1= highest quality, 3= cull.

cultivars produced similar grades and number of fruit per plant under both organic and conventional production systems in 2009.

CHAPTER SIX

Discussion and Conclusions

There are many aspects to be considered when analyzing differences in production between the organic and conventional production systems. The overall purpose of comparing organic and conventional production systems was to determine whether yield or fruit quality would be compromised by converting from a conventional production system to an organic production system.

2008 was closer to a typical growing season than 2009 (Table 6) and resulted in more differences between production systems. In 2008, 'Cherokee Purple' performed optimally under the organic treatment for individual fruit weight, size and grade, while production practices had no influence on number of fruit produced per plant. I suggest that since 'Cherokee Purple' is a locally adapted cultivar, it was better suited to survive under the less protected organic conditions. By observation, 'Cherokee Purple' had larger, coarser leaves than 'Crista' and appeared to be better able to compete for light water and nutrients. Landrace grains are coarser and better competitors than modern Green Revolution grains (Cralle, 1990). While the root system was not exhumed to see if this coarseness observed in the leaves equated with a more aggressive root system, that conclusion seems logical. If Cherokee Purple did indeed have an aggressive root system, that would also make it a better competitor. If this comparison is accurate, it is logical that 'Cherokee Purple' performed optimally under organic conditions where this competition gave it an advantage over the conventional system. With leaf mulch applied

Table 6: Precipitation, temperature and humidity for 2008 and 2009 growing seasons.

Month	Precipitation Total (Inch)		Temperature (F)						Humidity %			
	2008	2009	2008 Avg.	2009 Avg.	2008 Max.	2009 Max.	2008 Min.	2009 Min.	2008 Max.	2009 Max.	2008 Min.	2009 Min.
April	5.05	4.45	55.5	56.4	67.0	67.6	44.0	45.2	92	91	45	43
May	5.36	4.77	64.3	65.7	75.0	74.8	53.6	56.6	92	94	46	52
June	1.73	5.12	75.5	75.4	86.2	85.5	64.9	65.3	91	95	40	49
July	5.73	7.58	76.0	72.7	87.0	81.5	65.1	63.9	95	95	42	52
August	0.64	1.99	75.1	74.0	86.8	83.7	63.4	64.3	94	95	40	50
September	1.97	7.29	71.7	70.4	84.0	79.1	59.4	61.6	94	95	41	56
October	4.24	6.11	57.5	54.5	70.6	64.4	44.4	44.5	93	96	38	57

Weather information taken from Warren County Mesonet station, located on Western Kentucky University's Farm approximately 50 feet from this trial. Lat: 36.93˚; Lon: -86.47˚. Website: www.kymesonet.org.

between the rows on the organic portion, moisture levels were more consistent and the soil between the rows was not as compacted, it is possible that 'Cherokee Purple' was more sensitive to these conditions and responded favorably when they were moderated. Another possible explanation is that 'Cherokee Purple' is more sensitive to the various chemicals sprayed on and around plants in the conventional plot and as such responded negatively to that treatment.

In contrast, comparisons of 'Cherokee Purple' and ‘Mr. Stripey' and 'Crista' resulted in few differences between production systems. 'Mr. Stripey' produced significantly more fruit per plant under the organic setting. 'Mr. Stripey' was a prolific producer throughout the study. As discussed with 'Cherokee Purple', 'Mr. Stripey' is also similar to a landrace variety and as such performs well under marginal or less than ideal situations, perhaps more fruit per plant is its equivalent to 'Cherokee Purple's better fruit weight, size and grade (Cralle, 1990).

'Crista' produced significantly higher quality fruit under the conventional setting in 2008. Since 'Crista' was developed under and for the conventional cultural practices and likely would perform optimally under those same circumstances. The other cultivars did not produce significantly better grades under the conventional setting, likely since there were more options for controlling weeds, pests, and diseases. This performance may be a result of the conditions under which heirlooms are selected. As with 'Cherokee Purple' fruit weight, size and grade, and with 'Mr. Stripey's number of fruit per plant, it appears that these trends correlate directly with the conditions under which the cultivars were developed. It is most likely that these are the resulting differences of landrace varieties as compared to Green Revolution varieties (Cralle, 1990). These results do not fully agree with Rivard (2006), who found no significant differences in yield between the organic and conventional production settings.

The 2009 season differences in terms of planting time, weather (Table 6) and disease pressure, resulted in different results compared to 2008. 'Cherokee Purple' did not produce enough fruit in the organic production system, under black plastic, for statistical comparison of its productivity between the two production systems. 'Cherokee Purple's' poor production was due to the late planting and cool season. Due to the variety's tendency for late fruit set even under the best conditions, 'Cherokee Purple' did not set many fruit under these conditions and the fruit that were set ripened more slowly than 2008. Also 'Cherokee Purple' was more susceptible to the late blight that came earlier than usual because of weather conditions. This susceptibility prevented the plants from setting fruit before succumbing to disease. The use of strong fungicidal sprays may have deterred disease long enough to allow more fruit to set. As a side note, the study was intentionally kept in a area known to have several soil borne diseases in order to test disease resistance in the grafting part of the study, as such it was interesting that disease was not more prevalent than what was witnessed.

Under the less favorable conditions of 2009, 'Mr. Stripey' and 'Crista' produced similar results to those of 2008. Contrary to findings in the previous season, however, 'Mr. Stripey' had no significant differences for any of the traits. 'Mr. Stripey' did not produce more fruit per plant under organic treatment for the same reason 'Cherokee

Purple' produced so few fruit under organic treatment, disease overtook the plants before differences could be seen.

'Crista' produced significant differences in the size of fruit; it had significantly larger individual fruit under organic cultural practices compared to conventional cultural practices in 2009 (Table 3), despite how it was expected to perform under conditions similar to those in which the cultivar was developed. Some explanation may yet be found. Regardless of careful efforts, damage is sometimes inflicted on plants. The conventional portion exhibited severe stunting during the early stages of the study in 2009. Stunting could be responsible for the smaller fruit size observed on the conventional portion in 2009. Additionally, due to the use of leaf mulch in between the organic system's rows the organic matter content in the organic portion was higher than that in the conventional portion. Since access to fertilizer was delayed early in the study for the organic portion, application was also delayed from the conventional portion for consistency. However, the organic portion had an advantage during this time due to the higher residual organic matter content, which likes encouraged growth on that portion and masked any stress that would have been experienced due to lack of fertilizer. While disease appeared to injure both systems of the study equally, it is also possible that the disease occurred earlier on the conventional portion, thus limiting fruit size.

The considerable lack of differences found in 2009 can be largely attributed to disease. Fewer harvests were conducted in 2009 and disease stopped harvest early in the season. Because fewer harvests were collected the author suspects that trends which were displayed in 2008 were adversely affected in 2009.

Though the growing conditions of 2009 were not ideal, they did provide an unique opportunity to see how the varieties performed under two growing systems during times of stress. In 2009, our results were more similar to Rivard (2006) who found no significant differences in yield between productions systems. Although more research is needed, it may not be significantly detrimental to a producer to convert to an organic production system, unless they were exclusively using 'Cherokee Purple'.

The performance of the cultivars within the organic or conventional production systems was compared (Tables 4 and 5). 2008 was an excellent season for comparisons since all of the varieties seemed to perform optimally. Before delving to deeply into our analysis however, the purpose of this aspect of the study must be reiterated. Some popular area heirlooms were selected and compared to a popular hybrid to see if any loss in fruit yield or quality would be experienced if a producer switched from using commercial hybrids to using heirloom cultivars. Heirlooms were the item of interest because they would potentially bring more profit to a producer in a local market, and this whole study was focused on investigating ways to add value to the grower's product.

When looking at weight in 2008 (Table 4) all three cultivars performed similarly under both organic and conventional production systems. 'Cherokee Purple' and 'Crista' produced fruit similar weight, but both were significantly heavier than 'Mr. Stripey'. This difference among the cultivars is better understood upon a close observation of their fruits. According to Male (1999) and our observations, 'Cherokee Purple' is more similar to a beefsteak tomato, meaning it is meaty and more solid, while 'Mr. Stripey' is more similar to a stuffing tomato with open fruit cavities, which contained more juice and seeds. 'Crista' appears to follow the traits associated with a beefsteak as well. This difference may explain the difference in weight among cultivars.

Fruit anatomy may also explain the differences in size seen in Table 4. Under the organic setting 'Cherokee Purple' is significantly larger than both 'Mr. Stripey' and 'Crista', while 'Crista' is significantly larger than 'Mr. Stripey'. Under the conventional setting, the same trends are observed as was seen for weight for both treatments, with 'Cherokee Purple' and 'Crista' producing significantly larger fruit than 'Mr. Stripey'.

'Crista' produced the highest quality fruit under both production systems in 2008, while 'Mr. Stripey' and 'Cherokee Purple' produced fruit of similar quality under both systems. As discussed previously, 'Crista' was developed under conventional circumstances and so it is logical that it would produce higher quality fruit under this system (Cralle, 1990). Additionally, the system used to grade the fruit was built around hybrids that have few natural flaws, as such it is difficult for even the highest quality heirloom to grade well due to their tendency towards cracking and scarring.

For number of fruit produced per plant in 2008, there were no significant differences in varieties grown under the organic setting. Under the conventional setting 'Mr. Stripey' produced significantly more fruit per plant as compared to the other cultivars. 'Mr. Stripey' is a prolific cultivar as a whole, but it seems inconsistent that it produced significantly more per plant under conventional conditions and not organic conditions. However, this comparison is between cultivars and not production systems. While the point could be raised that the differences on the organic portion appear greater, they were not consistent enough to be significant. Two reasons that this difference was seen under conventional conditions and not organic were that 'Mr. Stripey' is more prolific under organic production, but so are the other two, as such it did not produce enough to be significant. Additionally, 'Cherokee Purple' nor 'Crista' produced as much under conventional settings while 'Mr. Stripey' was not as affected.

From the 2008 data it is apparent that production of the heirloom 'Cherokee Purple' was similar, if not superior, to that of the hybrid representative, especially under an organic production system. Therefore, it mght be profitable for producers to diversify their plantings with some heirloom varieties.

2009 provided the opportunity to compare these cultivars under stress conditions. 'Cherokee Purple' did not produce enough under the organic setting in 2009 for statistical comparison between it and the other varieties under the organic setting.

There were no significant differences in weight between 'Mr. Stripey' or 'Crista' under either of the production systems (Table 5). Under the conventional setting however, 'Cherokee Purple' produced significantly heavier fruit than both of the other cultivars. 'Cherokee Purple' producing large fruit overall is consistent with 2008 results. 'Crista', however, seemed to be much more sensitive to the weather conditions, resulting in lower weight which was not consistent with 2008 results for this meaty cultivar. As also mentioned earlier, plants in the conventional portion expressed some stunting early in the season which may be responsible for the reduction in size.

Fruit size for 'Crista' was more consistent with results from 2008 under the organic production system, where it produced significantly larger fruit than 'Mr. Stripey'.

This difference was consistent for these two cultivars under the organic setting and may be a result of basic fruit anatomy.

Under the conventional setting 'Cherokee Purple' and 'Crista' were similar in size, and 'Mr. Stripey' and 'Crista' were similar in size, but 'Cherokee Purple' was significantly larger than 'Mr. Stripey'. Again, these results follow the trend set in 2008 under the conventional setting, albeit with more similarities. The author suspects that the reason 'Mr. Stripey' and 'Crista' did not express differences, as they did in 2008 and under the organic setting, is because there were not have enough harvests to detect this difference. Another explanation for the similar fruit size between 'Crista' and 'Mr. Stripey' is influence of disease and stunting on 'Crista'.

There were no significant ($p<.05$) differences among cultivars for fruit grade under either production system. Considering the relatively poor grade throughout the study in 2009, failure to detect differences was likely due to disease, not differences between cultivars or production systems.

Finally, no significant differences were found in the number of fruit produced per plant in 2009 under either production system. The diminished number of fruit harvested in general likely prevented any differences that may have existed between cultivars; or disease itself may have deteriorated the plants to the extent that they did not flower or set as many fruit in 2009.

While production was not as consistent or prolific in 2009 as it was in 2008, heirloom cultivars produced similar, or occasionally better, quality and yield to hybrid cultivars. Producers might carefully consider adding a few heirloom cultivars in their systems, though the author would caution relying on them completely due to the poor performance of 'Cherokee Purple'.

There is a shortage of scientific comparisons between organic and conventional production systems that needs to be addressed. In future studies it would be appropriate and enlightening to see production comparisons done on some professional conventional and certified organic tomato farms. Such comparisons would be profitable because they would confirm or contradict the results from this study in the producers own world, and might reveal further differences between the systems. It would also be interesting to see if any gains in production would be made in the organic portion if studied on an established organic farm. The author is curious if the plants would react differently in a soil with even higher organic matter and biological activity, which would hopefully be present on an established organic farm.

While the deficit of scientific comparisons for organic and conventional production systems is great, scientific heirloom cultivar comparisons and evaluations are nearly non-existent. Not only would producers benefit from more heirloom and hybrid comparisons, but thorough heirloom production and quality evaluations are lacking as well.

Regardless, through this study the author is convinced that a producer would not regret choosing to add some variety to his/her produce in the form of heirloom cultivars and/or organic production. Either of these choices would provide economic gains, together the profit would be even higher. More research needs to be conducted, but results from this experiment indicate that the producer would not lose yield or quality from either option. However, the producer should be cautioned that due to their fragile nature, heirlooms must be marketed locally. As such the author would encourage gradual transition into heirloom production to allow time for establishing clientele.

CHAPTER SEVEN

Appendix

Listed in this appendix are the chemicals used in the study, where they are manufactured, their use and their nutrient.

- Mammoth Cave Transplants, 5394 Brownsville Road, Brownsville , Ky. 42210. Website: www.mammothcavetransplants.com. Started all seeds for 2008 and 2009 season.
- Earth Juice™ (2-1-1), produced by Earth Juice Grow, O.G.M., P.O. Box 3442, Chico, CA, 95927-3442. Website: www.earthjuice.com. Earth Juice is designed to "promote vigorous vegetative growth when increased Nitrogen is required". OMRI Approved.
- Dramatic "ONE"® (4-4-0.5), produced by DRAMM Corporation, P.O. Box 1960, 2000 North 18th Street, Manitowoc, WI 54220. Website: www.fishfertilizer.com. Dramatic "ONE" is "a nutrient catalyst for organic crop production". OMARI Approved.
- Organic Fish Powder® (9-1-1), produced by Planet Natural, 1612 Gold Ave., Bozeman, MT 59772. Website: www.planetnatural.com. Organic fish powder was soaked overnight and applied through the irrigation to supply Nitrogen. OMRI Approved.

- ❖ Miracle-Gro® Organic Choice® All Purpose Plant Food (7-2-1), produced by Scotts Miracle-Gro Products, Inc., 14111 Scotts Lawn Road, Maryville, OH 43041. Website: www.scotts.com. An all purpose fertilizer that was mixed with water and applied in a slurry form around the base of the plants. OMRI Approved.
- ❖ Green Light® Neem Concentrate, produced by Green Light Company, P.O. Box 17985, San Antonio, TX 78217-0985. Website: www.greenlightco.com. Applied to vegetables fruits and nuts as an insecticide, fungicide and miticide; kills aphids, white flies, spider mites, scale, and many other insect pests; controls powdery mildew, rust, anthracnose, leaf spot and other diseases; mixed 1 oz. per gallon and applied as a foliar spray, made from extract of Neem seed. OMRI Approved.
- ❖ DuPont™ Kocide® 3000, produced by E.I. du Pont Numours and Company, Wilmington, DE 19898. Website: www2.dupont.com. Provides superior disease control for citrus and vegetable crops through high levels of active copper. Protects against Anthracnose, Bacterial Speck, Bacteria Spot, Early Blight, Gray Leaf Mold, Late Blight, Septoria Leaf Spot. OMRI Approved.
- ❖ JMS Stylet-oil, produced by JMS Flower Farms Inc., 4423 5th Place SW, Vero Beach, FL 32968. Can be used as a fungicide, insecticide and for virus control. Organic approved alternative to Sulfur products, especially effective against Powdery Mildew and Mites. OMRI Approved.
- ❖ Quadris®, produced by ©Syngenta Crop Protection, Inc., P.O. Box 18300, Greensboro, NC 27419. Website: www.syngentacropprotection.com. Mobilized

throughout the plant through xylem and provides a wide spectrum control of fungal diseases.

- Dithane M45®, produced in France/Brazil for ©Dow AgroServices LLC, Indianapolis, IN 46268. Website: www.dowagro.com. Used to control Anthracnose, Early Blight, Gray Leaf Spot, Late Blight, Leaf Mold, Septoria Leaf Spot, Bacterial Speck and Spot.
- Syngenta Bravo Weather Stik®, produced by ©Syngenta Crop Protection, Inc., P.O. Box 18300, Greensboro, NC 27419. Website: www.syngentacropprotection.com. Fungicide used to control a broad spectrum of diseases.
- Captan, produced by, Southern Agriculture Insecticides, Inc., Palmetto, FL 34220. Website: www.southernag.com. A wetable powder used as a foliar spray to control certain fungus diseases.
- Thionex® Insecticide (Endosulfan), produced by Makheshim Agan Group, Golan Street, Airport City, 70151 Israel. Website: www.manainc.com. For use as a broad-spectrum, long-lasting insecticide.
- Capture® 2EC-CAL (Insecticide/Miticide), produced by FMC Corporation, Agriculture Products Group, 1735 Market Street, Philadelphia, PA 19103. Website: www.fmccrop.com. Used as a broad-spectrum pesticide.
- Sandea® (Herbicide), produced by Gowan Company LLC., Yuma, Arizona. Website: www.gowanco.com. Sandea is a selective herbicide providing both pre-

emergence and post-emergence control for broadleaf weeds through inhibiting cell growth.

- Conventional fertilizers were greenhouse grade potassium nitrates and calcium nitrates.

CHAPTER EIGHT

Literature Cited

Amer. Hort. Soc. Ill. Encycl. of Gardening. 1976. Tomatoes. The Amer. Hort. Soc., Mount Vernon, VA.

Bassett, M.J. (ed.). 1986. Breeding vegetable crops. AVI, Westport, CT.

Carver, G.W. 1936. How to grow the tomato and 115 ways to prepare it for the table. Tuskegee Inst. Expt. Sta. Bul. 36.

Coleman, E. 1989. The new organic grower: A master's manual of tools and techniques for the home and market garden. Chelsea Green Publ. Co., White River Junction, VT.

Coulter, L. 2006. Gardening with heirloom seed: Tried-and-true flowers, fruits and vegetables for a new generation. Univ. of N.C. Press, Chapel Hill, N.C.

Cox, S. 2000. I say tomayto, you say tomahto. 26, Aug. 2009. <http://www.landscapeimagery.com/tomato.html>.

Crulle, H. T. 1990. Agronomy: From world hunger to biotechnology. Coarse packet for AGRO 105. Texas A&M University, College Station, TX.

Cutler, K.D. 1997. From wolf peach to outer space: Tomato history and lore, p. 6-10. In: Cutler, K.D. and J. Marinelli (eds.). Tantalizing tomatoes: smart tips and tasty picks for gardeners everywhere. Brooklyn Botanic Gardens, Brooklyn, N.Y.

Dimitri, C. and Greene, C. 2002. Recent growth patterns in the U.S. organic foods market. USDA Agriculture Information Bul. 777.

FAO, Food and Agriculture Organization of the United Nations. 2000. XXII FAO regional conference for Europe, Porto, Portugal, 24-28 July 2000. (Proc. FAO Reg. Conf. for Europe 22).

Giovannucci, E. 1999. Tomatoes, tomato-based products, lycopene and cancer: Review of the epidemiologic literature. J. Natl. Cancer Inst. 91(4):317-331

Gold, M.V. 2009. Organic Production/Organic Food: Information Access Tool. 28 October 2009. < http://www.nal.usda.gov/afsic/pubs/ofp/ofp.shtml>.

Gould, W.A. 1983. Tomato production, processing and quality evaluation. AVI, Westport, CT.

Grunzke, L., D. Baumbauer, and T. Dougher. 2006. Hybrid versus heirlooms: A comparison study in garden productivity and marketability for small-scale commercial growers. HortScience 41: 967-1084 (abstr.).

Heuvelink, E. (ed.). 2005. Crop production science in horticulture: Tomatoes. CABI, Cambridge, MA.

Jepson, W. L. 1911. A flora of western middle California. 2nd ed. Cunningham, Curtiss and Welch, San Francisco, Cal.

Jones, Jr., J.B. 2008. Tomato plant culture: In the field greenhouse and garden. 2nd ed. CRC Press, Bocca Raton, FL.

Kendall-Jackson Winery, 2009. Tomato festival: The 13th annual Kendall-Jackson heirloom tomato festival. 3 November 2009. <http://www.kj.com/events/tomato-festival/>.

Lovelock, Y. 1972. The vegetable book: An unnatural history. St. Martin's Press, N.Y.

Male, C.J. 1999. 100 heirloom tomatoes for the American gardener. Workman, N.Y.

Maynard, D.N. and Hochmuth, G.J. 2007. Knott's handbook for vegetable growers. 5th ed. Wiley, Hoboken, N.J.

Oxford University Press, 2009. Oxford word of the year: Locavore. 2 November 2009. <http://blog.oup.com/2007/11/locavore/>.

Pollan, M. 2006. Omnivore's dilemma: A natural history of four meals. Penguin, N.Y.

Rice, E., M. Kransy, and M.E. Smith. 2006. Garden genetics: Teaching with edible plants. National Science Teachers Ass. (NSTA), Arlington, VA.

S.A.R.E., Southern Region. 2008. Common Ground: Grafting heirloom tomatoes. Sustainable Agriculture Research and Education Program, Griffin, GA.

Simpson, B.B. and Ogorzaly, M.C. 1986. Economic botany: Plants in our world. McGraw Hill, N.Y.

Smart, J. and N.W. Simmonds. 1976. Evolution of crop plants. Longman, Essex, England.

Smith, A. 1994. The tomato in America: Early history, culture and cookery. Univ. of S.C. Press, Columbia, S.C.

Stickland, S. 1998. Heirloom vegetables: A home gardener's guide to finding and growing vegetables from the past. Fireside, N.Y.

Ucko, P.J. and G.W. Dimbleby. 1996. The domestication and exploitation of plants and animals. Gerald Duckworth & Co., London.

USDA, AMS, 2009. Farmers market and local food marketing. Farmers market growth: 1994-2009. 3 November 2009. <http://www.ams.usda.gov/AMSv1.0/ams.fetchTemplateData.do?template=TemplateS&navID=WholesaleandFarmersMarkets&leftNav=WholesaleandFarmersMarkets&page=WFMFarmersMarketGrowth&description=Farmers%20Market%20Growth&acct=frmrdirmkt>.

Veteto, J. R. 2007. The history and survival of traditional heirloom vegetable varieties in the southern Appalachian Mountains of western North Carolina. Agriculture and Human Values. 25:121-134.

Yue, C. and C Tong. 2009. Organic or local? Investigating consumer preference for fresh produce using a choice experiment with real economic incentives. HortScience. 44:366-371.