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Investigation of Yield and Quality of Grafted Heirloom and Hybrid Tomatoes

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INVESTIGATION OF YIELD AND QUALITY OF GRAFTED HEIRLOOM AND HYBRID TOMATOES

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INVESTIGATION OF YIELD AND QUALITY OF GRAFTED HEIRLOOM AND HYBRID TOMATOES

Stephen T. Flomo May 2010 54 Pages

Directed by: Dr. Martin J. Stone

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Tomatoes (*Lycopersicon esculentum Mill*) are one of the most popular vegetable crops grown for fresh market and processing in the U.S. Grafting involves the uniting of a shoot or bud scion with a rootstock to form a compound plant, mainly for managing soil-borne diseases and increasing crop yield. The objectives were to examine the effects of reciprocal and self grafts on tomato fruits, number of fruits, weight, and quality of the cultivars, ‘Cherokee Purple’, ‘Mister Stripey’, ‘Crista’, and ‘Maxifort’. Grafted seedlings were planted at WKU Farm on raised beds, protected with red or black plastic mulch under drip irrigation system with regular supply of water. Matured fruits were harvested, weighed, and number of fruits from each plant recorded. The highest yielding combination was the scion ‘Cherokee purple’ on ‘Maxifort’ rootstock, which produced 304g and 745g heavier fruits than ‘Crista’ and ‘Mister Stripey’, respectively. The quality grade of ‘Crista’ was superior to ‘Cherokee Purple’ and ‘Mister Stripey’ while ‘Mister Stripey’ produced the greatest number of fruits but were of lower quality. Fruits from plants grown on red plastic mulch were significantly larger, heavier, and were of higher quality than those grown on black plastic mulch. However, plants grown on black plastic mulch produced significantly more fruits per plant. There was little

advantage for self-grafting of ‘Cherokee Purple’ and ‘Crista’. However, ‘Mister Stripey’ was responsive to self-grafting and merits further investigation. The best rootstock was ‘Maxifort’ which produced the biggest, heaviest fruits of the best quality. ‘Cherokee Purple’ as a scion produced the largest and heaviest fruits, while ‘Crista’ produced the highest quality fruits. ‘Mister Stripey’ was the most prolific in terms of number of fruits per plant.

CHAPTER I

Introduction

In recent years the agricultural economy of Kentucky has shifted away from tobacco while locally produced foods have surged in popularity. Enterprising producers should seek such an opportunity to produce high-value, perishable, heirloom tomatoes. Their taste, health benefits, and popularity make them appealing to both growers and consumers. However, their susceptibility to disease makes their reliability questionable and producers may be unwilling to commit resources to such a venture.

Grafting is a technique that growers can use to increase soil-borne disease resistance in tomatoes and increase crop yield. Heirloom tomato cultivars lack genetic disease resistance and are particularly susceptible to epidemics in the field. Once a field has been infested it is several years before a susceptible cultivar can be reintroduced safely. Grafting can be used to unite the soil borne disease resistance and enhanced vigor of hybrid tomato cultivars with the high value, taste, and popularity of heirlooms. The selection of such rootstocks and scions and their compatibility are critical to economic and biological success.

Plastic mulch is used to suppress weeds, conserve water, and warms the soil to enhance crop production. It is often used in conjunction with drip irrigation. However, the color of the mulch and its effect on tomato plant growth and fruit production is not well understood, especially with grafted tomato production in south central Kentucky

This study sought to determine the production of two heirloom tomato cultivars and a commercial hybrid standard when grafted reciprocally to each other and to a commercial rootstock. Additionally, these graft combinations were grown on black or red plastic mulch to determine its effect on fruit production.

CHAPTER II

Review of Literature

Grafting tomatoes (*Lycopersicon esculentum* Mill) is an expensive, laborious, and time-consuming venture. It is the art of joining two pieces of living plant tissue together in such a manner that they will unite and grow as one composite plant. The scion is the top of the plant whose fruit one desires and the rootstock is the lower portion of the graft which develops into the root system. The technique is mainly for managing soil-borne diseases and increasing crop yield.

One of the earliest known references to grafting was in 323 B.C., which revealed grafting as an established practice in Greece (Smith, 2007). Chinese documents from a similar period also mentioned that it was common in the Far East. Nature was probably the first teacher of grafting. Limbs that grew in close proximity to each other rubbed together in such a way that their cambium layers came into contact to form a natural graft. It has been observed that grafting is one of the most exciting things one can do in the garden (Swiader et al., 1992).

Grafting vegetable crops have been used extensively in greenhouse and tunnel production as a way to decrease reliance on chemical fumigants (Oda, 1999). Greenhouse and tunnel production typically do not use crop rotation and high levels of soil-borne pathogen inoculums can lead to significant disease incidence and ultimately crop failure. Even when crop rotations are available, the long intervals required between similar crops result in an economic loss to the grower. In field-grown, conventional, ungrafted vegetables, chemical fumigants are utilized to decrease soil-borne disease levels. In tomato, yield increases have shown that a vigorous root system in non-infested soils can lead to increased crop productivity (Upstone, 1968). Yield increases were seen in eggplant as well, even without the presence of soil-borne pathogens.

Grafting is especially popular for tomato, eggplant, and cucurbit production in Asia. In 1998, 540 million transplants were grafted in Korea and 750 million in Japan (Lee et al., 1998). Increased pressure to produce tomatoes sequentially in the same soil favors the buildup of many pathogens. Soil-borne disease problems were of lesser importance in the early years but increased in importance as intensive tomato production has continued. The use of grafted tomato (*Lycopersicon esculentum* Mill) for commercial production in Asia is important because soil-borne disease pressure is high (Bletsos, 2005; Ioannou, 2001; Oda, 1999; Rivard, 2006). By grafting tomatoes, New Zealand producers were able to reduce the level of corky root rot, caused by *Pyrenochaeta lycopersici* R.W. Schneid & Gerlach. Grafting led to a highly developed root system and ultimately increased nutrient uptake (Bradley, 1968).

In Morocco, grafting is used commercially to control root-knot nematodes and other soil-borne diseases in over 2000 ha of greenhouse tomato, melon, and watermelon (Abdelhaq 2004; Besri 2001). Grafting with resistant rootstock has been successful against root-knot nematodes (*Meloidogyne incognita* Kofoid & White) for cucumbers in Greece (Giannakou and Karpouzas, 2003). Grafting onto resistant tomato rootstock for greenhouse production has also been adopted in eggplant production in this region. This technique is highly effective for managing root-knot nematodes, and provides equivalent control as compared to fumigants in winter production (Ioannou, 2001). Similarly, eggplant rootstocks may provide resistance to root-knot nematodes for eggplant production (Rahman et al., 2002).

In greenhouse production, eggplant grafted onto tomato rootstock showed improved yields as a result of increased fruit size and number compared to non-grafted controls and those with eggplant rootstock (Passam et al., 2005). Increases in tomato fruit yield are typically a result of increased fruit size (Augustin et al., 2002; Pogonyi et al., 2005).

The use of wild eggplant genotypes for rootstock in tomato production has also been well-documented (Matsuzoe, Okubo, and Fujieda, 1993). Wild eggplant rootstocks are resistant to bacterial wilt as well as root-knot nematodes. Similarly, grafting eggplant onto wild *Solanum* rootstock showed significant yield increases as compared to self-grafted controls (Ibrahim et al., 2001; Rahman et al., 2002). Grafting watermelons with saline-tolerant rootstocks showed yield increases up to 81% under greenhouse production in the Mediterranean (Colla et al., 2006). The use of salt-tolerant rootstock may be an important management tool for vegetable production. Yields were increased by grafting in watermelon (Ruiz and Romero, 1999; Yetisir and Sari, 2003), and similar results have been found in cucumber (Pavlou et al., 2002).

Bacterial wilt, *Ralstonia solanacearum* (Smith) Yabuuchi et al. is a devastating soilborne disease in tomatoes grown in eastern North Carolina. ‘Hawaii 7996’ rootstocks were highly effective at reducing bacterial wilt in naturally-infested soils when utilized as a resistant rootstock for heirloom tomato (Rivard, 2006). No evidence of wilt was seen among resistant rootstock treatments when terminal disease incidence among non-grafted treatments was 75% and 79% in 2005 and 2006, respectively. Based on his research, an heirloom scion grafted onto a rootstock-specific cultivar ‘Maxifort’, showed no symptoms of Fusarium wilt while non-and self-grafted controls had 45-50% disease incidence. In the mountainous region of North Carolina, verticillium wilt (*Verticillium albo-atrum* S.J. Paternotte, *Verticilium dahliae* M. Daami-Remadi) was an especially severe problem for tomato growers as crop rotation was not typically employed. In his opinion, grafting with `Maxifort’ showed high potential as a management tool for this disease based upon increased vigor under continuous and rotational treatments.

Ralstonia solanacearum (Smith) Yabuuchi et al. enters plant roots from the soil through wounds or natural openings via transplanting, insects, nematodes, or mechanical wounding and may also infect the undisturbed root system of a susceptible host through microscopic wounds caused by the emergence of lateral roots (McCarter, 1991). According to Rivard (2006), grafting with a disease resistant and highly vigorous rootstock is an important component in an integrated approach to manage soil-borne disease and improved yields. In his study, grafting with resistant rootstocks eliminated bacterial wilt disease incidence in severely infested fields. `Maxifort’ rootstock provided complete protection to the scion and functionally compensated for a lack of crop rotation.

Plastic mulches have been used commercially on vegetables since the early 1960s in the United States. Although a variety of vegetables can be successfully grown using plastic mulches, response is particularly marked in muskmelon, tomato, green pepper, cucumber, squash, egg-plant, watermelon and okra, all of which show significant improvements in earliness, yield and fruit quality when grown under plastic mulch (Lamont and Marr, 1990). The advantages of using plastic mulches for the production of high-value vegetable crops have been recognized since the late 1950s (Emmert 1957, Schales and Sheldrake 1965, Waggoner et al. 1960).

The greatest benefit from plastic mulch is that the soil temperature in the upper 20 - 30 cm of soil is elevated promoting faster crop development and earlier harvest (Bhella, 1988; Schalk et al. 1979; West and Pierce, 1988; Lamont 1993, Green et al. 2003, Taber, 1983). The growth of plants on mulch can be twice that of plants in unmulched soil. The result is greater total yield throughout the season (Jones et al., 1977; Wien and Minotti, 1987). Soil water loss is reduced under plastic mulch (Bhella, 1988; Liakatas et al. 1986). As a result, more uniform soil moisture is maintained and irrigation frequency can be reduced. Fertilizer beneath the mulch is not lost by leaching, so that fertilizers are optimally used and not wasted. The soil under plastic mulch remains loose, friable and well-aerated. Roots have access to adequate oxygen, and microbial activity is enhanced. Another advantage is that soil splashing onto fruits is reduced, leading to reduced disease incidence and cleaner fruit (Lamont, 1993, Ham et al., 1993; Wien and Minotti, 1987). Finally, sunlight is reflected from the mulch and increases photosynthetic activity (Mahmoudpour and Stapleton, 1997). This would take place early in the season because later the plant canopy would close and eliminate the effect.

Polyethylene is one of the most commonly used plastic materials for mulching, due to the fact that it is easy to process, has excellent chemical resistance, high durability, flexibility, and is odorless as compared to other polymers. It forms a relatively impermeable vapor barrier on the soil surface, changing the pattern of heat flow and evaporation (Tripathi and Katiyar, 1984). The color of the mulch largely determines its energy-radiation behavior and its influence on the microenvironment surrounding the plants. Soil temperature under plastic mulch depends on the thermal properties (reflectivity, absorptivity, or transmittancy) of a particular material in relation to the incoming solar radiation (Schales and Sheldrake, 1963; Tripathi and Katiyar, 1984). Thus, color affects the surface temperature (Lamont, 1993). The degree of contact between the mulch and the soil also affects soil warming. The better contact the mulch has with the soil, the more effective the warming properties of the mulch (Lamont, 1996).

The most widely used color of plastic mulch is black (Lamont, 1993). Plant growth, development, and productivity are dependent on both the quantity and wavelength distribution of light color. Spring-planted fresh-market tomatoes and summer squash often are grown with a black polyethylene mulch cover on the soil. The black mulch absorbs most of the ultraviolet (UV), visible, and infrared portions of the solar spectrum and also radiates energy as heat (Ham et al., 1993; Hatt et al., 1993).

The color of polyethylene mulch influences the microclimate around the root system. Black polyethylene is preferred for growing early season tomatoes, but heat accumulation under the black plastic during sunny days in mid-to late summer or early fall is thought to limit its use for a double-cropping system (Graham et al., 1995). To address this problem, they suggested the use of a mulch system that changes color from black to white at the termination of the spring crop and before planting the summer crop.

Recent studies by Hanna et al. (1997) and Schmidt and Worthington (1998) indicated that soil temperature is somewhat lower under white than under black mulch.

According to Bhella (1988), there were thousands of hectares of stalked fresh-market tomatoes planted annually in the southern United States on black polyethylene mulch and drip-irrigated beds. Black mulch increased early tomato yield by retaining moisture and heat. Since the long growing season in the south offers the potential for double-cropping of existing mulched and drip-irrigated beds, many growers would like to produce a second short-season crop, such as cucumbers, following tomatoes. The practice of double-cropping vegetables reduces production costs by enabling succeeding crops to use the existing polyethylene mulch, drip tape, and fertilizers applied to the first crop (Bryan and Dalton, 1974; Hayslip et al., 1978; Stall et al., 1978). In Florida, cost analysis of this practice indicated that savings were great enough to justify double-cropping watermelon following tomatoes (Hewitt and Zimet, 1987).

A phytoregulatory role for upwardly reflected light on tomato plant development in plastic mulch culture has been established (Decoteau et al., 1988). Morphological development of young tomato plants was altered by subtle changes in the wavelength composition of light reflected from various painted colors of polyethylene surfaces (Decoteau et al., 1986). Differences in tomato plant development can be induced in controlled environments by exposure to red (R) and far-red (FR) light, implicating phytochrome as the sensing mechanism (Decoteau et al., 1988; Tucker, 1975). Tomato plants treated with far-red light to extend the day grew taller and had fewer branches than tomato plants treated with red light. Even subtle changes in the FR:R ratio can have a major influence on plant growth (Kasperbauer, 1988; Kasperbauer et al., 1964). Nutrient uptake of tomato plant has also been reported to be effected by light spectral quality (Tremblay et al., 1988). Since tomato plant growth is responsive to subtle changes in the plant light environment, alternative colors of mulch that selectively reflected desired wavelengths of light into the plant canopy may have potential for improving tomato yields under field conditions.

Yield from plants growing on the Sonoco Red 2 plastic mulch was almost double compared to the tomato plants grown on the standard black plastic mulch and plants grown on red mulch produced more fruit per plant than plants growing on black (Orzolek, 1993). Tomato response to red plastic mulch has been variable and average yield increase was about 10% greater than black (Kasperbauer and Hunt, 1985). They evaluated several other vegetables and concluded that vegetable crops respond differently to colored mulches.

In commercial applications, mulch is typically laid down by machine. There are basically three operations involved in applying the mulch: 1) bedding the soil, 2) pressing the bed, 3) laying the plastic mulch and drip tube. Drip irrigation is recommended for use with plastic mulches. Plastic mulch should not be used without irrigation of some kind.

In the early 1960's, photo- or biodegradable materials were recognized as one solution to the disposal problem associated with plastic mulches (Lamont, 1993). Photodegradable plastic breaks down under ultraviolet sunlight. The rate of breakdown depends on several factors such as temperature, type of crops and amount of sunlight received during the growing season. When using these materials, it is necessary to lift the buried edges out of the soil and expose them to sunlight at the end of the season to favor their decomposition and its effect on soil composition (Lamont, 1996; Greer and Dole, 2003).

A major problem with plastic mulch is removing it from the field after completion of the cropping season for disposal. Plastic mulches, especially black plastic, do not break down and should never be disked or incorporated into the soil (Lamont, 1993), which implies a serious risk for the environment. However, the process of recovering and recycling them later is difficult as approximately 80% of the weight is non-plastic materials (Gonzalez et al., 2003). A large proportion of plastic films is left on the field or burnt by the farmers without legal control, emitting harmful substances with the associated negative consequences to the environment (Briassoulis, 2006; Scarascia-Mugnozza et al., 2006).

Heirloom tomatoes are known for their taste and unique shapes and colors. They include purple, orange and yellow tomatoes sharing catalogue space with red ones (Grassbaugh et al., 1999). Heirloom varieties are open pollinated, which means that seeds harvested and planted for the next generation will produce the plant and fruit similar to the previous generation. Heirloom varieties were developed over time in isolated gardens and communities, allowing for the development of unique characteristics. They require particular growing conditions, and each variety is different. The key to success with heirlooms is choosing a variety that is well suited to your growing conditions. Since heirloom tomatoes have not been bred for generations to promote vigor and disease resistance, these varieties are more susceptible to pathogens. Many growers agree that they are worth the extra work. Heirlooms produce flavorful tomatoes of many shapes, sizes and hues, for many culinary tastes. U.S. markets for these varieties are consumer-driven, and revenue generated from heirloom production is typically higher than that of standard field-grown fresh market fruits (Grassbaugh et al., 1999).

Hybrid tomato seed is produced as the result of two or more genotypes being crossed and the seeds harvested from the resulting fruits. Hybrid tomato seeds will produce a plant with uniform vegetative and fruiting characteristics for one plant generation. Hybrid tomatoes have been bred for disease resistance, uniformity, and ability to withstand mechanical harvesting, packing and shipping. They have an appealing exterior and withstand shipping, but taste is not a desirable attribute. For large-scale commercial growers, hybrid tomatoes are the standard. For consumers expecting bright red tomatoes in the middle of winter, hybrids provide them. Most of the hybrid tomatoes purchased from grocery stores have been harvested many days prior to ripening and treated with agents to turn them red. They are bred to stay firm and to be less susceptible to bruising during shipping and storage.

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 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. 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.

The objectives of this research were to examine the effects of the reciprocal grafting of two heirlooms, a commercial standard, a commercial rootstock and self-grafting on tomato yield, quality, and disease susceptibility; and to investigate the influence of plastic mulch color on tomato fruit weight, size class, number of fruits per plant and USDA grade.

CHAPTER III

Materials and Methods

In 2008, seedlings of the heirloom cultivars ‘Cherokee Purple’ and ‘Mister Stripey’; the commercial standard ‘Crista’ and the rootstock ‘Maxifort’ were grown. Seedlings were grown by a local greenhouse to ensure seedling uniformity. For description of the cultivars, please see Appendix. In 2009, seeds of these same cultivars were sown in the laboratory on the campus of Western Kentucky University. The seeds of ‘Maxifort’ were delayed for one week in sowing due to its vigorous growth habit so that they would all be more nearly equal in size and height of other seedlings during grafting. After two weeks in the laboratory, seedlings were later transplanted from the flats into trays in order to space and provide more ventilation. They were grown in the greenhouse for two weeks before being grafted.

Seedlings were grafted reciprocally using splice grafting method. Plastic clips or latex tubes were used to hold the grafts together tightly. The stem diameters of the rootstock and scion were similar in size and height. Both scion and rootstock were sliced at a 45 degree angle. The rootstock stem was inserted halfway into the tube so as to leave room for the scion stem which was gently inserted into the tube from the other end of the tube, keeping parallel to the stem of the rootstock. The clips remained on the seedlings until they naturally hardened, split, and fell off in the field. This procedure permitted the scion and rootstock to be in complete contact with one another. Success depended upon alignment of the vascular system of the rootstock and scion.

Grafted seedlings were placed in a humidity chamber built with transparent plastic for fast healing. Seedlings were maintained in a dark chamber for seven days to slow transpiration of the plant and to prevent the scion from becoming water stressed during this fragile period. Using a vaporizer, walls of the plastic were lightly misted with water to raise the humidity. After a week, the seedlings were placed in the greenhouse for another week in order to harden them off.

Transplanting was conducted on May 30, 2008 and June 29, 2009 on 16 raised beds covered with either red or black plastic mulch using a drip irrigation system. The rows were nine meters long, two meters between the center of rows and plants 0.6 meter apart. Due to crop failure experienced by the local transplant producer in 2009, seedlings were replanted delaying grafting and field planting approximately one month.

The experimental design was a split-block. Plastic mulch color was the main block. Within a row, each graft combination appeared once. Plants with common rootstocks were planted together. Between rootstocks, spacer plants were employed to inhibit rootstock-rootstock competition. Spacer plants were also planted at the beginning and the end of all rows to ensure similar competition for all plants. Each row had 20 and 15 treatments in 2008 and 2009. Total number of treatments for 2008 and 2009 research projects were 320 and 240, respectively. The 2008 and 2009 projects were conducted on the same experimental site at Western Kentucky University Agriculture Research Farm in Warren County, Kentucky. Since ‘Maxifort’ was bred as a rootstock, using it as a scion did not produce desirable fruits in 2008 research. Therefore, it was used as a rootstock in

2009 research. In both research projects, tomato plants were staked and pruned regularly as needed.

Based on soil tests in both years (see Appendix), a pre-plant fertilizer was applied to the field. The remainder of the fertilizer was injected weekly through the irrigation system; 10-20-20, 20-20-20, and calcium nitrate 15.5-0-0 was applied at the rate of 2.27 kg/ha. Plants were observed twice weekly for foliar, stem, or root diseases. 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 I). In both seasons, weeds were controlled between the rows with Sandea 75 DF herbicide (Appendix I).

Only ripe fruits (showing significant color) were harvested. Harvesting was conducted by hand two to three times per week in 2008 and once per week in 2009. All fruits were counted, graded, weighed, and sized on the day of harvest. Tomato fruits were graded based on USDA standards (1-3). Number 1=best, 2=flaw, and 3=cull. Fruit weight was measured in grams. Sizes were measured (S-XXL), S=1, M=2, L=3, XL=4, and XXL=5. Poor weather, disease, and late planting resulted in fewer harvest in 2009.

Data were analyzed using SAS software (SAS Institute, Inc., 100 SAS Campus Drive, Cary, N.C. 27513-2414). 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 or T-test. Soil was fertilized according to soil tests.

CHAPTER IV

Results

Plants grown under red plastic mulch produced significantly ($p<0.05$) heavier fruit weight (227.0 g), compared to those grown on black plastic mulch (186.1 g) (Table 1). Similarly, red plastic mulch produced larger fruit size (3.93) compared to black plastic mulch (3.55). Black plastic mulch produced significantly ($p<0.05$) more fruits per plant (3.07) than red plastic mulch (2.52), but red plastic mulch resulted in significant ($p<0.05$) better quality fruits (2.17) using the USDA grade (Table 1).

In 2008 on black plastic mulch, the graft combinations MSCP (4.67) produced significantly ($p<0.05$) the largest fruits, but was not different ($p>0.05$) than CPCP (4.48), CPMX (4.57), and CRMX (4.48) (Table 2). The largest fruits on red plastic mulch were produced by CPCR (4.51), but was not different ($p>0.05$) than CPCP (4.17), CPMX (4.22), CRMX (4.18), and CPMS (4.17). The smallest fruits grown on black plastic mulch were produced by the MSCR (2.76) and MSMS (2.75) combinations. On red plastic mulch, the smallest fruits were grown by MSCP (2.71) (Table 2).

MSCP (363.2 g) and CPMX (345.0 g) produced the heaviest fruits on black plastic mulch (Table 2). CPCR (313.3g) produced significantly ($p<0.05$) the heaviest fruits on red plastic mulch, but was not different ($p>0.05$) than CPMX (286.0 g), CRMX (291.0 g), and MSMS (277.0 g). The lightest fruits on black plastic mulch were produced by MSCR (100.0 g) and MSMS (127.1 g), while on red plastic MSCR (91.0 g) produced the lightest fruits (Table 2).

Table 1. Influence of plastic mulch color on tomato fruit weight, size class, number per plant and USDA grade in 2008 and 2009.

	Plastic Mulch Color[1]			
Tomato Fruit	Red		Black	
Weight/gram	227.0	a	186.1	b
Size class[2]	3.93	a	3.55	b
Number/plant	2.52	b	3.07	a
USDA grade[3]	2.17	b	2.35	a

[1]Means for fruit characters within the same row with different letters are significantly different at $P<0.05$ level. Mean separation by Duncan Multiple Range Test.
[2]Diameter of each fruit was determined by which size class it belonged. Each size class was given a numeric value (Small=1, medium=2, large=3, extra large=4, extra, extra large=5).
[3]USDA grade was assigned each fruit (1=best, 2=flaw, 3=cull).

Table 2. Tomato fruit production for grafted treatments for size, weight, grade, and fruit number in 2008 on red and black Plastic mulch.

	Plastic mulch color															
	Size				Wt.(g)				USDA Grade				No of fruits/plant			
Treatment	Black		Red		Black		Red		Black		Red		Black		Red	
CPCP[2,3]	4.48	abc[1]	4.17	abc	300.0	b	259.0	b	2.21	bc	2.39	ab	2.89	cde	2.33	cd
MSCP	4.67	a	2.71	f	363.2	a	132.0	e	1.90	d	2.38	b	2.17	ef	3.15	bc
CRCP	4.00	de	3.68	e	250.0	c	213.4	cd	1.66	e	2.06	c	1.71	f	2.63	cd
CRCR	4.28	bcd	3.97	bcde	263.3	c	259.0	b	1.50	ef	1.69	d	1.98	ef	2.43	cd
CPCR	4.27	bcd	4.51	a	300.0	b	313.3	a	2.13	c	2.14	c	2.33	def	1.41	e
MSCR	2.76	g	2.46	g	100.0	e	91.0	f	2.58	a	2.61	a	4.90	b	3.86	ab
CPMX	4.57	ab	4.22	ab	345.0	a	286.0	ab	2.12	c	2.27	c	3.18	cd	2.55	cd
CRMX	4.48	abc	4.18	abc	277.0	bc	291.0	ab	1.39	f	1.47	e	2.68	cdef	2.33	cd
MSMX	3.59	f	3.81	cde	182.0	d	200.0	d	2.27	bc	2.06	c	6.49	a	4.13	a
MSMS	2.75	g	3.87	bcde	127.1	e	277.0	ab	2.55	a	2.40	ab	5.80	a	2.48	cd
CPMS	3.94	e	4.17	abc	254.2	c	254.2	bc	2.25	bc	2.13	c	2.52	cdef	2.35	cd
CRMS	3.89	e	4.03	bcde	245.2	c	250.0	bc	1.66	e	1.61	de	2.33	def	2.35	cd

[1]Means within the same column followed by the same letter are not significantly different according to Duncan's Multiple Range Test (p>0.05).

[2]First two letters= scion and last two letters= rootstock.
[3]CP='Cherokee Purple', MS='Mister Stripey', CR='Crista', and MX='Maxifort'.

The best USDA fruit grade was observed with CRMX (1.39) on black plastic mulch, but was not different ($p>0.05$) than CRCR (1.50) (Table 2). Similarly on red plastic mulch, CRMX (1.47) produced the best USDA fruit grade, but was not different ($p>0.05$) than CRMS (1.61). The lowest USDA fruit grade were observed on MSCR (2.58) and MSMS (2.55) on black plastic mulch, while on red plastic, the lowest quality of fruits were observed on MSCR (2.61), but was not different ($p>0.05$) than CPCP (2.39) and MSMS (2.40) (Table 2).

The greatest number of fruits was produced with the graft combination MSMX (6.49) and MSMS (5.80) on black plastic mulch (Table 2). While on red plastic mulch, the greatest number of fruits were observed on MSMX (4.13), but was not different ($p>0.05$) than MSCR (3.86). The lowest number of fruits were produced by CRCP (1.71) on black plastic mulch, but was not different ($p>0.05$) than CRCR (1.98), while on red plastic, it was observed on CPCR (1.41) (Table 2).

In 2009, the graft combinations CPMS (5.00) and MSMX (4.86) produced significantly ($p<0.05$) the largest fruits on black plastic mulch but were not different ($p>0.05$) than CPCP (4.00), MSCP (4.67), CPCR (4.67), CPMX (4.46), and CRMX (4.67) (Table 3). The largest fruits grown on red plastic mulch were produced by CPCP (4.14), MSCP (4.56), CRCR (4.67), CPMX (4.73), CRMX (4.78), MSMX (5.00), and CPMS (4.50), but were not different ($p>0.05$) than CRCP (4.00), MSCR (4.00), CRMS (4.08).

Table 3. Tomato fruit production for grafted treatments for size, weight, grade, and fruit number in 2009 on red and black plastic mulch.

Plastic mulch Color

	Size				Wt.(g)				USDA Grade				No of fruits/plant			
Treatment	Black		Red		Black		Red		Black		Red		Black		Red	
CPCP[2,3]	4.00	abcd[1]	4.14	a	222.4	cde	295.1	bc	2.10	ab	2.64	ab	2.60	ab	1.50	ns
MSCP	4.67	ab	4.56	a	354.1	abc	327.0	ab	2.00	ab	2.22	abc	2.00	ab	1.78	ns
CRCP	3.08	d	4.00	ab	145.3	de	213.4	bcd	2.31	ab	2.20	abc	2.92	ab	1.20	ns
CRCR	---------		4.67	a	218.0	cde	336.0	ab	2.50	a	1.83	abc	2.17	ab	1.33	ns
CPCR	4.67	ab	--------		277.0	bcd	345.0	ab	1.83	ab	1.00	c	1.67	b	1.00	ns
MSCR	3.25	cd	4.00	ab	145.3	de	277.0	bcd	2.25	ab	2.33	abc	1.25	b	1.33	ns
CPMX	4.46	abc	4.73	a	250.0	bcde	245.2	bcd	1.15	b	1.73	abc	2.62	ab	1.73	ns
CRMX	4.67	ab	4.78	a	381.4	ab	331.4	ab	1.14	b	1.00	abc	2.47	ab	2.48	ns
MSMX	4.86	a	5.00	a	236.1	cde	350.0	ab	1.93	b	2.04	c	4.00	a	1.00	ns
MSMS	3.00	d	2.53	b	150.0	de	109.0	d	2.43	a	2.60	ab	2.00	ab	3.67	ns
CPMS	5.00	a	4.50	a	300.0	abc	268.0	bcd	2.20	ab	2.86	ab	2.27	ab	1.79	ns
CRMS	3.17	d	4.08	ab	150.0	de	236.1	bcd	2.00	ab	1.62	c	2.00	ab	2.39	ns

[1]Means within the same column followed by the same letter are not significantly different according to Duncan's Multiple Range Test (p>0.05).

First two letters= scion and last two letters= rootstock

[3]CP='Cherokee Purple', MS='Mister Stripey', CR='Crista', and MX='Maxifort'.

The smallest fruits on black plastic mulch was observed with MSMS (3.00), but was not different (p>0.05) than CRCP (3.08), MSCR (3.25), and CRMS (3.17) and CPCP (4.00). On red plastic mulch, the smallest fruits were grown by MSMS (2.53) but was not different than CRCP and MSCR (both 4.00), and CRMS (4.08) (Table 3).

CRMX (381.4 g) produced the heaviest fruits on black plastic mulch, but was not different (P>0.05) than MSCP (354.1 g) and CPMS (300.0 g) (Table 3). MSMX (350.0g) produced the heaviest fruits on red plastic mulch, but was not different (P>0.05) than MSCP (327.0 g), CRCR (336.0 g), CPCR (345.0g), and CRMX (331.4 g). The lightest fruits produced on black plastic mulch were CRCP (145.3 g), MSCR (145.3 g), MSMS (150.0g), CRMS (150.0g), and CPCP (222.4) while on red plastic mulch, it was observed with MSMS (109.0g).

The highest quality USDA fruit grade was observed with CRMX (1.14) on black plastic mulch, but was not different (p>0.05) than CPMX (1.15), MSMX (1.93), and other treatments (Table 3). CPCR (1.00) produced the highest quality USDA fruit grade on red plastic mulch, but was not different (p>0.05) than CRMS (1.62), MSMX (2.04) and other treatments. The lowest USDA fruit grade on black plastic mulch was produced by CRCR (2.50), MSMS (2.43), and others while on red plastic mulch, it was observed on CPCP (2.64), MSMS (2.60), CPMS (2.86), and other treatments.

The greatest number of fruits were significantly (p<0.05) produced with the graft combination MSMX (4.00) on black plastic but was not different than many other treatments (Table 3). On red plastic mulch, it was observed with MSMS (3.67). The lowest number of fruits was produced by the graft combination MSCR (1.25), CPCR

(1.67) and others on black plastic mulch, while on red plastic, it was observed on CRCP (1.20), CPCR (1.00), MSMX (1.00), and other treatments (Table 3).

The largest fruits were produced by the rootstocks MX (4.25) and CP (4.14) in 2008, while MX (4.94) produced the largest fruits in 2009 (Table 4). The smallest fruits were grown on CR (3.56) in 2008 while in 2009, CR (4.28), CP (3.98), and MS (3.86) were not different but were smaller than MX (4.94).

The heaviest fruits were produced on MX (254.2 g) and (291.0g) in 2008 and 2009, respectively (Table 4). In 2008, CP (250) was not different from MX. CR (195.2 g) and MS (204.3) produced the lightest fruits in 2008. The lightest fruits were produced by MS (195.2 g) in 2009 but were not different than CR (218.0) and CP (222.4).

The best USDA fruit grade was observed with MX (1.99) and (1.90) in 2008 and 2009, respectively. The lowest was observed on CP (2.22) and (2.47) in 2008 and 2009, respectively (Table 4). CR (2.13) was not different ($P>0.05$) than MS (2.19) in 2008 while CR (2.30) was not different ($P>0.05$) than MS (2.27) in 2009.

The greatest number of fruits was produced by MX (3.74) in 2008. The lowest number of fruits was observed with CP (2.51). MS (2.84) and MX (2.34) produced the greatest number of fruits in 2009 while the fewest fruits were produced by CR (1.75), but not different ($P<0.05$) than CP (2.25) (Table 4).

Table 4. Comparison of the effect of tomato rootstock on fruit characteristics in 2008 and 2009.

	Fruit Characterization							
	Size		Wt. (g)		USDA Grade		No of fruits/plant	
Rootstock	2008	2009	2008	2009	2008	2009	2008	2009
MX[2]	4.25 a[1]	4.94 a	254.2 a	291.0 a	1.99 c	1.90 c	3.74 a	2.34 ns
CR	3.56 c	4.28 b	195.2 b	218.0 b	2.13 b	2.30 ab	3.20 b	1.75 ns
CP	4.14 a	3.98 b	250.0 a	222.4 b	2.22 a	2.47 a	2.51 c	2.25 ns
MS	3.75 b	3.86 b	204.3 b	195.2 b	2.19 ab	2.27 ab	3.43 b	2.84 ns

[1]Means within the same column followed by the same letter are not significantly different according to Duncan's Multiple Range Test($p>0.05$)

[2]MX='Maxifort', CR='Crista', CP='Cherokee Purple', and MS='MisterStripey'.

The largest fruits were produced by the scion CP (4.49) and (4.60) for size in 2008 and 2009, respectively. MS (3.37) and (3.92) produced the smallest fruits in 2008 and 2009 (Table 5). CR (4.19) was not different (P>0.05) than MS (3.92) in 2009.

CP scion (281.4 g) and (259.0 g) produced the heaviest fruits in 2008 and 2009 respectively (Table 5). In 2009, CP was not different from CR (236.1). The lightest fruits were produced by MS (163.4 g) and (195.2 g) in 2008 and 2009, respectively. The best USDA fruit grade was observed with CR scion (1.68) and (2.13) in 2008 and 2009, respectively, while the lowest fruits were produced by MS (2.34) and (2.43) in 2008 and 2009, respectively (Table 5).

The greatest number of fruits was produced by MS (4.29) and (2.92) in 2008 and 2009, respectively (Table 5). The fewest fruits were observed with CR (2.29) in 2008, which was not different (p>0.05) than CP (2.52). Similarly, CP (2.04) produced the lowest in 2009 (Table 5).

In 2008 on black plastic mulch, the non-grafted CPO and MSO produced significantly (p<0.05) larger and heavier fruits compared to the self-grafted CPCP and MSO (Table 6).

Table 5. Comparison of the effect of tomato scion on fruit characteristics in 2008 and 2009.

	Fruit Characterization							
	Size		Wt. (g)		USDA Grade		No of fruits/plant	
Scion	2008	2009	2008	2009	2008	2009	2008	2009
CR[2]	4.15 b[1]	4.19 bc	259.0 b	236.1 bc	1.68 c	2.13 ns	2.29 b	2.18 ns
CP	4.49 a	4.60 ab	281.4 a	259.0 ab	2.24 b	2.17 ns	2.52 b	2.04 ns
MS	3.37 c	3.92 c	163.4 c	195.2 d	2.34 a	2.43 ns	4.29 a	2.92 ns

[1]Means within the same column followed by the same letter are not significantly different according to Duncan's Multiple Range Test (p>0.05).

[2]CR='Crista', CP='Cherokee Purple', and MS='Mister Stripey'.

Table 6. Comparison of fruit characteristics between non-grafted and self-grafted tomato plants grown on black plastic mulch in 2008.

	Black Plastic Mulch			
Treatment	Size	Wt.(g)	USDA Grade	No of fruits/plant
CPO[z]	4.70*	257.9*	2.41*	2.47
CPCP	4.31	300.5	2.21	2.89
CRO	4.19	268.8	1.61*	2.15*
CRCR	4.35	261.5	1.50	1.98
MSO	3.15*	128.0*	2.33*	3.46*
MSMS	2.82	101.7	2.55	6.49

Paired mean comparisons for non-grafted and self-grafted plants. *indicates significance at ($p<0.05$).

[z]Two letters with 'O'= not grafted, CPCP= 'Cherokee Purple' grafted onto self, MSMS= 'Mister Stripey' grafted onto self, and CRCR= 'Crista' grafted onto self.

The better USDA fruit grade was observed with CPCP (2.21) (Table 6). CRCR (1.50) produced the better USDA grade, and lower number of fruits. The greater number of fruits was produced by CRO (2.15). The larger fruits were observed with MSO (3.13), while MSMS (2.75) produced the smaller fruits (Table 6).

On black plastic mulch in 2009, the majority of the fruit characteristics exhibited no advantage or disadvantage when self-grafting (Table 7). The only exception was that CPO (420.0g) was significantly heavier than CPCP (223.4g).

Table 7. Comparison of fruit characteristics between non-grafted and self-grafted tomato plants grown on black plastic mulch in 2009.

	Black Plastic Mulch			
Treatment	Size	Wt.(g)	USDA Grade	No of fruits/plant
CPO[z]	4.75	420.0*	2.25	1.25
CPCP	4.00	223.4	2.10	2.60
CRO	3.50	211.1	3.00	1.25
CRCR	-----	-------	-----	----
MSO	3.00	145.30	3.00	1.00
MSMS	3.00	148.0	2.43	2.00

Paired mean comparisons for non-grafted and self-grafted plants. *indicates significance at ($p<0.05$).

[z]Two letters with 'O'= not grafted, CPCP= 'Cherokee Purple' grafted onto self, MSMS= 'Mister Stripey' grafted onto self, and CRCR = ‘Crista’ grafted onto self.

Paired comparisons showed that there were no significant differences ($p<0.05$) in fruit size among non-grafted and self-grafted combinations (Table 8) when grown on red plastic mulch in 2008 (Table 8). Non-grafted MS (215.2 g) was heavier than the self grafted treatment (275.1) but the other cultivars were not significant for weight. Similar to weight, non-grafted MS was of higher quality and produced more fruit than its self-grafted comparison.

In 2009 on red plastic mulch, the non-grafted MS (3.61) was significantly larger than self-grafted (2.60) (Table 9). There were no differences between self- and non-grafted fruits for weight. However, non-grafted CP and non-grafted MS were of significantly higher quality than their self-grafted comparisons. Non-grafted MS produced more fruit than the self-grafted comparison while CP and CR were not different.

Table 8. Comparison of fruit characteristics between non-grafted and self-grafted tomato plants grown on red plastic mulch in 2008.

	Red Plastic Mulch			
Treatment	Size	Wt.(g)	USDA Grade	No fruits/plant
CPO[z]	4.27	260.1	2.43	2.63
CPCP	4.41	258.8	2.39	2.33
CRO	4.12	252.4	1.72	2.02
CRCR	4.02	258.3	1.69	2.43
MSO	3.91	215.2*	2.22*	4.30*
MSMS	4.13	275.1	2.40	2.48

Paired mean comparisons for non-grafted and self-grafted plants. *indicates significance at ($p<0.05$).

[z]Two letters with 'O'= not grafted, CPCP= 'Cherokee Purple' grafted onto self, MSMS= 'Mister Stripey' grafted onto self,and CRCR= 'Crista' grafted onto self.

Table 9. Comparison of fruit characteristics between non-grafted and self-grafted tomato plants grown on red plastic mulch in 2009.

	Red Plastic Mulch			
Treatment	Size	Wt.(g)	USDA Grade	No of fruits/plant
CPO[z]	5.00	279.7	1.86*	1.79
CPCP	4.57	293.3	2.64	1.50
CRO	4.50	254.2	1.83	2.67
CRCR	5.00	335.1	1.83	1.33
MSO	3.61*	134.4	2.13*	5.24*
MSMS	2.60	108.5	2.60	3.67

Paired mean comparisons for non-grafted and self-grafted plants. *indicates significance at ($p<0.05$).
[z]Two letters with 'O'= not grafted, CPCP= 'Cherokee Purple' grafted onto self, MSMS= 'Mister Stripey' grafted onto self, and CRCR = ‘Crista’ grafted onto self.

In 2008, the graft combinations CPCP (4.57), CPCR (4.59), and CPMX (4.67) significantly ($p<0.05$) produced the largest fruits, but were not different ($p>0.05$) than CRMX (4.45) (Table 10). The smallest fruits were grown with MSCP (3.32) and MSMS (3.50). The heaviest fruits were grown on CPMX (319.6 g), but not different ($p>0.05$) than CPCR (304.6g). The lightest fruits were produced by MSCR (98.1g). The best quality USDA fruit grade was produced by CRMX (1.42), while the lowest USDA fruit grade was produced by MSCR (2.59), but was not different ($p>0.05$) than MSMS (2.47). The greatest number of fruits were produced by MSCR (4.58) and MSMX (4.93), but were not different ($p>0.05$) than MSMS (4.41) (Table 10).

In 2009, the graft combination CRMX (5.24) produced significantly ($p<0.05$) larger fruits, but was not different ($p>0.05$) than MSCP (4.87), CRCR (5.00), CPCR (4.67), CPMX (4.58), MSMX (5.00), and CPMS (5.03) (Table 11). The smallest fruits were produced by MSMS (2.73), but was not different ($p>0.05$) than CRCP (3.33), MSCR (3.71), and CRMS (3.79). The heaviest fruits were produced by MSCP (339.1g), CRCR (335.1g), and CRMX (351.4g). The lightest fruits was produced by MSMS (120.8g), but was not different ($p>0.05$) than CPCP (264.2g), CRCP (165.3g), MSCR (201.1g), CPMX (247.4g), MSMX (251.5g), and CRMS (208.8g). The best USDA fruit grade was produced by MSMX (1.13), but was not different ($p>0.05$) than MSCP (2.13), CRCR (1.83), CPCR (1.83), CPMX (1.42), CRMX (2.00), and CRMS (1.74). There were no differences between treatments for the number of fruits per plant (Table 11).

Table 10. Tomato fruit production for grafted treatments for size, weight, USDA grade, and fruit number per plant. Means are for 2008 combined both plastic mulch colors.

	Fruit characteristics			
Treatment	Size	Wt.(g)	USDA grade	No. of fruits/plant
CPCP	4.57 a	281.9 bc	2.29 cd	2.64 dc
MSCP	3.32 f	186.6 gh	2.26 de	2.91 c
CRCP	3.85 de	230.2 ef	1.89 f	2.23 dc
CRCR	4.18 c	260.1 cde	1.60 g	2.21 d
CPCR	4.59 a	304.6 ab	2.13 e	1.99 d
MSCR	2.68 g	98.1 i	2.59 a	4.58 a
CPMX	4.67 a	319.6 a	2.18 de	2.92 c
CRMX	4.45 ab	282.4 bc	1.42 h	2.55 dc
MSMX	3.78 e	190.7 gh	2.16 de	4.93 a
MSMS	3.50 f	203.4 fg	2.47 ab	4.41 ab
CPMS	4.23 bc	255.6 cde	2.19 de	2.44 dc
CRMS	4.04 cd	246.1 de	1.63 g	2.34 dc

Means within the same column followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($p>0.05$). CR= 'Crista', CP= 'Cherokee Purple', MS= 'Mister Stripey', and MX= 'Maxifort'.

Table 11. Tomato fruit production for grafted treatments for size, weight, USDA grade, and fruit number per plant. Means are for 2009 combined both plastic mulch colors.

	Fruit characteristics			
Treatments	Size	Wt(g)	USDA grade	No of fruits/plant
CPCP	4.33 bcde	264.2 bcde	2.42 ab	1.96 ns
MSCP	4.87 abc	339.1 ab	2.13 abc	1.87 ns
CRCP	3.33 def	165.3 cde	2.28 ab	2.44 ns
CRCR	5.00 abc	335.1 ab	1.83 abc	1.33 ns
CPCR	4.67 abcd	276.9 bcd	1.83 abc	1.67 ns
MSCR	3.71 bcdef	201.1 bcde	2.29 ab	1.29 ns
CPMX	4.58 abcd	247.4 bcde	1.42 bc	2.21 ns
CRMX	5.24 ab	351.4 ab	2.00 abc	2.47 ns
MSMX	5.00 abc	251.5 bcde	1.13 c	3.63 ns
MSMS	2.73 f	120.8 e	2.55 ab	3.14 ns
CPMS	5.03 abc	285.1 bc	2.52 ab	2.03 ns
CRMS	3.79 bcdef	208.8 bcde	1.74 bc	2.26 ns

Means within the same column followed by the same letter are not significantly different according to Duncan's Multiple Range Test ($p>0.05$).

CR= 'Crista', CP= 'Cherokee Purple', MS= 'Mister Stripey', and MX= 'Maxifort'

Summary of Results

In comparing plastic mulches, it was observed that plants grown under red plastic mulch produced fruits that were heavier, larger, and of a better USDA fruit grade, while black plastic mulch produced more fruits per plant. When comparing grafted treatments for 2008 and 2009, MSCP produced the largest fruits in 2008 while in 2009, the largest fruits were produced by MSMX and CPMS. For fruit weight, MSCP produced the heaviest fruits in 2008, while CRMX produced the heaviest fruits in 2009. The overall heaviest for both years was CRMX. For USDA fruit grade, CRMX produced the best USDA fruit grade in 2008 and also for 2009. For number of fruits per plant, MSMX produced the highest number of fruits per plant in both years.

The best rootstock was observed with ‘Maxifort’ rootstock for size, weight, USDA grade, and number of fruits per plant for both 2008 and 2009. For scion, the best scion was observed with CP, for size and weight in both years. CR scion was the best for USDA grade in both years, while MS scion produced the highest number of fruits per plant for both years. Self-grafted CPCP produced the largest, heaviest, best USDA grade, and highest number of fruits per plant. Non-grafted MSO produced the largest fruits and best USDA grade, but the self-grafted MSMS produced significantly ($p<0.05$) the highest number of fruits per plant in 2008. The non-grafted CPO produced the largest and heaviest fruits in 2009 compared to self-grafted, but CPCP produced the best USDA grade and highest number of fruits per plant. CRCR could not be compared with CRO in 2009, because the data were missing.

CHAPTER V

Discussion and Conclusions

Plastic Mulch Color

Tomato plants grown on red plastic mulch produced fruits that were significantly ($p<0.05$) heavier and larger than fruits grown on black plastic mulch. These results are in agreement with Kasperbauer and Hunt (1985), who found that tomato yields were higher over red-painted mulch than over black plastic mulch. According to them, red mulch enhanced early crop yields of tomato compared with yields over standard black plastic mulch. In their study, they found that the effectiveness of the red mulch was attributed primarily to the FR/R photon ratio reflected to the developing fruit and nearby leaves from the mulch surface. These results are also similar to the results found by Orzolek (1993) that yield from tomato plants growing on the red plastic mulch was almost double compared to the tomato plants grown on the standard black plastic mulch and also plants grown on red mulch produced more fruit per plant than plants growing on black.

In contrast to these results, the use of black plastic mulch produced the greatest number of fruits per plant (Table 2). This is in agreement to Bhella (1988) who found that the use of black mulch increases early tomato yield by retaining moisture and heat. These results are also in agreement with Hanna et al, (1997) who found that the use of black plastic significantly increased the quality and total yields of cucumbers.

It is likely that these results are due to the physical properties of light interacting with the mulch color and the tomato plant's physiological response to such light. It seems that the black mulch would heat the soil faster in the spring resulting in faster growth and earlier maturation of fruit. The black plastic mulch was observed to have more abundant harvest and the highest quality USDA grade contrary to what Kasperbauer and Hunt (1985) found. Similar results were found by Waggoner et al. (1960) that black plastic mulch gave a harvest earlier by some 7-14 days. Since black plastic warms the soil and hastens maturity of crops, this could facilitate the development of roots in the top few inches of the soil where moisture, oxygen, temperature, and nutrients are most favorable for early root growth. Once there is early root growth, plants may be producing fruits sooner and longer into the fall as temperature drops which lead to increase in number of fruits and better grade.

Grafted Combinations

The grafted combination MSCP produced the largest fruits in 2008. It is likely that since 'Mister Stripey' is a large beefsteak-type tomato and using it as a scion on 'Cherokee Purple' rootstock resulted in the increased size of the fruits. Since 'Cherokee Purple' is a robust plant, it has a vigorous root system this might have contributed to the largest fruit size. The combinations MSCR and MSMS produced the lightest fruits in 2008 on black plastic. This is likely due to the fact that 'Crista' did not perform well as a rootstock for 'Mister Stripey', because it was not developed as a rootstock. 'Crista' is a widely grown cultivar that was included as a commercial standard. It was developed under a directed breeding program for fruit size, quality, consistency, and overall production. It would have been developed under exceptional field conditions such as optimal weed control, fertilizer, and irrigation. The size and aggressiveness of the root system would not have been an important genetic trait to the breeders. ‘Mister Stripey’ appears to be the most influenced scion by rootstock but the mechanism in unknown.

MSMS produced the lightest fruits in both years and this appears to be a genetic trait of the cultivar. Non-grafted MS produced fruits significantly lighter than CP or CR in 2008. This is partially due to the anatomy of MS. ‘Mister Stripey’ is used as a ‘stuffing’ tomato because it has more open cavities in its fruit (Male, 1999).

For 2009, it is important to note that the combinations CPMS and MSMX produced the largest fruits. Since 2009 was characterized by a later planting date and a disease-shortened season, the results are skewed towards the graft combinations that mature early; later maturing graft combinations such as those containing CP, were generally under-represented in the data. This means that ‘Maxifort’ rootstock provided enough protection for ‘Mister Stripey’ against soil-borne diseases and increased crop yield. Others have found that in tomato, increases in fruit yield are typically a result of increased fruit size (Augustin et al., 2002; Pogonyi et al., 2005). For CPMS, it is likely that both graft partners being developed by past generations in outdoor gardens for many years may have led to their success in producing large fruits. Additionally, ‘Cherokee Purple’ and ‘Mister Stripey’ were observed to have aggressive root systems that would enable them withstand fierce competition.

In 2008, the graft combination MSCP followed the same trend by producing the heaviest fruits. As previously mentioned, this was observed to be the vigorous root system of ‘Cherokee Purple’. In 2009, the graft combinations MSCP and CRMX produced the heaviest fruits. Since MSCP are both heirlooms that were developed in gardens many years ago they produced well under adverse conditions. Since ‘Crista’ was bred under controlled conditions, using ‘Maxifort’ rootstock will protect it from soil-borne diseases and increase crop yield. According to Rivard (2006), grafting with a disease resistant and highly vigorous rootstock may be an important component in an integrated approach to manage soil-borne disease and improved yields. The lowest fruits were produced by MSCR in both 2008 and 2009 suggesting that ‘Crista’ did not provide protection for ‘Mister Sripey’. ‘Crista’ was bred for producing heavier and high quality fruits but not as a rootstock. It is interesting that despite several rootstocks, it is the MS scion that produced the greatest number of fruits per plant. It was observed that CRMX produced significantly ($p<0.05$) the highest quality fruits in both 2008 and 2009. ‘Maxifort’ rootstock was bred against soil-borne diseases and to improve crop yield.

In 2008, MSMX produced the greatest number of fruits. This increased due to the protection from ‘Maxifort’ rootstock and also that ‘Mister Stripey’ is prolific. In fact, it produced the greatest number of fruits in 2008 and 2009. The graft combination CPCR produced fewest fruits in 2008 and 2009 due to the fact that ‘Crista’ was used as a rootstock. Therefore, ‘Crista’ should rarely, if ever be used as a rootstock, because scions on a ‘Crista’ rootstock did not perform well. ‘Maxifort’ and ‘Cherokee Purple’ rootstocks performed the best because ‘Maxifort’ is a commercial rootstock and ‘Cherokee Purple’, is better suited and adapted to environmental stress. This is in agreement with Passam et al. (2005) that eggplant grafted onto tomato rootstock showed improved yields as a result of increased fruit size and number compared to non-grafted controls.

Rootstocks

In comparing the effects of rootstock in 2008 and 2009 in tomato production, ‘Maxifort’ produced the largest fruits, the heaviest fruits and the highest quality USDA grade as well as number of fruits per plant. This is in agreement with Rivard, (2006) who found that ‘Maxifort’ as a vigorous rootstock appeared to be successful. Ibraham et al. (2001) and Rahman et al. (2002) found that grafting eggplant onto wild solanum rootstock showed significant yield increases as compared to self-grafted controls. According to (Passam et al., 2005), eggplant grafted onto tomato rootstock showed improved yields as a result of increased fruit size and number compared to non-grafted controls and those with eggplant rootstock and (Augustin et al., 2002; Pogonyi et al., 2005) also found that in tomato, increases in fruit yield are typically a result of increased fruit size.

For ‘Cherokee Purple’, it was bred to be a large beefsteak-type fruit with a solid fruit body and appeared better to compete for light, water, and nutrients. Overall, it was the coarsest plant and produced large fruits that matured later than ‘Crista’ or ‘Mister Stripey’. ‘Mister Stripey’ frequently cracked due to its large size. However, being developed for a large fruit with excellent taste, its large size was evident when examine broadly across several rootstocks.

Scion

In comparing the effects of scion in 2008 and 2009, 'Cherokee Purple' produced the largest and heaviest fruits. This was not unexpected because it is an heirloom with a vigorous root system which enables the roots to absorb adequate nutrients and water for better plant growth which led to great number and heavier fruits. 'Crista' scion produced the highest quality of fruits (Table 6). It was bred for this purpose, being a hybrid, gave it the potential to produce high quality fresh tomatoes. 'Mister Stripey' produced the lowest quality fruits. It is likely that any rough harvest, such as by machine, would result in cracks or other fruit injuries that would lead to lower grade. 'Crista' on the other hand, was bred with the characteristics of possessing firm outer covering of the fruits and also for long distance transport. Another reason for 'Crista' fruits having firm texture when ripe is that they are harvested when the fruits are green and less matured.

Self-grafting

With a few exceptions, the procedure of self-grafting contributed little to the size, weight, quality, or number of fruits per plant. The cultivar that consistently exhibited an effect of self-grafting was MS. In ten of sixteen measurements, it was affected positively or adversely. In general, self-grafting MS decreased the size and quality. The results for MS in terms of weight and number of fruit per plant were conflicting depending on year and plastic mulch color. Considering the expense involved in the process of grafting, the loss rate incurred, and the skilled labor required, it does not appear from these data that it is justified. The exception may be MS which seemed responsive to the procedure and deserves more investigation into its response.

APPENDIX I

Chemicals in the research project, including manufacturers, and use.

- 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, NC27419. 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.
- Pre-plant fertilizer 10-20-20, NPK 20-20-20, and Calcium Nitrate 15-0-0 were applied throughout the growing season.

Cultivar Description

‘Cherokee Purple’ is an heirloom plant and an open-pollinated cultivar of tomato. Cherokee Purple tomatoes are beefsteak in style, with green shoulders across the top. They are also notable for having a dense, juicy texture, with small seed locules irregularly scattered throughout the flesh. The comparatively dark interior color is enhanced by the tendency of the seeds to be surrounded by green gel Edlin (2009).

‘Mr. Stripey’ is a type of heirloom tomatoes with unusually small leaves and a mix of a yellow and red color that can fool some growers into thinking they are picking an unripe tomato. Under good conditions in size, shape and internal structure, it may be considered a beefsteak. Like other heirlooms, ‘Mr. Stripey’ has an appearance that differs considerably from other tomatoes. In coloration, it is generally somewhat more yellow near the stem and redder towards its underside, with gentle stripes of red and yellow blending into each other along the sides. This coloration may extend into the interior of the fruit, which tends to be more yellow than red.

‘Crista’ is a semi-determinate selection, which means it grows the foliage and then sets the fruit in relatively distinct stages over a short season. ‘Crista’ tomato is a medium-to- large size tomato which is uniformly round, firm fleshed, and highly flavored with a good balance of acid to sugars Edlin (2009).

‘Maxifort’ rootstock is a commercial rootstock developed to withstand soil-borne diseases and to improve crop yields. It provides protection to the scion and functionally compensate for lack of crop rotation. The plant grows vigorously with an aggressive root system. Its fruits are similar in size and shape to that of ‘Cherry’ tomatoes; but the fruits are yellow when ripe Edlin (2009).

Table 12. Soil test analysis for 2008 and 2009 under organic and conventional tomato production techniques*.

	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
	Kg/ha			
Phosphorus (P)	98.1	94.4	92.6	35.4
Potassium (K)	219.7	185.2	192.5	88.1
Calcium (Ca)	3031.0	1397.4	3382.3	1520.0
Magnesium (Mg)	199.7	179.8	203.3	167.1
	(%)			
Organic Matter	2.3	1.5	4.4	1.7

*A&L Analytical Laboratories, Inc. 2790 Whitten Rd. Memphis, TN 38133.

LITERATURE CITED

Abdelhaq, H. 2004. Integrated production and protection in greenhouse crops: Agronomique et Veterinaire Hassan II.

Augustin, B., V. Graf, and N. Laun. 2002. Temperature influencing efficiency of grafted tomato cultivars against root-knot nematode (*Meloidogyne arenaria*) and corky root (Pyrenochaeta lycopersici). Zeitschrift Fur Pflanzenkrankheiten Und pflanzenschutz-Journal of Plant Diseases and Protection 109:371-383.

Besri. M. 2001. New developments of alternatives to methyl bromide for the control of tomato soil-borne pathogens in covered cultivation in a developing country, Morocco. 2001 Annual International Research Conference on Methyl Bromide Alternatives and Emissions Reductions. November 5-8, 2001, San Diego, California, USA.

Bhella, H.S. 1988. Tomato response to trickle irrigation and black polyethylene mulch. J. Ameri. Soc. Hort. Sci. 113:543-546.

Bletsos, F. A. 2005. Use of grafting and calcium cyanamide as alternatives to methyl bromide soil fumigation and their effects on growth, yield, quality and fusarium wilt control in melon. Journal of Phytopathology 153:155-161.

Bradley, J. A. 1968. Tomato grafting to control root diseases. New Zealand Journal of Agriculture 116:26-27.

Briassoulis, D. 2006. Mechanical behavior of biodegradable agricultural films under real field conditions. Polymer Degradation and Stability 91, 1256-1272. Doi:10.1016/j.polymdegradstab.2005.09.016.

Bryan, H.H. and J.D. Dalton. 1974. Yield responses of tomatoes and second cropped butternut squash to fertilizer rate and placement under plastic mulch on rockdale soil. Proc. Florida. State Hort. Soc. 87:159-164.

Colla, G., Y. Roupahel, M. Cardarelli, and E. Rea. 2006. Effects of salinity on yield, fruit quality, leaf gas exchange, and mineral composition of grafted watermelon plants. Hortscience 41: 622-627.

Decoteau, D.R., D.D. Daniels, M.J. Kasperbauer, and P.G. Hunt. 1986. Colored plastic mulches and tomato morphogenesis. Proc. Natl. Agr. Plastics Congr. 19:240-248.

Decoteau, D.R., M.J. Kasperbauer, D.D. Daniels, and P.G. Hunt. 1988. Plastic mulch color effects on reflected light and tomato plant growth. Scientia Hort. 34:169-175.

Edlin, D.J. 2009. Heirloom and hybrid tomato yield and quality in organic and conventional production systems. Master Thesis, Western Kentucky University.

Emmert, E. 1957. Black polyethylene for mulching vegetables. Proceedings, American Society of Horticultural Science 69: 464-469.

Giannakou, I. O., and D. G. Karpouzas. 2003. Evaluation of chemical and integrated stragegies as alternatives to methyl bromide for the control of root-knot nematodes in Greece. Pest Management Science 59:883-892.

Gonzalez, A., J.A. Fernandez, P. Martin, R. Rodriguez, J. Lopez, S. Banon, and J.A. Franco. 2003. Behavior of biodegradable film for mulching in open-air melon cultivation in South-East Spain. KTBL-Schrift, 71-77.

Graham, H.A.H., D.R. Decoteau, and D.E. Linvill. 1995. Development of a polyethylene mulch system that changes color in the field. HortScience 30:265-269.

Grassbaugh, E., T. Harker, B. Bergefurd, and M. Bennett. 1999. Specialty and heirloom tomato production and marketing. Department of Health and Consumer Science: Ohio Agricultural Research and Development Center.

Green, D.S., E.L. Kruger, and G.R. Stanosz. 2003. Effects of polyethylene mulch in a short-rotation, popular plantation vary with weed-control strategies, site quality and clone. Forest Ecol Manage 173, 251-260. Doi:1016/S0378-1127(02)00003-8.

Greer, L. and J.M. Dole. 2003. Aluminium foil, aluminium-painted, plastic and degradable mulches increase yields and decrease insect-vectored viral diseases of vegetables. HortTech 13, 276-284.

Ham, J.M., G.J. Huitenberg, and W.J. Lamont. 1993. Optical properties of plastic mulches affect the field temperature regime. J. Amer. Soc. Hort. Sci. 118, 188-193.

Hanna, H.Y., E.P. Millhollon, J.K. Herrick, and C.L. Fletcher. 1997. Increased yield of heat-tolerant tomatoes with deep transplanting, morning irrigation, and white mulch. HortScience 32:224-226.

Hatt, H.A., M.J. McMahon, D.E. Linvill, and D.R. Decoteau. 1993. Influence of spectral qualities of mulch film on bell pepper growth and production. Proc. Natl. Agr. Plastics Congr. 24:233-239.

Hayslip, N.C., J.W. Mishoe, and R.M. Sonoda. 1978. Methods of fumigation and fertilization between successive crops in established plastic mulch-covered beds. Proc. Fla. State Hort.Soc. 91:313-316.

Hewitt, T.D. and D. Zimet. 1987. Fall production of watermelon: The potential for double cropping and markets. Proc. Fla. State Hort. Soc. 100:262-264.

Ibrahim, M., M. K. Munira, M. S. Kabir, A. K. M. S. Islam, and M. M. U. Miah. 2001. Seed germination and graft compatibility of wild rootstock as tomato. Journal of Biological Sciences 1:701-703.

Ioannou, N. 2001. Integrating soil solarization with grafting on resistant rootstocks for management of soil-borne pathogens of eggplant. Journal of Horticultural Science and Biotechnology 76:396-401.

Jones, T.L., U.S. Jones, and D.O. Ezell. 1977. Effect of nitrogen and plastic mulch on properties of Troup Loamy Sand and yield of “Walter” tomatoes. J. Amer. Soc. Hort. Sci. 102: 273-275.

Kasperbauer, M.J., H.A. Borthwick, and S.B. Hendricks. 1964. Reversion of phytochrome 730 (Pfr) to P660 (Pr) in Chenopodium rubrum L. Bot. Gaz. 125:75-90.

Kasperbauer, M. J., and P. J. Hunt. 1985. Tomato production trial with plastic mulch. USDA-ARS Soil and Water Conservation Research lab, Florence, SC.

Kasperbauer, M.J. 1988. Phytochrome involvement in regulation of the photosynthetic apparatus and plant adaptation. Plant Physiol. Biochem. 26(4):519-524.

Lamont, W.J. and C.W. Marr. 1990. Muskmelons, honeydews and watermelons on conventional and photodegradable plastic mulches with drip irrigation in Kansas. Proceedings, National Agricultural Plastics Congress 22: 33-39.

Lamont, W.J. 1993. Plastic mulches for the production of vegetable crops. HortTech 3, 35-39.

Lamont, W.J. 1996. What are the components of a plasticulture vegetable system? HortTech 6 (3), 150-154.

Lee, J. M., H. J. Bang, and H. S. Ham. 1998. Grafting of vegetables. Journal of the Japanese Society for Horticultural Science 67:1098-1104.

Liakatas, A., J.A. Clark, and J.L. Monteith. 1986. Measurements of the heat balance under plastic mulches. Part I. Radiation balance and soil heat flux. Agr Forest Meteorol 36, 227-239.

Mahmoudpour, M.A. and J.J. Stapleton. 1997. Influence of sprayable mulch color on yield of eggplant (*Solanum melongena* L. cv. Millionaire). Sci. Hortic 70, 331-338.

McCarter, S. M. 1991. Bacterial Wilt. In Compendium of Tomato Diseases, edited by J. B. Jones, J. P. Jones, R. E. Stall and T. Zitter. St. Paul, MN:APS Press.

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

Matsuzoe, N., H. Okubo, and K. Fujieda. 1993. Resistance of tomato plants grafted on solanum rootstocks to bacterial wilt and root-knot nematode. Journal of the Japanese Society for Horticultural Science 61:865-872.

Oda, M. 1999. Grafting of vegetable to improve greenhouse production. College of Agriculture: Osaka Prefecture University.

Orzolek, M. D. 1993. The effect of colored polyethylene mulch on the yield of squash and pepper. Proc. Natl. Ag. Plastics Cong. 24:157-161.

Passam, H. C., M. Stylianou, and A. Kotsiras. 2005. Performance of eggplant grafted on tomato and eggplant rootstocks. European Journal of Horticultural Science 70:130-134.

Pavlou, G. C., D. J. Vakalounakis, and E. K. Ligoxigakis. 2002. Control of root and stem rot of cucumber, caused by *Fusarium oxysporum f. sp radicis-cucumerinum*, by grafting onto resistant rootstocks. Plant Disease 86:379-382.

Pogonyi, A., Z. Pek, L. Helyes, and A. Lugasi. 2005. Effects of grafting on the tomato's yield, quality and main fruit components in spring forcing. Acta Alimentaria 34:453-462.

Rahman, M. A., M. A. Rashid, M. A. Salam, M. A. T. Masud, A. S. M. H. Masum, and M. M. Hossain. 2002. Performance of some grafted eggplant genotypes on wild Solanum rootstocks against root-knot nematodes. Journal of Biological Sciences 2:446-448.

Rivard, C. L. 2006. Grafting for disease resistance in heirloom tomatoes. North Carolina Cooperative Extension Service Ag-675.

Ruiz, J. M., and L. Romero. 1999. Nitrogen efficiency and metabolism in grafted melon plants. Scientia Horticulturae 81:113-123.

Scarascia-Mugnozza, G., E. Schettini, G. Vox, M. Malinconico, B. Immirzi, S. Pagliara. 2006. Mechanical properties decay and morphological behavior of biodegradable films for agricultural mulching in real scale experiment. Polym Degrad Stab 91, 2801-2808. Doi:10.1016/j.polymdegradstab.2006.02.017.

Schales, F.D., and R. Sheldrake. 1963. Mulch effects on soil conditions and tomato plant response. Proc. IV Natl Agr Plastic Conf, 78-90.

Schales, F.D. and R. Sheldrake. 1965. Mulch effects on soil conditions and muskmelon response. Proceedings, American Society for Horticultural Science 88: 425-430.

Schalk, J.M., C.S. Creighton, R.L. Fery, W. Sitterly, B.W. Davis, T.L McFadden, and A. Day. 1979. Reflective film mulches influence insect control and yield in vegetables. J. Ameri. Soc. Hort. Sci.104:759-762.

Schmidt, J.R. and J.W. Worthington. 1998. Modifying heat unit accumulation with contrasting colors of polyethylene mulch. HortScience 33:210-214.

Smith, M. 2007. The plant propagator's bible. Published by Rodale Inc.

Stall, W.M., H.H. Bryan, and J.W. Mishoe. 1978. Commercial use of plastic mulch and drip irrigation on vegetables in south Florida. Intl. Agr. Plastics Congr. Proc., p.372-377.

Swiader, J. M., Ware, G. W., & McCollum, J. P. 1992. Producing vegetable crops. Interstate Publishers, Inc.

Taber, H.G. 1983. Effects of plastic soil and plant covers on Iowa tomato and muskmelon production. Proc. Natl. Agr. Plastics Conf. 17:37-45.

Tremblay, N., M.C. Gasia, M.-Th. Ferauge, A. Gosselin, and M.J. Trudel. 1988. Effects of light spectral quality on nutrient uptake by tomato. Can. J. Plant Sci. 68:287-289.

Tripathi, R.P. and T.P.S. Katiyar. 1984. Effect of mulches on the thermal regime of soil. Soil Till Res 4, 381-390.

Tucker, D.J. 1975. Far-red light as a suppressor of side shoot growth in tomato. Plant Sci. Lett. 5:127-130.

Upstone, M. E. 1968. Effects of methyl bromide fumigation and grafting on yield and root diseases of tomatoes. Plant Pathology 17:103

Waggoner, P.E., P.M. Miller, and H.C. DeRoo. 1960. Plastic mulching: Principles and benefits. Connecticut Agricultural Experiment Station Bulletin, New Haven 634-44 pp.

Wien, H.C. and P.L. Minotti. 1987. Growth yield and nutrient uptake of transplanted fresh-market tomatoes as affected by plastic mulch and initial nitrogen rate. J. Amer. Soc. Hort. Sci. 112:759-763.

West, J. and L.C. Pierce. 1988. Yields of tomato phenotypes modified by planting density, mulch, and row covers. HortScience 23:321-324.

Yetisir, H., and N. Sari. 2003. Effects of different rootstock on plant growth, yield and quality of watermelon. Australian Journal of Experimental Agriculture 43: 1269-1274.