COLORED MULCH TYPE AFFECTS SOIL TEMPERATURE AND EARLY TOMATO YIELD - A SYSTEMATIC APPROACH

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Early market tomatoes command the highest price in mid-July, the price per pound dropping one-half by mid August. High quality early tomato production involves a number of culture techniques: proper variety selection, windbreaks, plastic mulch types, staking and pruning, microirrigation, row covers, and high tunnels. Extensive research has been conducted on all of these practices, singly or in combination, and the merits and disadvantages published. Two principal factors govern early yield production with plastic mulch: the soil temperature effect and/or reflected light into the plant canopy. Over five site-year experiments we found inconclusive results for selecting one film type over another. Generally, years where the mulch increased early spring soil temperatures (clear, wavelength selective, or red compared to black) resulted in highest early yields.

Our objective for this project was to evaluate date of planting, plastic mulch type, and use of row covers for enhancing early marketable yield of a commercial early variety, Sunstart.

Materials and Methods

The experiment was conducted at the Horticulture Station in central Iowa. The soil type was a well drained sandy loam soil with a pH of 6.2 and an organic matter content of 2.3%. A soil test indicated P and K were in the high range so none was applied. Sixty-five pounds of N, as urea, was broadcast and rotovated in with the herbicide just prior to laying the 4-ft wide plastic films on 6-ft row centers. To aid in weed control Treflan 4E (trifluralin) plus Sencor DF (metribuzin) were pre-plant incorporated at recommended rates for the soil type, and mechanical cultivation was used as needed for row middles. Weed control was adequate in all treatments throughout the growing season. Trickle irrigation tubing was set 4-inches off row center and the soil moisture was maintained at 25 to 30 kPa, as monitored by tensiometers.

Mulch treatments, whole plots, included: black, clear, infrared (Sonoco Products Co., Hartsville, SC), wavelength selective - SRM-olive (Ken-Bar, Inc, Reading, MA), and wavelength reflective - SRM-red (Ken-Bar). A sixth mulch treatment included was SRM-olive + row cover. The row cover was slitted, clear plastic placed over wire hoops, spaced every 5 ft in the row on the day of transplanting. The height of the row cover over the plastic mulch was 14 inches. The subplot was date of planting, either May 1 or May 16, 2001. The average frost free date (25% chance) for the area is May 8. All treatments were replicated four times in a randomized, complete block design.

Five-week old transplants of the early commercial variety ‘Sunstart’ were set 1.5 feet in-row with rows 25 feet long. Orientation of the rows were in an East-West direction. Plants were staked using the Florida stake and weave system.

Soil temperatures were measured for all treatments in three blocks with copper-constantan thermocouples placed 4 inches to the south side of the transplant and 4 inches deep. Three thermocouples were wired in parallel according to give one average output reading for each plot. Temperatures were monitored with a CR-10 data logger (Campbell Scientific, Logan, UT) with a scan rate of 5 min and averaged hourly.

Reflective light measurements were taken at a 12-inch height between plants over the plastic strips of the May 16 planting using a Li-Cor 1800-11 remote cosine receptor head mounted in a horizontal orientation on June 1 and June 8. Readings were taken between 12 and 1 pm, central time. Sky conditions were cloudy, bright both dates. Each measurement consisted of the average of three spectral scans from 400-800 nm at 5 nm intervals. To determine the R (red) : FR (far red) ratio, energy values for R = 650-670 nm and for FR = 720-740 nm were calculated.

Whole plants were harvested June 1 from the May 1 plant date and June 18 from the May 16 plant date. Dry weight, number of flower clusters, and open flowers were determined. Harvest began July 17 for the May 1 plant date and July 26 for the May 16 plant date. All fruit with ≥ 30% color were harvested weekly and sorted into marketable and cull categories. Culls included small fruit and fruits with rots, cracks, and catfacing. Catfaced fruit was extensive this year for both planting dates.

Results - Summary

The 2001 spring season was typical of a continental climate. Average April air temperature was 2 °F below normal. The last spring frost was April 24. From May 1 (1st planting date) to May 15 temperatures were 5 °F above normal while from May 16 (2nd planting date) to June 2 temperatures were 4 °F below normal (Fig. 1). From May 16 to the first part of June maximum daily temperature was in the low 60's while the minimum was in the high 40's. The air temperature the remainder of the growing season was normal with rainfall 7.4 inches below normal.

The row cover was removed at initial flowering (June 1). By June 8, the most effective soil warming plastic treatment was infrared > clear > wavelength selective > black = red (Table 1, Fig. 2). When expressed as soil heat unit accumulation the infrared and clear plastic films were superior (Fig. 3). As expected, the clear and infrared mulches had 20 and 17 days, respectively, where daily maximum soil temperature was >86 °F but rarely over 90 °F. Approximately half of these times occurred in mid May and early August and the other half in late June and early July. The other plastic mulches had only 8 or 9 days of soil temperatures exceeding 86 °F. High soil temperatures within four inches of the base of the plant were moderated by partial shading of the plant foliage

Plant dry weight, flower cluster number, and number of open flowers were determined at 1st flower appearance, June 1 and June 18, for the May 1 and May 16 plant date, respectively. There were no plastic treatment effects on any parameter measured either date (data not presented). Reflected radiation measured June 1 showed a 14.7% reduction in the R:FR ratio compared with the black plastic (Table 2). However, by June 8 this difference was not detectable, red = 1.08 and black = 1.07.

Harvest was weekly from July 17 to August 13. Yield was highest from the May 1st planting, compared with the May 16 plant date, for the first three harvests (Fig. 4). After the third harvest the cumulative marketable yield from the May 1st planting was 58 cwt/acre more than the May 16th planting. The 2001 growing season was not favorable for tomato production resulting in rough, misshapened, and catfaced fruit. The pickings from the May 16th planting contained 62% culls compared to 32% cull fruit from the May 1st planting.

There was a significant effect of plastic treatment on yield for the May 1 planting, but not the May 16 planting date (Table 3). Total marketable yield at 240 cwt/a was highest with the red mulch. This was the result of the lowest amount of cat-faced fruit. The red film was superior to all other treatments only at the 4th harvest date, August 7. We do not know why only red mulch reduced the cull percent. Fruit size was not significantly affected by plastic treatment, averaging 6.6 ounces each. The trend of larger fruit size for the infrared mulch was evident in all four harvests. The SRM-olive + row cover treatment yielded 16% less, 38 cwt/acre, than the red but 24% greater than the black and infrared films. The black, SRM-olive, clear, and infrared total marketable yield was similar. After four weeks of harvest the red reflective mulch produced 75 cwt/a more than the other mulches. This effect cannot be explained on the basis of soil temperature differences.

The first harvest, July 17, was only from the May 1st plant date (Table 4). The SRM-olive + row cover treatment gave the first ripe fruit and the marketable yield of 10.9 cwt/acre was double that of treatments without a row cover. Interestingly, there was no difference among the colored mulches even through soil temperature values were significantly different (Table 1). Marketable fruit size was 2 ounces greater with the infrared film, compared to red or clear, but similar to the other treatments. There was no affect of plastic mulch on fruit yield or characteristics at first harvest (July 26) of the May 16 planting date.

For this trial, the most profitable practice was to plant an early maturing variety 7 days prior to the frost free date using a wavelength selective plastic (SRM-olive) with a slitted, clear row cover. Response of plastic mulch can be confounded with factors other than soil temperature, such as light intensity (cloudy) and soil moisture.

Plastic Mulch for Tomato Production

For commercial production there are two major types of mulches - organic and plastic. Paper mulch is still in the experimental stage, but with the proper resin development to improve stability in the field paper mulch may eventually be the answer to the plastic disposal problem.

<u>**Advantages**</u>

1. **Earliness**. Higher soil temperature under plastic means faster crop development and earlier yields. For example, tomatoes require a root temperature >60 ^{o}F for good shoot growth and 1st flower cluster development. Organic mulches keep the soil cold, retarding

plant growth. Organic mulches should only be applied in late May or early June when soil temperature is >68 °F. Depending on the crop, but with the highly responsive cucurbits (cukes, muskmelon, summer squash) black plastic can advance harvest by 7-10 days and clear plastic by 2-3 weeks.

2. **Carbon dioxide** builds up under the plastic and escapes through the plant holes and into the plant canopy enhancing vegetative growth. Although research has documented this point I'm not sure it is of great benefit in Iowa with our constant wind conditions.
3. **Reduced soil moisture** loss. But, plant growth early in the season on plastic could be twice that of bare ground plants and will need irrigation sooner. Drip tape under the plastic is a very effective way to conserve water.
4. **Weed growth** and herbicide use are reduced. But, nutsedge, if present at the site, will puncture through the plastic. Weeds that come up in the plant hole will have to be pulled by hand to eliminate competition. A type of mulch called wavelength selective (SRM-olive) blocks the photosynthetic radiation but allows the longer wavelengths to pass through. Thus, soil temperature increase is between black and clear without the weed growth of the clear. However, some weeds will grow under the SRM, most notably the sedges.
5. **Reduced soil compaction**. More oxygen to roots because of increased aeration.
6. **Fertilizer efficiency** is increased, or, specifically nitrate is not lost due to leaching.
7. **No root pruning** because of the lack of cultivation. Root pruning has been documented to slow crop growth and maturity.
8. **Root death** due to excess water is eliminated. The heavy rains (this spring!) are shed off the plastic mulch, keeping roots from being waterlogged.
9. **Cleaner product**. Less contaminating soil is splashed onto ripening vegetables reducing fruit rots.

10 **Insect populations** may be reduced. Silver repels aphids, but yellow attracts thrips, aphids, whiteflys, etc. Yellow plastic is used in some areas on field edges to serve as a trap where insects can be destroyed before reaching the crop field.

<u>Disadvantages</u>.

1. **Removal** and disposal problem.
2. **Increased cost** - product and the labor to put down.
3. **Burn effect** on tender transplants during very hot weather. We observed this during the May 15-17 period in 2001 when parts of the state received 90 °F at the time of transplanting. Tomato and pepper plant stems that touched the edge of the plastic hole were scorched resulting in stem breakage similar to cutworm damage.
4. **Fruit spoilage** due to lack of foliage cover and fruit lying on plastic. Example are some determinate tomato varieties such as Early Cascade, Firechief, and Sunstart. This can be overcome by staking or caging.
5. **Lack of certification** of product. There are no national manufacturing standards, so know your supplier. You do not know if the plastic mulch is according to specifications. This is particularly true with the wavelength products called IRT or SRM and are green or olive (brown?) depending on the manufacturer. But, to be effective, they must contain a specific pigment to allow the mulch to transmit maximum infrared radiation while limiting (only 14%) visible light.

Table 1. Effect of plastic mulch on soil temperature, at the 4-inch depth, and cumulative soil heat units after transplanting for the May 1 plant date.

Plastic mulch	Soil Temperature[1] Min	Max	Cumulative Heat Units[2] Warm	Cool	Total
Infrared	57.4 A[3]	70.7 A	159 A	71 A	230 A
Clear	57.4 A	69.8 B	152 B	66 A	218 B
SRM-olive + RC	56.8 B	67.8 C	129 C	56 C	185 C
SRM-olive	56.3 C	67.1 D	117 C	52 D	169 D
SRM-red	46.4 D	65.1 E	109 D	40 E	149 E
Black	46.4 D	64.8 E	108 D	39 E	147 E

1) Averaged over the cool period, from May 23 to June 8 with average daily Mj/m^2 of 9.1 and 10 days with rain.

2) Warm period = May 7 to May 23 with average daily Mj/m^2 of 11.5 and 6 days with rain. Cool period = May 23 to June 8. Heat unit calculated as: (Soil T_{max}+ T_{min})/2 - 56, where 56 is the lower threshold temperature. If T_{min} < 56, then T_{mi}n set to 56.

3) Mean values in a column followed by the same letter do not si

Table 2. Red:Far red ratios of reflective light measured 12 inches from the mulch surface on June 1, 2001 at 12 noon. Sky conditions were cloudy bright. The sensor was placed between two plants and 10 inches south of the plant center line.

Plastic Treatment	R:FR Ratio	PPFD[Z]
Sky	1.241	2025
Clear	1.02 B[Y]	178 B
Infrared	1.07 B	328 A
Black	1.15 A	102 B
SRM-Olive	1.04 B	149 B
SRM-red	0.98 B	127 B

Z PPFD =photosynthetic photon flux density, a measure of the radiation necessary for the plant's photosynthesis processes.

Y mean values in a column followed by the same letter do not significantly differ.

Table 3. Total marketable yield from July 17 to August 7 (4 harvests) of Sunstart tomato as affected by plastic type planted either May 1 or May 16, 2001, central Iowa.

	Planting Date		
Plastic type	May 1	May 16	Fruit Size, May 1
	— marketable yield,	Cwt/acre ——-	Ounces each
SRM-olive + RC[1]	202	97	6.6
Black	159	98	6.6
SRM-olive	176	95	6.6
SRM-red	240	99	6.1
Clear	175	99	6.4
Infrared	148	120	7.2
Std. Error (P=.05)	———————— 33	——————-	ns

[1] Slitted, clear row cover removed on June 8

Table 4. Effect of plastic mulch type on yield and fruit size at first harvest, July 17, of Sunstart tomato planted May 1, 2001, central Iowa.

	———— July 17 yield, cwt/acre ———-			Fruit size,
Plastic type	Marketable	Cull	Total	ounces each
SRM-olive + RC	10.9 A[1]	1.5 AB	12.5 A	6.5 AB
Black	5.4 B	3.3 A	8.7 AB	6.1 AB
SRM-olive	4.5 B	1.9 AB	6.4 BC	6.3 AB
SRM-red	4.1 B	0.7 AB	4.8 BC	5.0 B
Clear	4.3 B	0.0 B	4.3 BC	5.7 B
Infrared	2.5 B	O.2 B	2.8 C	7.4 A

1 Mean values in a column followed by the same letter do not significantly differ, at the 5% level.

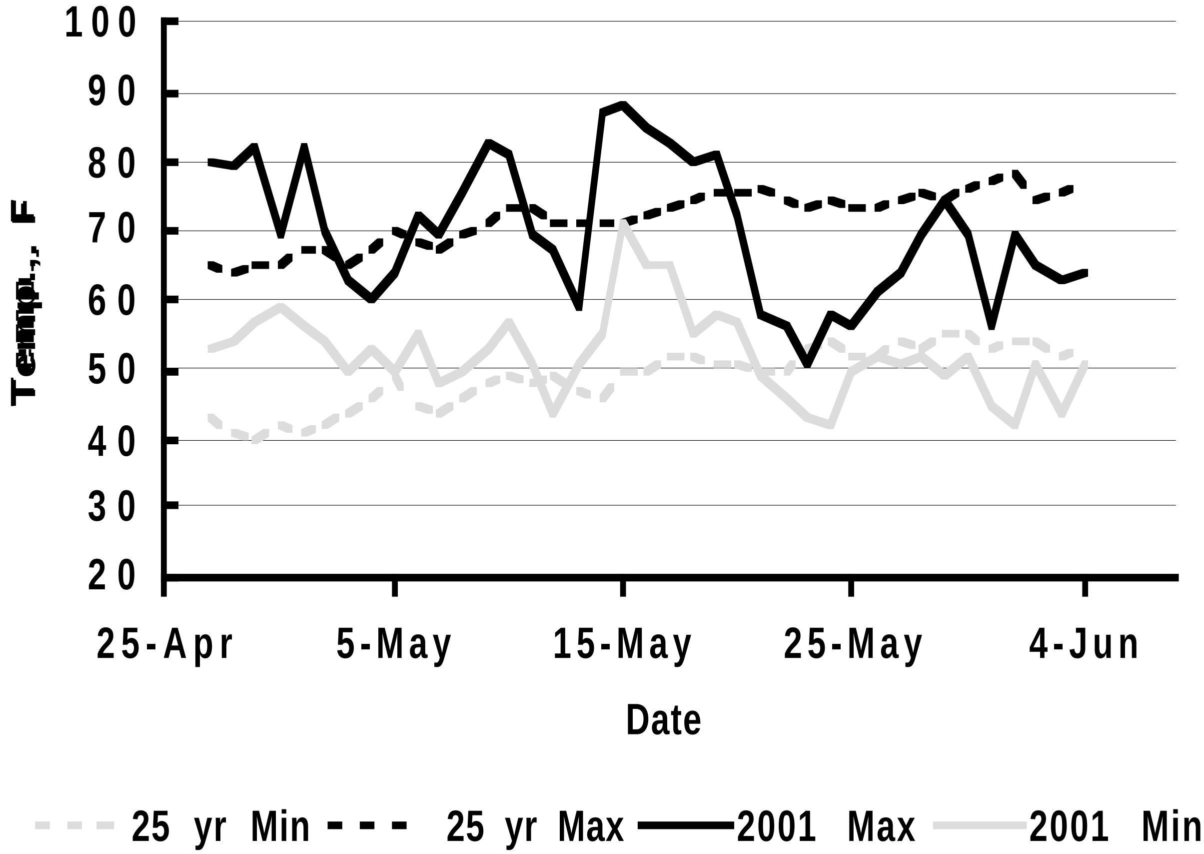

Fig. 1. May 2001 maximum and minimum air temperatures compared with the 25 year average for the Horticulture Station, central Iowa.

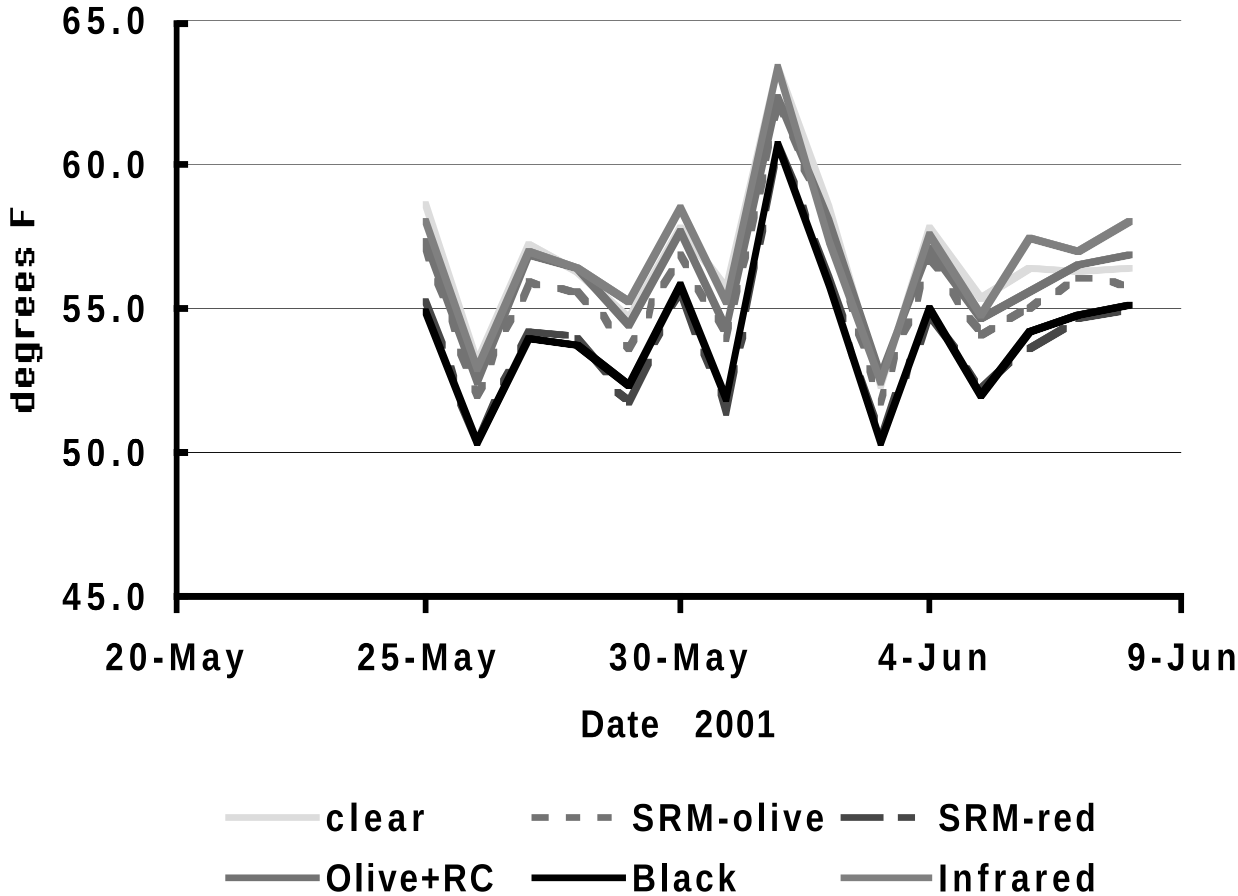

Fig. 2. Daily minimum soil temperature as affected by plastic mulch treatment during a cool period, May 23 to June 8, 2001, for the May 1 plant date. Central Iowa.

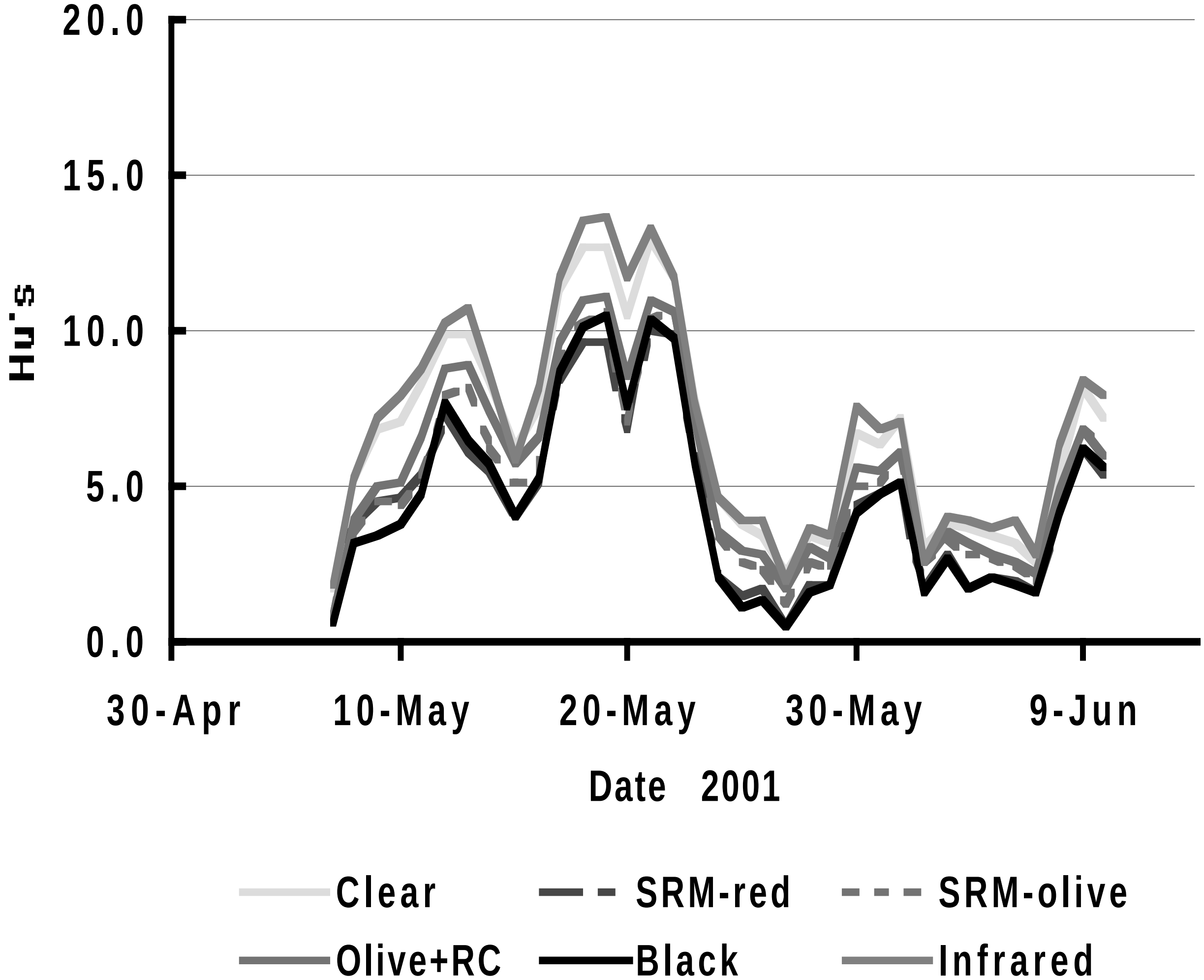

Fig. 3. Daily soil heat units (minimum threshold of 56 °F) to onset of flowering, June 8, for the May 1 plant date, 2001, central Iowa.

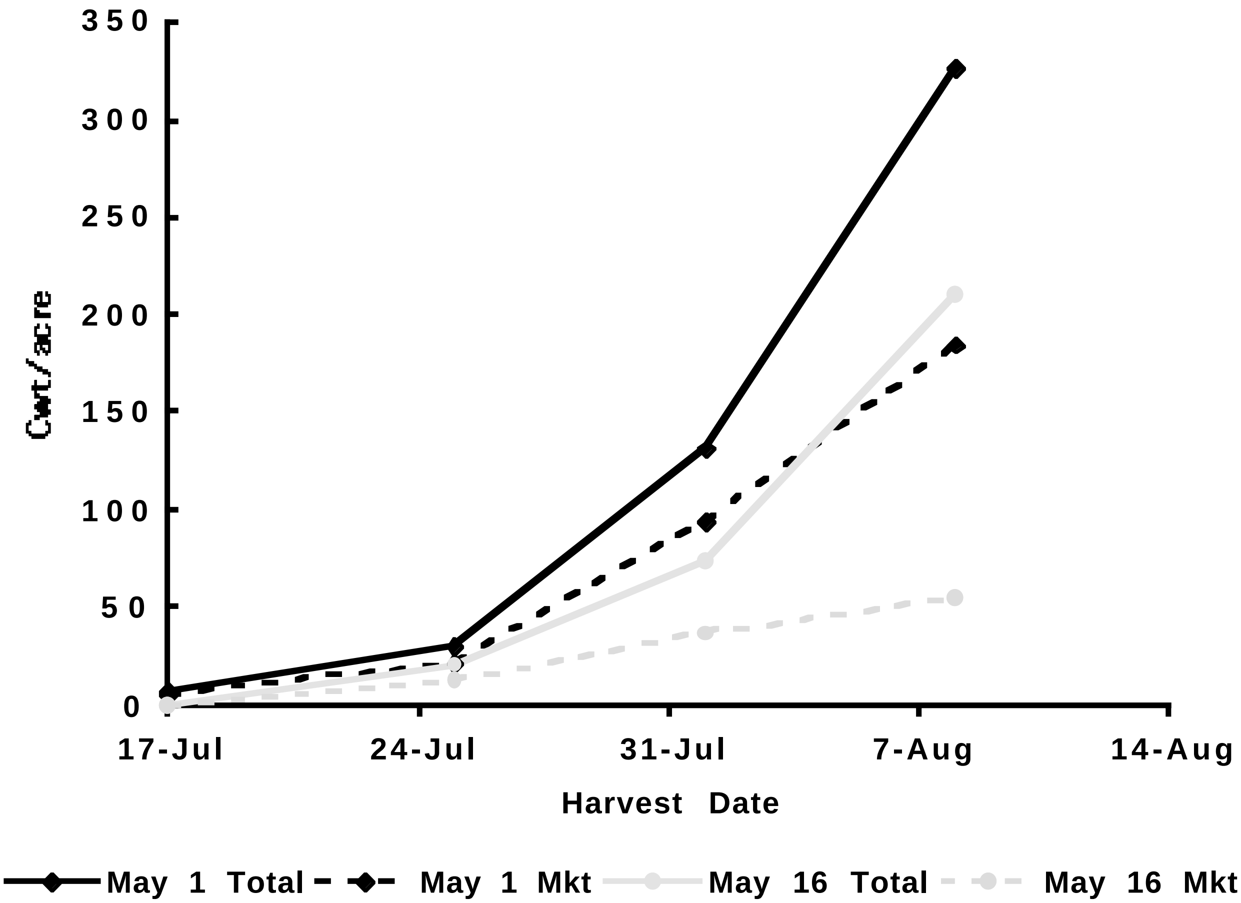

Fig. 4. Total and marketable cumulative yield for 4 harvests for two planting dates, May 1 and May 16. Data averaged across the plastic treatments. There was no ripe fruit on July 17 from the May 16 planting date.