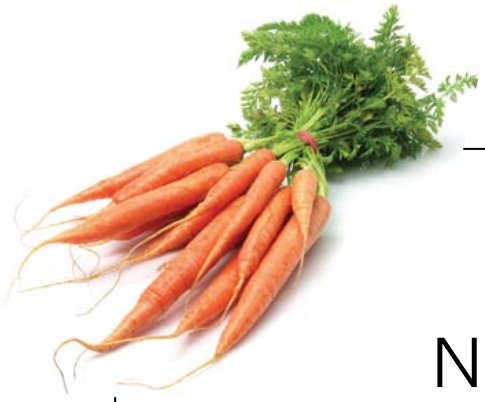

Vegetable Yield Evaluations and Nutritional Contents

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RJ-216
May 2012

University of Wyoming
Extension

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Funds for this project were provided through the Wyoming Department of Agriculture and the USDA's Specialty Crop Block Grant Program

Editor: Robert Waggener, Waggener Editorial Services, Laramie, Wyoming

Graphic Designer: Bernadette van der Vliet, College of Agriculture and Natural Resources, Office of Communications and Technology

UNIVERSITY OF WYOMING EXTENSION

Issued in furtherance of extension work, acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Glen Whipple, director, University of Wyoming Extension, University of Wyoming, Laramie, Wyoming 82071.

This bulletin describes one part in a series of three projects conducted in 2009 and 2010 at the University of Wyoming's Sheridan Research and Extension Center. Peppers, tomatoes, and eggplants were grown both years in the field, in a high tunnel, or under row covers. Yields of each plant type were recorded, and total phenols, total flavonoids, and antioxidants were determined at the University of Nebraska-Lincoln's Small Molecule Analysis Lab. Results of yields and nutritional status depended on plant type and whether the plants were grown in the field, in a high tunnel, or under row covers. Tables of yield data and graphs of nutritional contents are included.

Funded by a Wyoming Department of Agriculture Specialty Crop Block Grant Program grant, the overall goal of this project was to develop and promote sustainable specialty horticultural practices for Wyoming. The specific objective was to evaluate several vegetable crops for yield and nutritional content using different fertilization levels. Basic yields as well as nutritional information gained from laboratory analyses of total phenols, total flavonoids, and antioxidant activity will be valuable to vegetable producers and consumers alike.

Nutritional parameters of total flavonoids, total phenols, and antioxidants were assessed as these are important in overall human health. Flavonoids, naturally occurring compounds found in many plants, number more than 4,000. They can be found in many fruits, vegetables, and beverages including cranberry, apple, peanut, chocolate, onion, tea, and red wine. Flavonoids have antioxidant activity, meaning they help neutralize free radicals (Cleveland Clinic, 2011), which can cause cancer and contribute to the aging process. Flavonoids act against cardiovascular diseases, ulcers, viruses, arthritis, and other ailments (Patel, 2008). Phenols are strong antioxidants as well, preventing free radical damage and decreasing chances of cancer and cardiovascular disease (Hollman, 2001). Antioxidants in general, as measured by oxygen radical absorbance capacity, are known to help eliminate free radicals from the body. Antioxidants can be found in a large variety of fruits, nuts, and vegetables (Nutrient Data Laboratory, 2007).

Trials of several varieties of tomatoes, peppers, beets, and carrots were grown to compare general performance, yield, and nutritional content under different fertilization schemes. Vegetables were planted at the University of Wyoming's Sheridan Research and Extension Center (ShREC), seven miles east of Sheridan, Wyoming, in May 2009 and May 2010. Transplants of tomatoes and peppers were used, and carrots and beets were direct-seeded into the plots.

Activities Performed and Outcomes

In 2009, nine plants of each cultivar of tomatoes and peppers and seeded rows of carrots and beets were treated with zero, 1/2 rate, or full rate of traditional fertilizer available to homeowners (Scotts Miracle-Gro® 24-8-16), corresponding to zero, 1/2 tablespoon per gallon, or 1 tablespoon per gallon of water, applied June 5 and July 17. Plants were irrigated as needed. Tomato and pepper transplants were placed at 3-foot intervals. Carrots and beets were initially seeded thickly. After emergence, carrots were thinned to 2 inches between plants, and beets were thinned to 4 inches. All carrot and beet varieties were in 3-foot rows, corresponding to 18 carrots per variety row and nine beets per variety row.

In 2010, nine plants of each cultivar of tomatoes, peppers, beets, and carrots were treated with zero, 1/2 rate, or full rate of Miracle-Gro 24-8-16 or organic kelp-plus fertilizer, a liquid fertilizer derived from seaweed. Miracle-Gro was supplied as per 2009. The organic kelp fertilizer was applied at 1 tablespoon per gallon for 1/2-rate treatments and 2 tablespoons per gallon for full-rate treatments. Fertilizers were applied on June 22 and July 20. Beets and carrots were fertilized additionally on July 12, and tomatoes and peppers were given an additional fertilization August 20. Plants were irrigated as needed.

Data collected for both years included yields and nutritional content of each cultivar; however, due to low production numbers, meaningful statistical analyses could not be performed. Analysis of produce for total phenols, total flavonoids, and oxygen radical absorbance capacity (ORAC, a measure of antioxidants) was completed in December 2009 and October 2010 at the University of Nebraska-Lincoln's Small Molecule Analysis Lab.

2009

Varieties of crops grown were:

- Tomatoes: 'Paragon', 'Bush Ace', 'Early Red Chief'
- Peppers: 'Lipstick', 'Orion', 'California Wonder', 'Sweet Chocolate', 'California Wonder Orange'
- Beets: 'Kestral', 'Cylindra', 'Lutz'
- Carrots: 'Danvers Half Long', 'Little Finger', 'Atomic Red'

Tomatoes and peppers were started from seed in the greenhouse at Sheridan College. They were transplanted to the field on May 20. Carrots and beets were sown in the field the same day.

2009 Variety Trial Yields

Tomato yields:

Tomatoes 2009 (9 plants per location)						
	Total yield (g)			% non-yielding plants		
Cultivar	control	1/2 rate	full rate	control	1/2 rate	full rate
Paragon	1,087	1,383	1,172	22%	22%	44%
Bush Ace	546	140	276	67%	89%	89%
Early Red Chief	473	740	469	67%	67%	67%

'Paragon' showed the highest total yields and lowest zero-production plants. 'Bush Ace' had the highest number of plants yielding no fruit, while the most overall yield was in the unfertilized controls. 'Early Red Chief' showed highest yields under the 1/2 rate of fertilization, while 2/3 of the plants yielded no fruit.

Pepper yields:

Peppers 2009 (9 plants per location)						
	Total yield (g)			% non-yielding plants		
Cultivar	control	1/2 rate	full rate	control	1/2 rate	full rate
Lipstick	558	189	371	11%	56%	22%
Orion	688	431	192	33%	33%	56%
California Wonder	253	310	178	56%	56%	67%
Sweet Chocolate	692	327	281	11%	22%	33%
California Wonder Orange	737	578	543	11%	11%	44%

The unfertilized controls of 'Lipstick', 'Orion', 'Sweet Chocolate', and 'California Wonder Orange' produced the highest yields. The 1/2-rate 'California Wonder Orange' was the highest-yielding cultivar in that treatment. 'California Wonder' was the variety with the highest level of non-yielding plants.

Beet yields:

Beets 2009 (9 plants per location)			
	Total fresh weights (g)		
Cultivar	control	1/2 rate	full rate
Kestral	130	87	145
Cylindra	205	161	315
Lutz	220	143	180

Each beet variety showed different responses to fertilization levels. 'Kestral' and 'Cylindra' showed highest fresh weights with full rate of fertilization, while unfertilized 'Lutz' had the most total fresh weight.

Carrot yields:

Carrots 2009 (9 plants per location)			
	Total fresh weights (g)		
Cultivar	control	1/2 rate	full rate
Danvers Half Long	60	45	48
Little Finger	125	42	136
Atomic Red	60	10	85

'Little Finger' and 'Atomic Red' showed highest fresh weights when fertilized at the full rate, while 'Danvers Half Long' showed highest fresh weights in the unfertilized controls.

2010

In 2010, seeds of the same varieties used in 2009 were again sown in the greenhouse at Sheridan College. However, due to a severe infestation of aphids, the plants were not usable. Replacements of the same varieties were not available at a local garden center, so the varieties purchased and used were:

- Tomatoes: 'Husky Red', 'Super Fantastic', 'Yellow Perfection'
- Peppers: 'Better Belle', 'Mandarin', 'Golden Wonder', 'Red Beauty'.

Seeds of the same varieties of beets and carrots used in 2009 were also available in 2010:

- Beets: 'Kestral', 'Cylindra', 'Lutz'
- Carrots: 'Danvers Half Long', 'Little Finger', 'Atomic Red'

Tomatoes and peppers were planted in the field June 1 and 2. Carrots and beets were sown in the field April 20.

2010 Variety Trial Yields

Tomato yields:

Tomatoes 2010 (9 plants per location)					
		Total yield Miracle-Gro (g)		Total yield kelp-plus (g)	
Cultivar	control	1/2 rate	full rate	1/2 rate	full rate
Husky Red	239	278	261	65	280
Super Fantastic	309	370	412	284	616
Yellow Perfection	353	393	376	310	440

Highest yields occurred in both 'Super Fantastic' and 'Yellow Perfection' with the full-rate kelp-plus fertilizer treatment. Yields were lowest in the variety 'Husky Red' with 1/2-rate kelp-plus.

Pepper yields:

Peppers 2010 (9 plants per location)					
		Total yield Miracle-Gro (g)		Total yield kelp-plus (g)	
Cultivar	control	1/2 rate	full rate	1/2 rate	full rate
Better Belle	1,179	4,067	1,011	3,364	1,209
Mandarin	2,047	1,020	1,862	1,360	1,627
Golden Wonder	1,083	1,054	689	793	446
Red Beauty	1,886	926	265	1,660	924

The best performer, 'Better Belle', produced most fruit in both 1/2-rate treatments. Pepper yields were highest in the unfertilized controls of 'Mandarin', 'Golden Wonder', and 'Red Beauty'.

Beet yields:

Beets 2010 (9 plants per location)					
		Total yield Miracle-Gro (g)		Total yield kelp-plus (g)	
Cultivar	control	1/2 rate	full rate	1/2 rate	full rate
Kestral	4,901	1,370	1,297	3,058	8,407
Cylindra	3,860	4,610	5,981	4,194	2,072
Lutz	7,611	1,985	2,033	3,057	1,818

Control, unfertilized plants of 'Lutz' showed the highest yield in that variety; full-rate, organically fertilized plants had the lowest yields. 'Cylindra' and 'Kestral' showed mixed results. 'Cylindra' fertilized with both rates of Miracle-Gro and 1/2-rate kelp-plus yielded higher numbers than the control, but the full-rate kelp-plus was lowest in that variety. With 'Kestral', the only treatment with higher yields than the controls was full-rate kelp-plus; the other three treatments had lower yields than the controls.

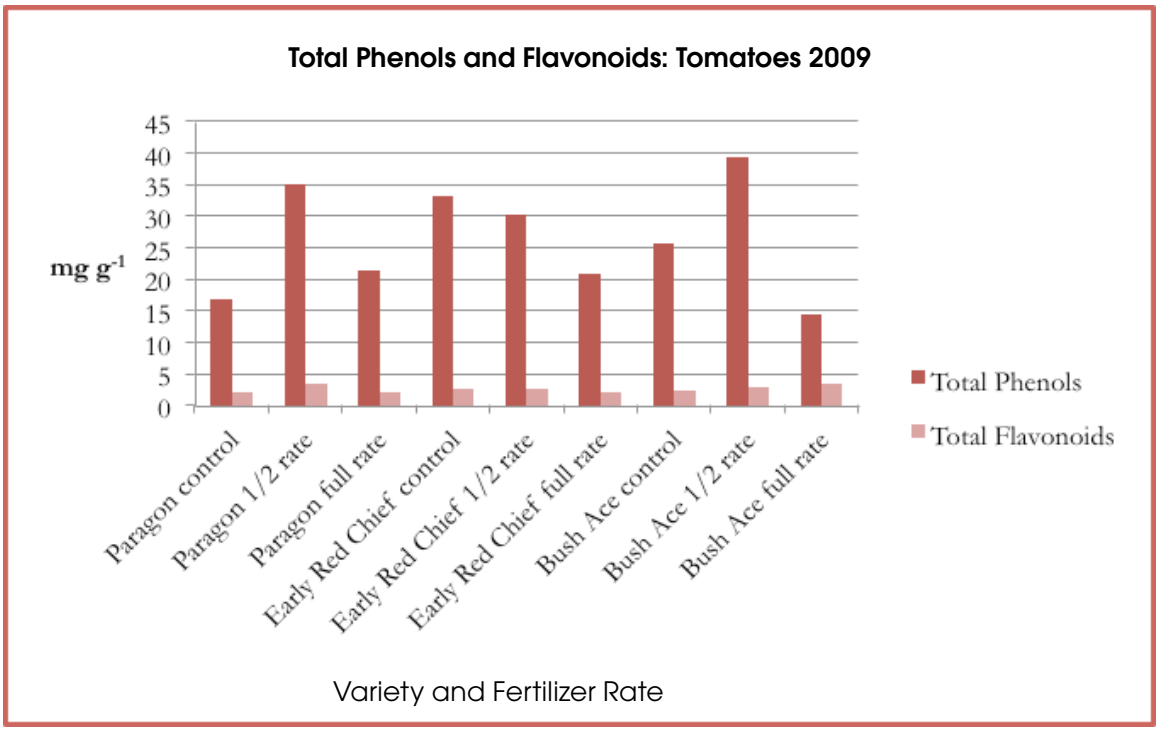
Carrot yields:

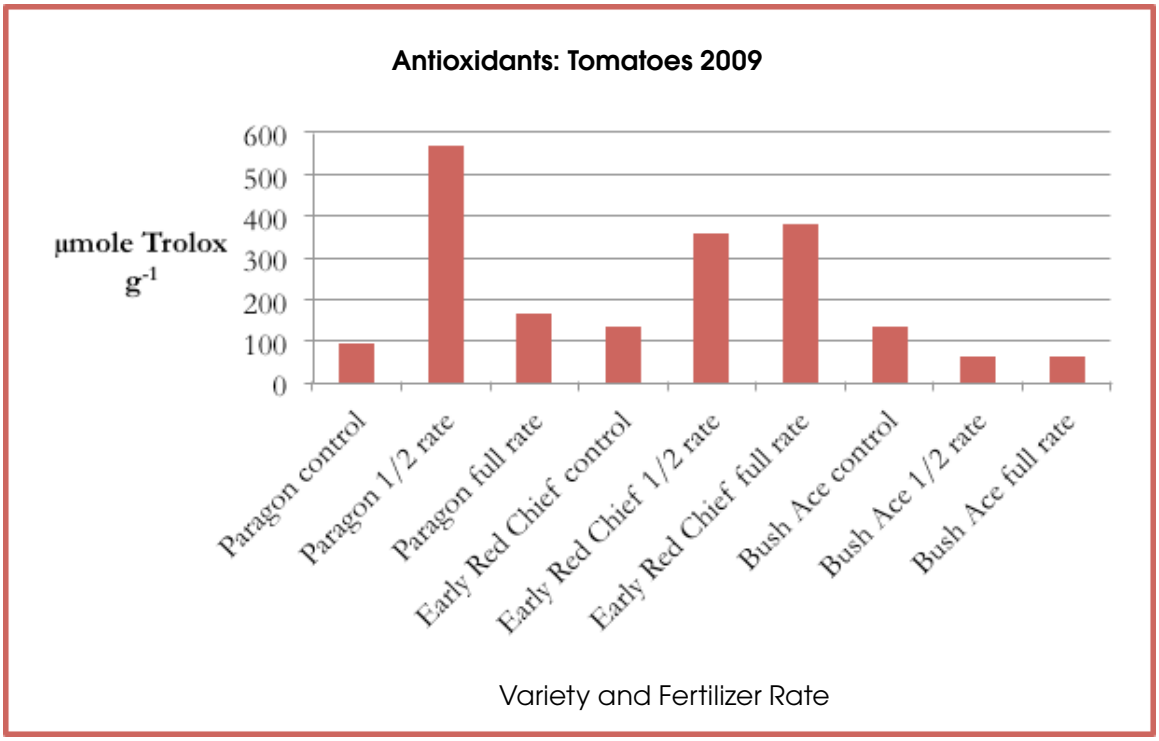
Carrots 2010 (9 plants per location)					
		Total yield Miracle-Gro (g)		Total yield kelp-plus (g)	
Cultivar	control	1/2 rate	full rate	1/2 rate	full rate
Danvers Half Long	2,073	1,205	604	975	214
Little Finger	1,013	987	391	232	56
Atomic Red	183	34	550	43	207

'Danvers Half Long' in the unfertilized control treatments had higher yields than any of the fertilizer treatments, while the 'Little Finger' control nearly equaled the yield of 'Danvers Half Long' fertilized with 1/2-rate Miracle-Gro. 'Atomic Red' showed higher yields than controls only in both full-rate fertilization treatments.

2009 Variety Trial Nutritional Analyses

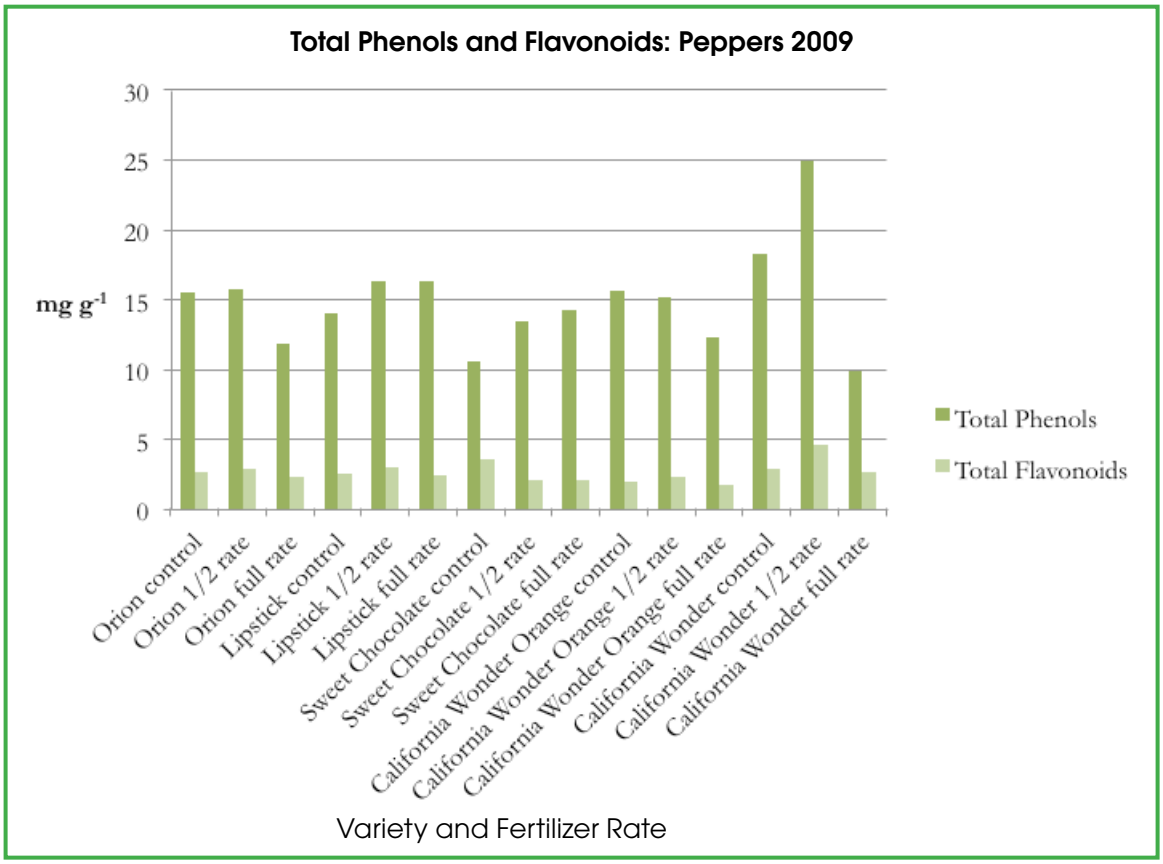
Tomato nutritional analyses:

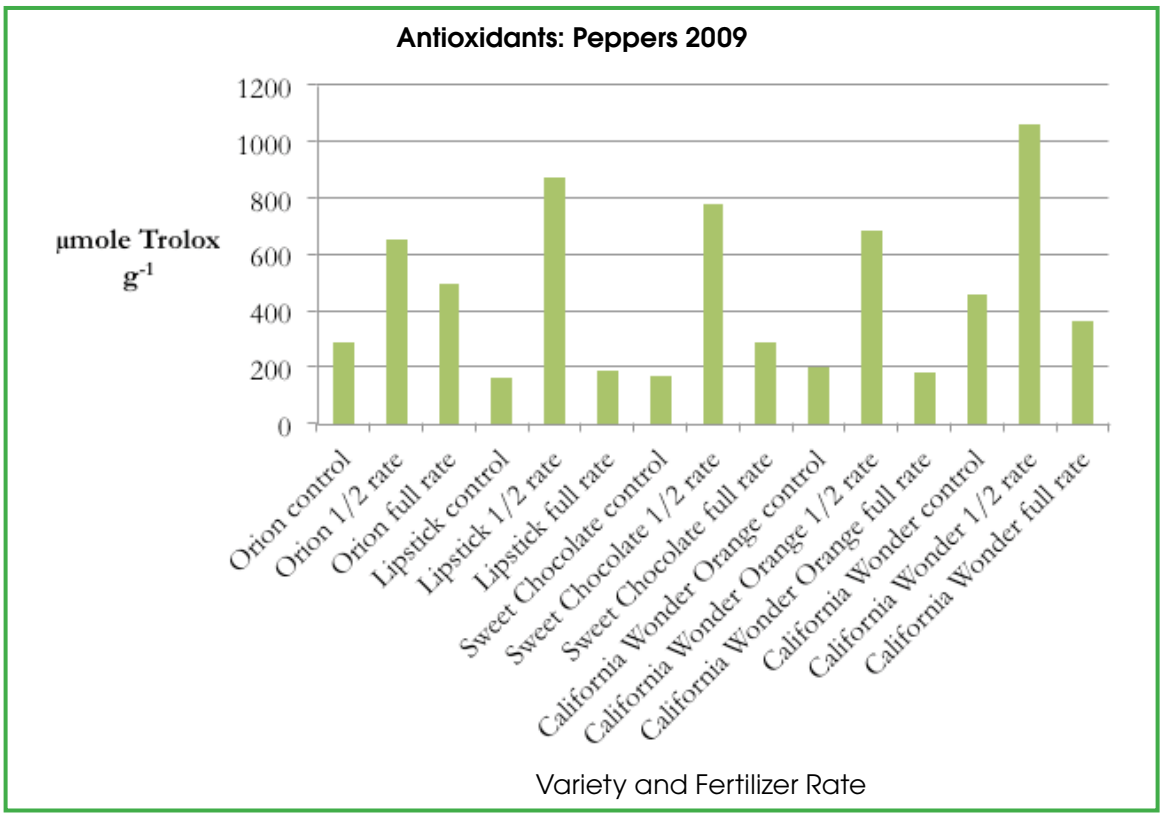




Total phenols were highest in 1/2-rate plants of 'Bush Ace' and 'Paragon', respectively, and unfertilized 'Early Red Chief'. Differences among varieties in total flavonoids were small but were slightly higher in 1/2-rate fertilized 'Paragon' and 'Early Red Chief' and full-rate 'Bush Ace'. Antioxidants varied widely. In 'Bush Ace', the control was highest. In 'Paragon,' 1/2 rate was highest. The full fertilizer rate produced the highest level of antioxidants in 'Early Red Chief.'

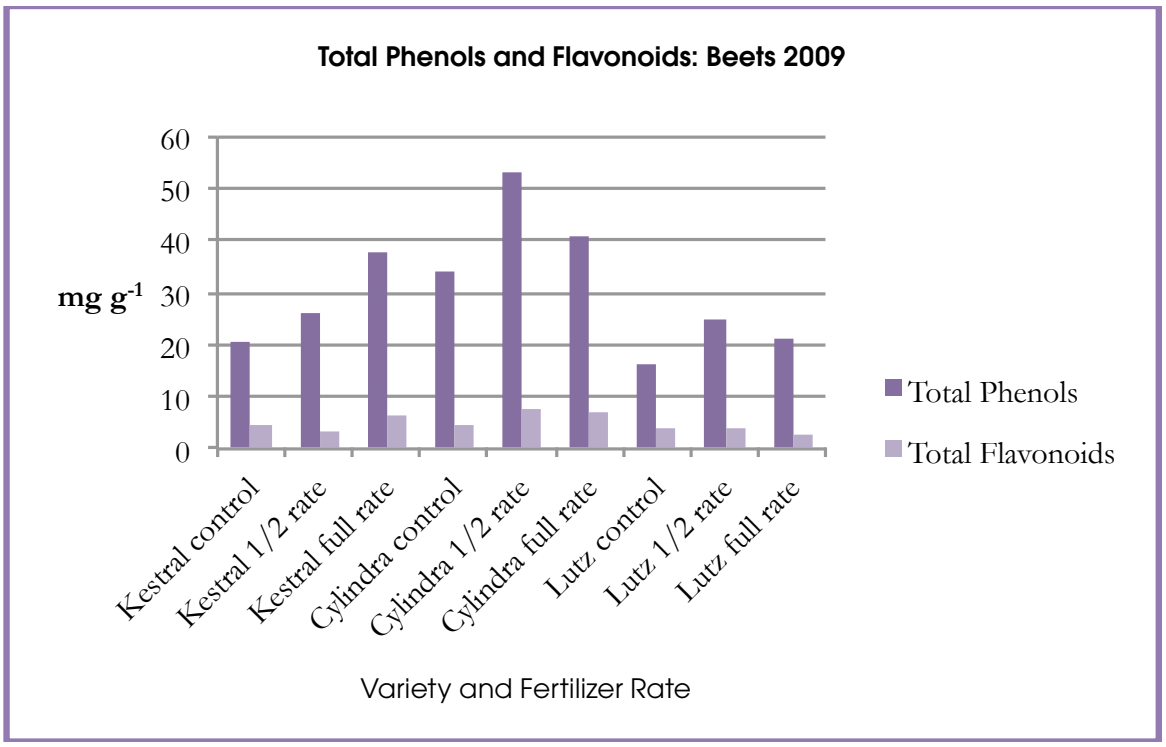
Pepper nutritional analyses:

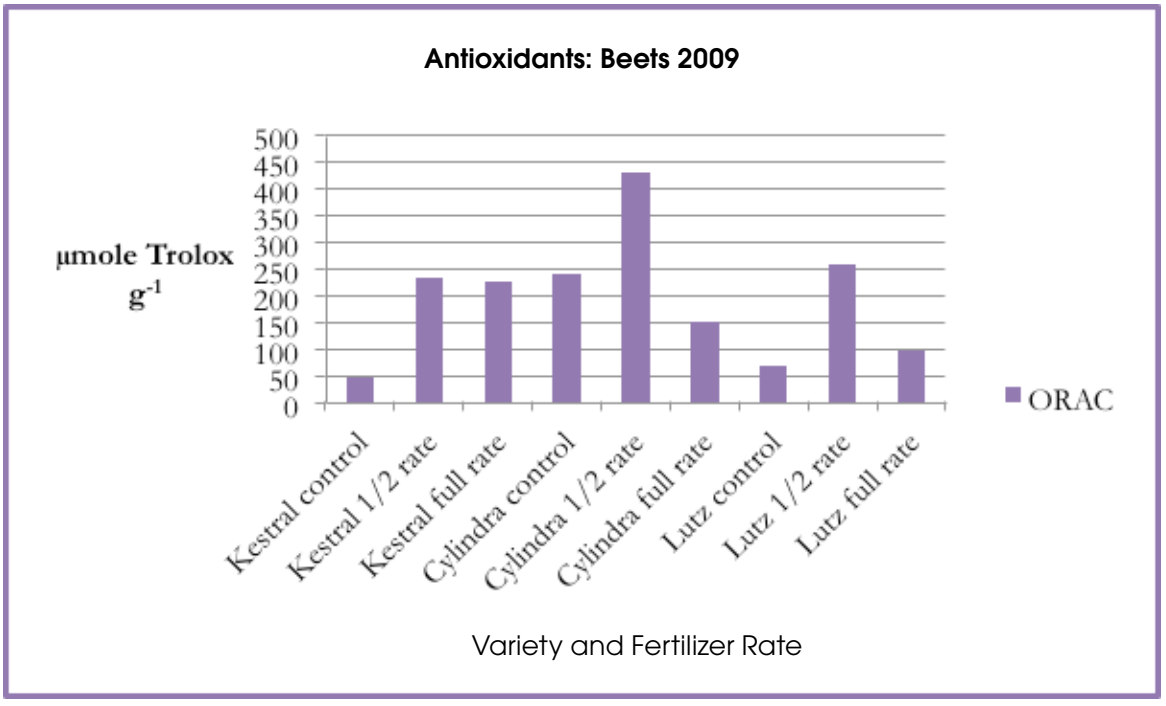




Total phenols were highest in 'California Wonder' fertilized at 1/2 rate and the unfertilized control. 'California Wonder Orange' showed highest phenols with no fertilizer. Total flavonoids were highest in 1/2-rate fertilized 'Orion', 'Lipstick', 'California Wonder Orange', and 'California Wonder' and unfertilized 'Sweet Chocolate'. Antioxidants were highest in the 1/2-rate fertilized treatment of all five varieties.

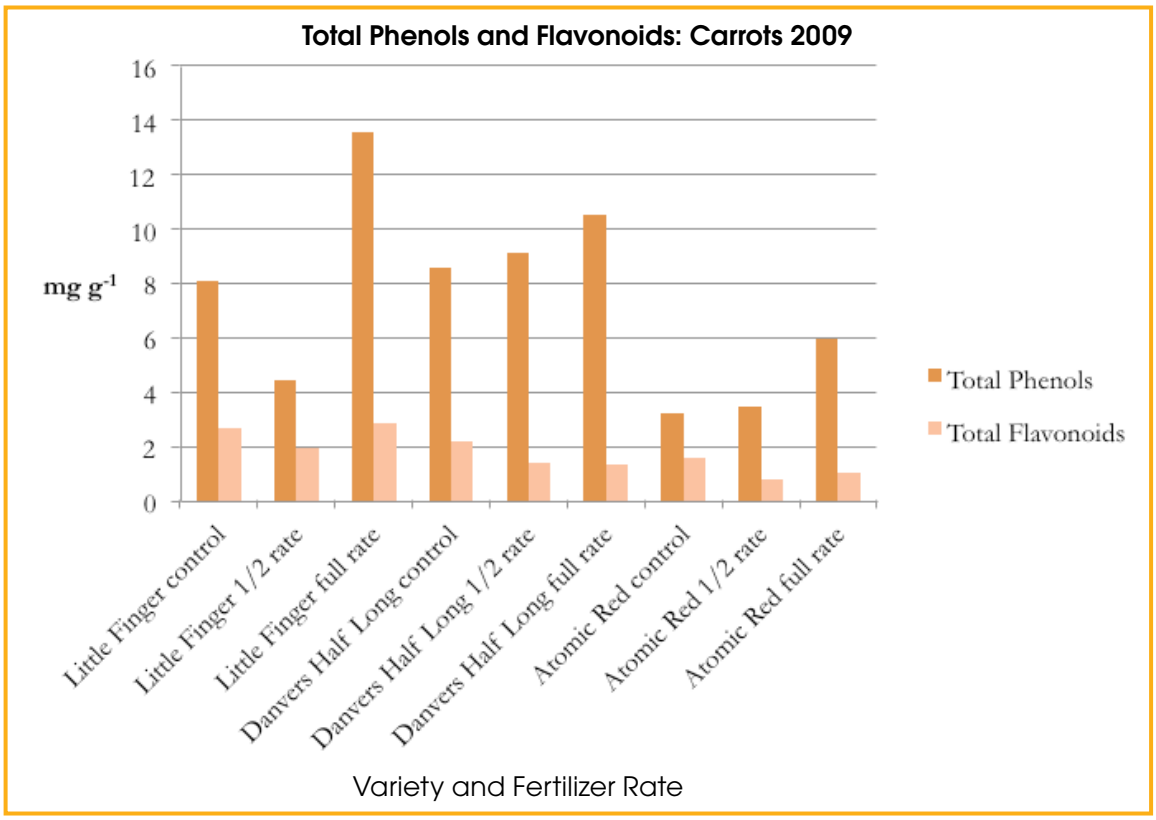
Beet nutritional analyses:

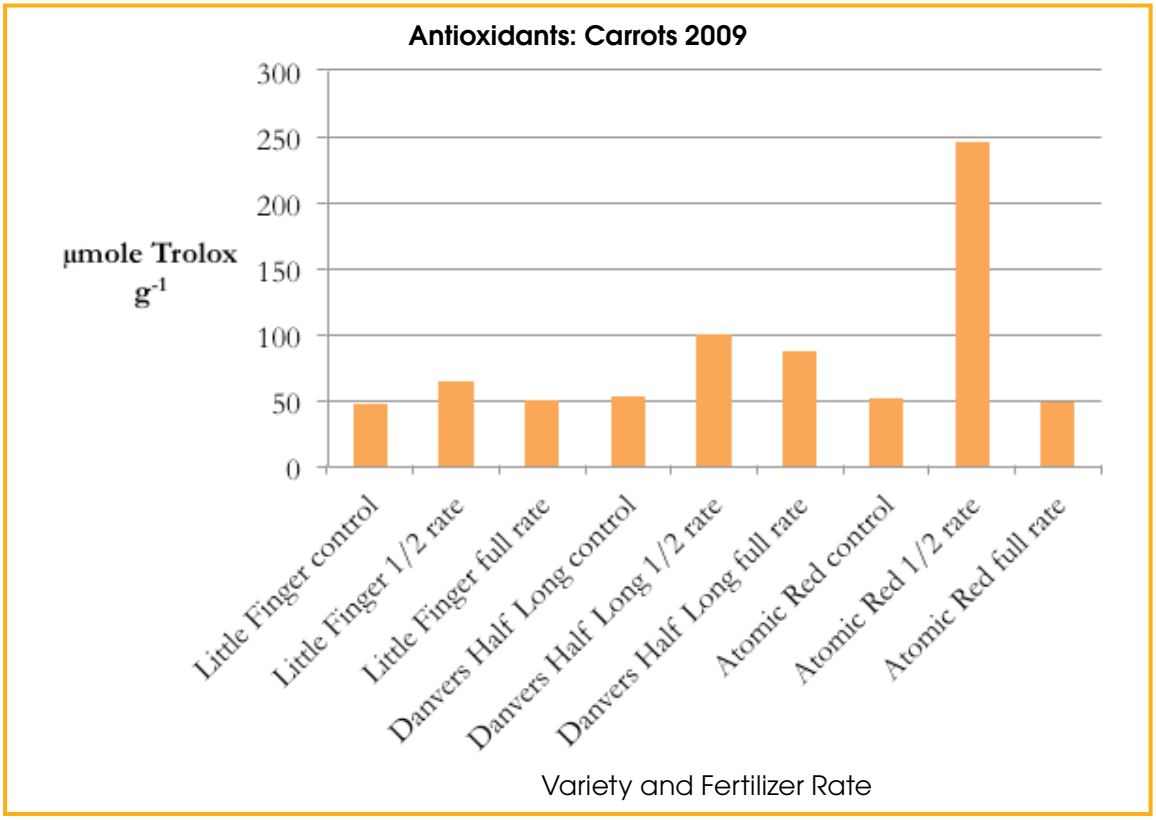




Total phenols and total flavonoids were highest in 'Kestral' at the full fertilizer rate and the 1/2 rate of both 'Cylindra' and 'Lutz'. Antioxidants were highest in all three varieties at the 1/2 rate of fertilization.

Carrot nutritional analyses:

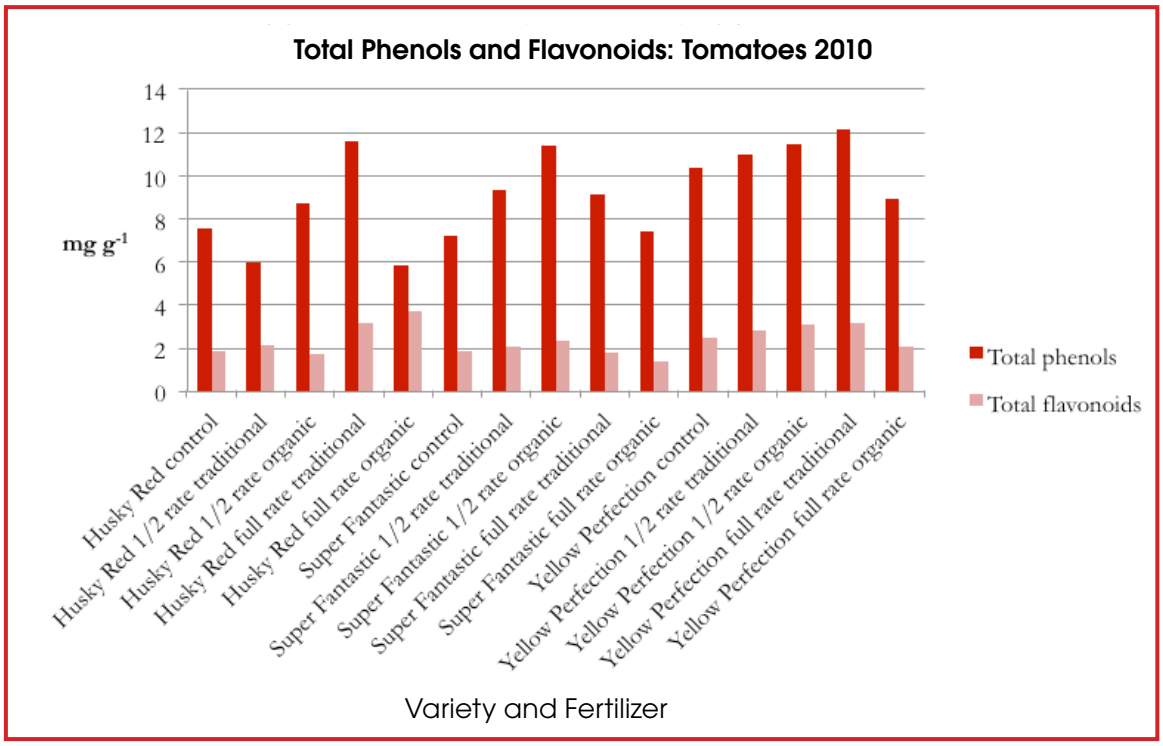


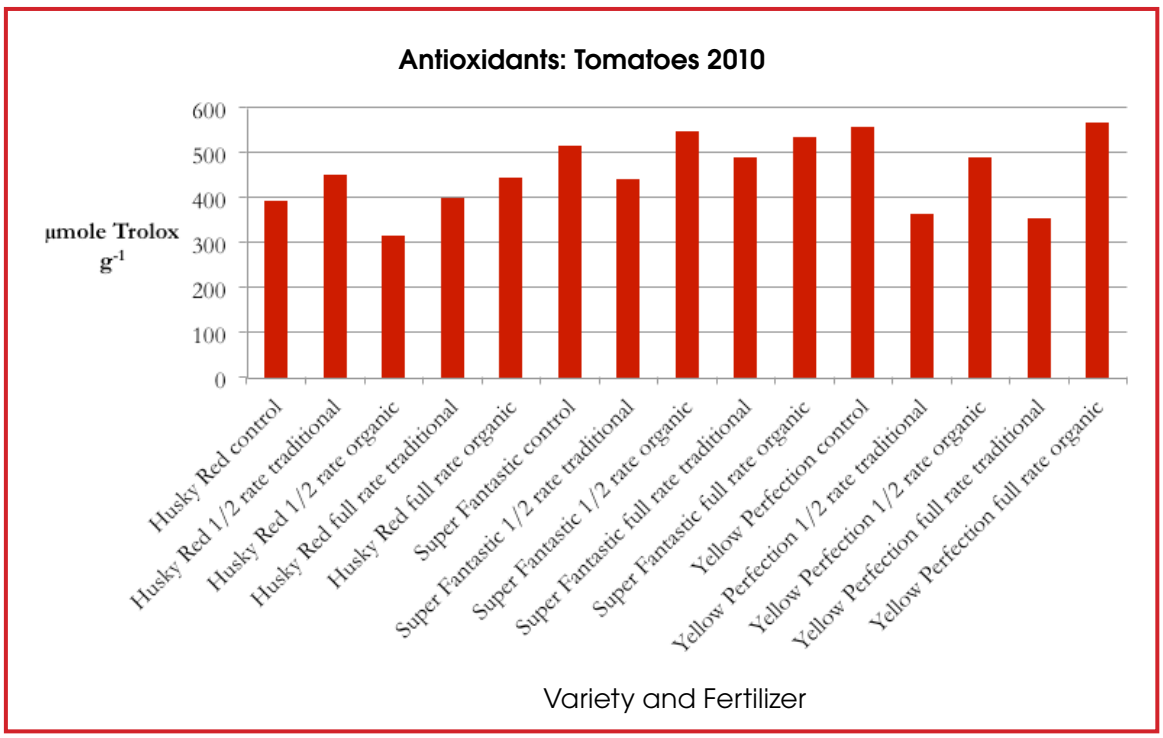


Total phenols were highest at the full rate of fertilization in all three varieties. Total flavonoids, however, were highest in unfertilized 'Danvers Half Long' and 'Atomic Red' and in 'Little Finger' fertilized at the full rate. Antioxidants were highest in the 1/2-rate fertilizer treatment for all varieties.

2010 Variety Trial Nutritional Analyses

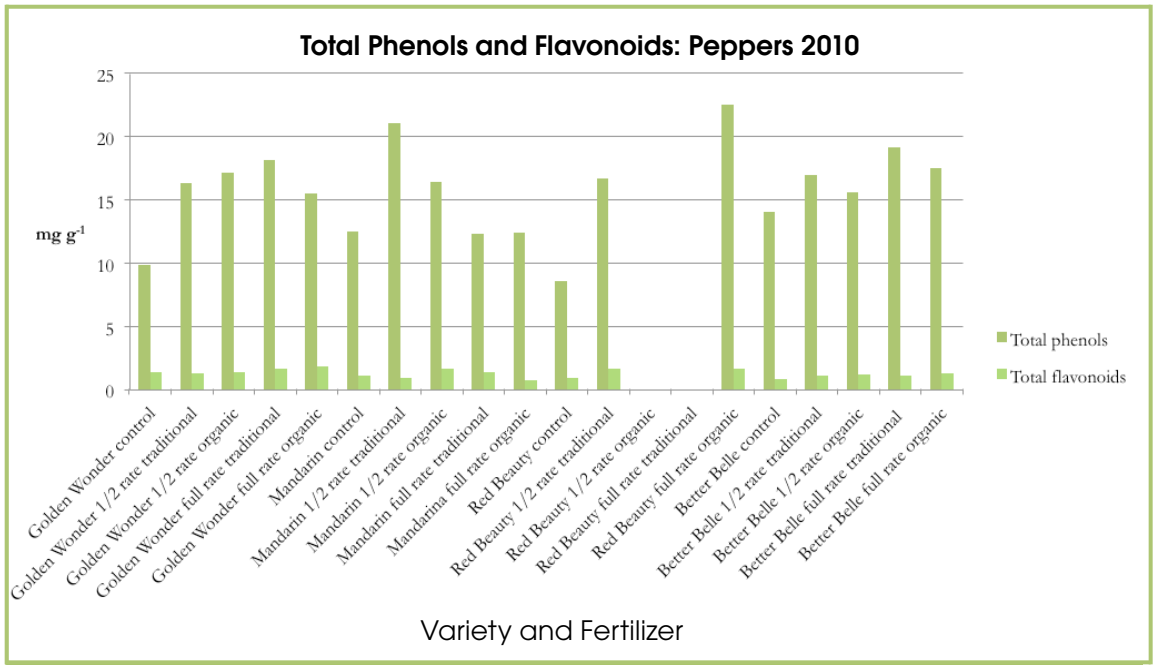
Tomato nutritional analyses:

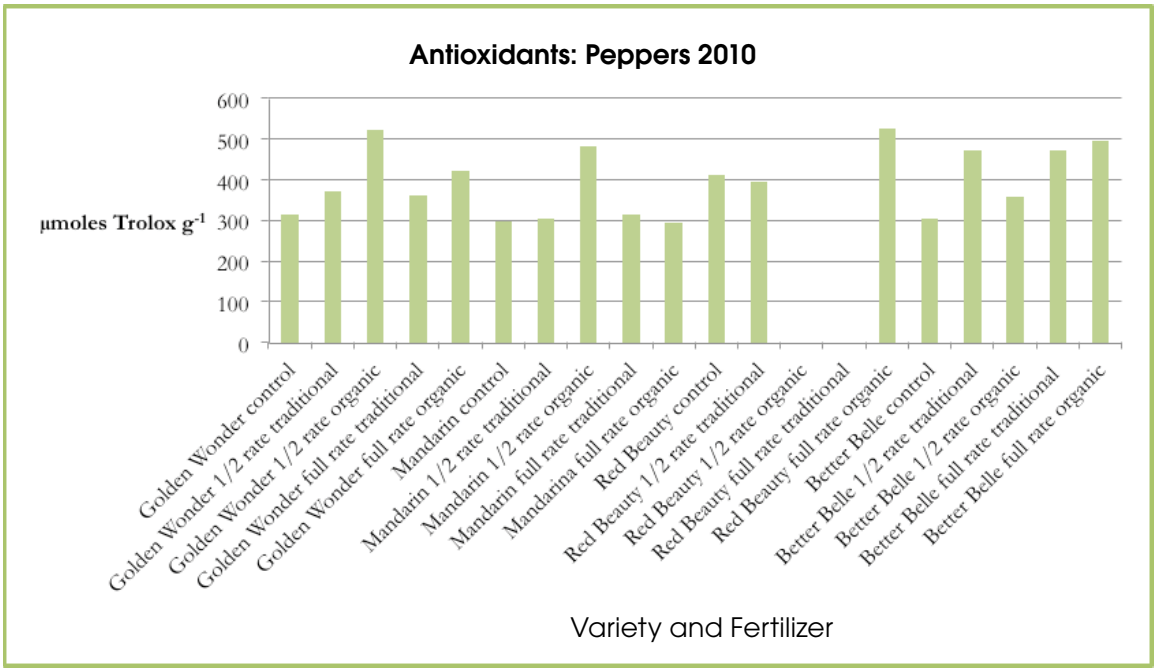




Total phenols were highest in the 'Yellow Perfection' cultivar for each of the fertilizer types/application rates. Total flavonoids were highest in 'Yellow Perfection' in all but the full-rate organic kelp-plus fertilizer treated plants; 'Husky Red' had the highest flavonoids level in this treatment. Highest flavonoids overall were in the 1/2-rate organic kelp-plus and full-rate traditional Miracle-Gro fertilizer treatments. Antioxidant levels varied with no particular trends as far as varieties or treatments.

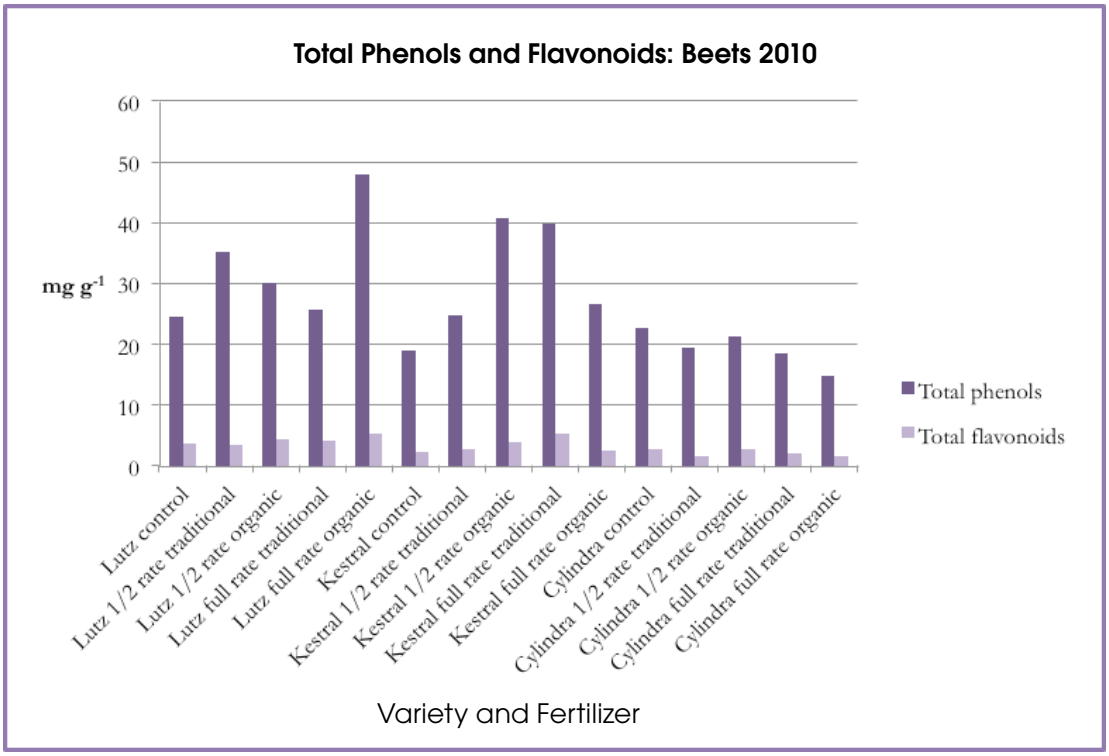
Pepper nutritional analyses:

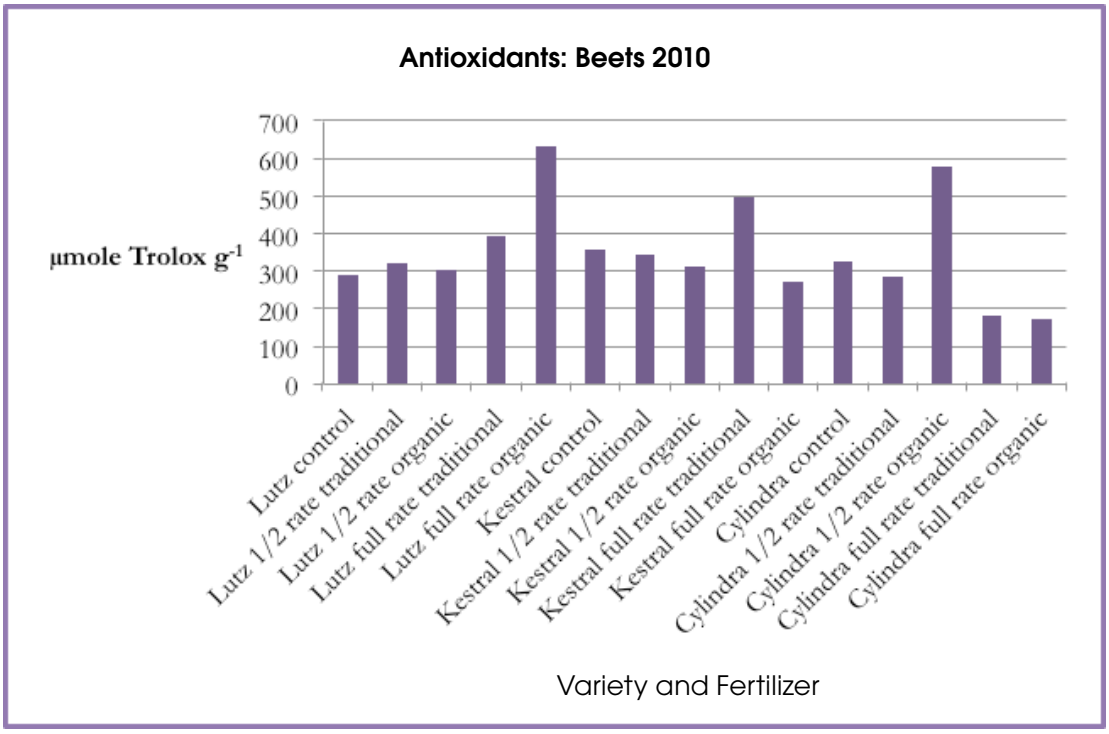




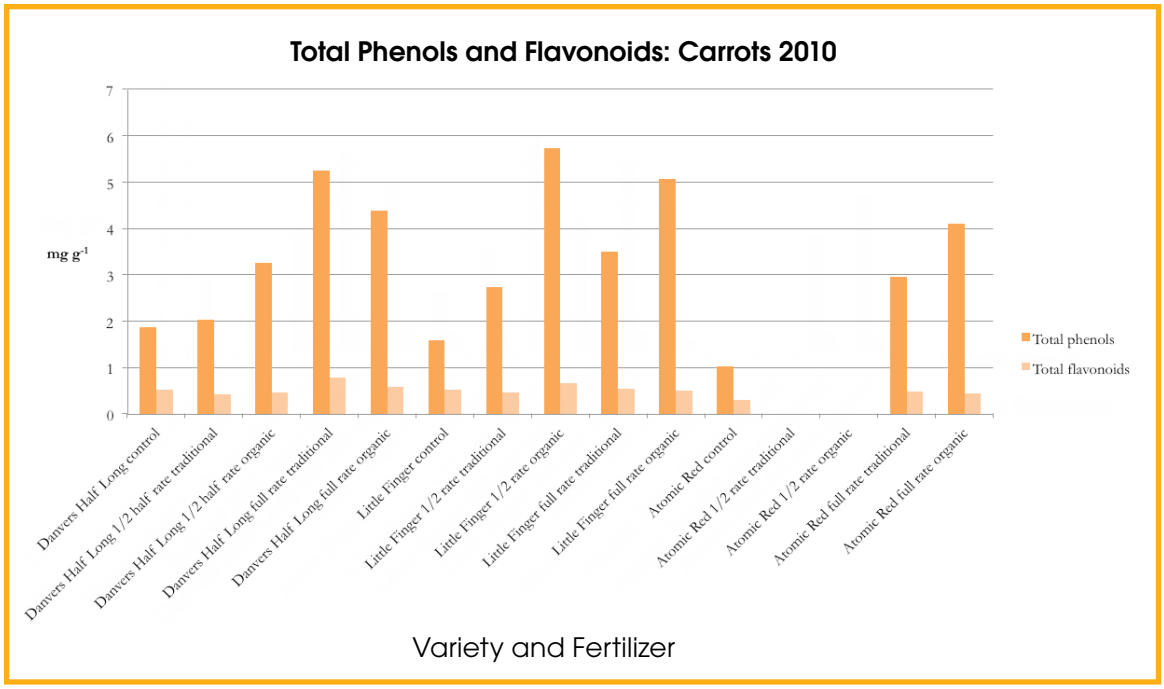
Cultivars varied in total phenols and flavonoids with no clear trends, although 'Better Belle' and 'Golden Wonder' were among the highest under all treatments for total phenols. Antioxidants showed no particular patterns across cultivars or treatments. In two treatments, 1/2-rate organic and full-rate traditional fertilizer, 'Red Beauty' analyses could not be done due to poor samples.

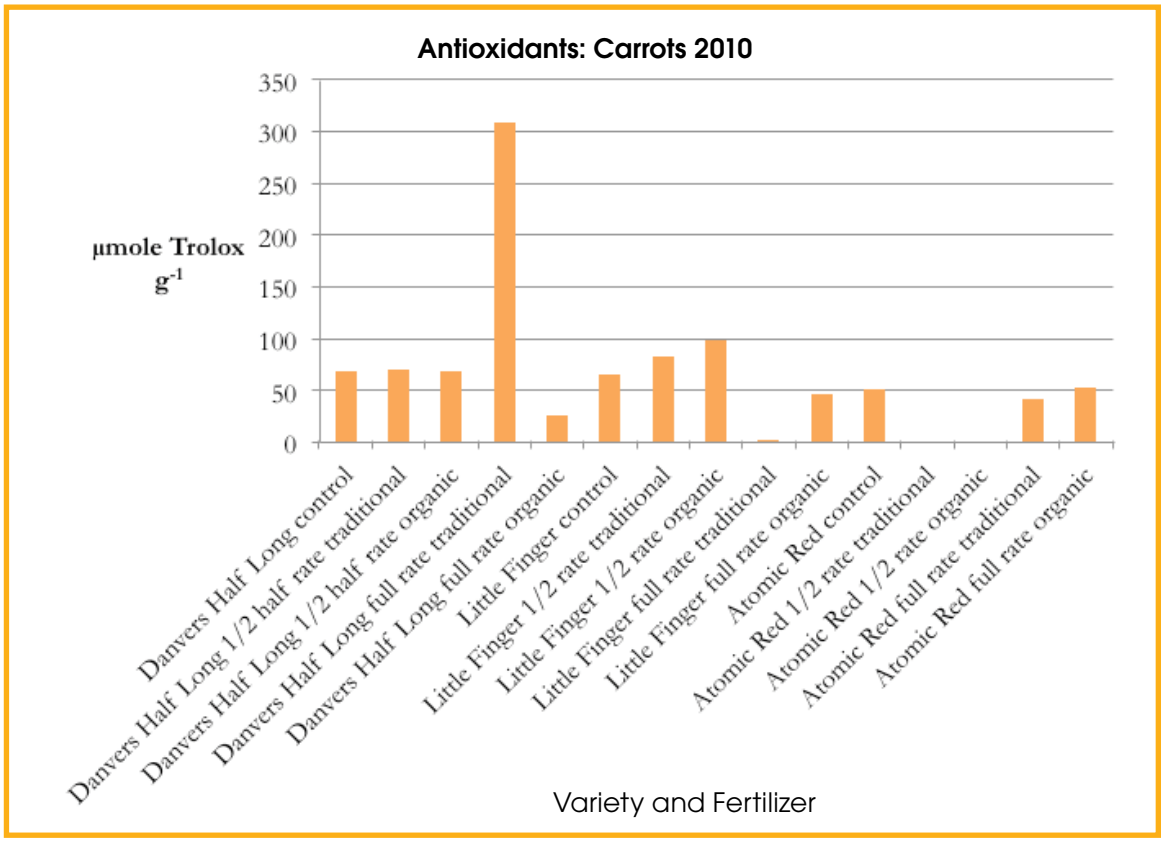
Beet nutritional analyses:





Among the beet cultivars, 'Lutz' showed highest phenols under control, 1/2-rate traditional, and full-rate organic fertilizers. 'Kestral' was highest under 1/2-rate organic and full-rate traditional treatments. 'Lutz' also showed highest flavonoids under all treatments except full-rate traditional fertilizer, where 'Kestral' had the highest total. In antioxidants, 'Kestral' showed the highest amounts under all treatments except 1/2-rate organic fertilizer, where 'Cylindra' was highest, and full-rate organic fertilizer, where 'Lutz' was highest.





Carrot nutritional analyses:

Total phenols were quite variable depending on variety. The highest levels overall were in 'Little Finger' 1/2-rate organic and 'Danvers Half Long' full-rate traditional fertilizer. Total flavonoids were highest overall in those varieties and treatments as well. As for antioxidant levels, 'Danvers Half Long' full-rate traditional fertilizer was far higher than any other variety or treatment. Nutritional analyses on 'Atomic Red' carrots produced under the 1/2-rate traditional and 1/2-rate organic fertilizer treatments could not be done due to poor samples.

Impacts and Recommendations

Reasons for many plants producing little to no fruit can be attributed to grasshoppers both years. Colorado potato beetles were also present in high numbers. Damage to the vegetable plants was severe enough to inhibit production.

Soil analysis results conducted in June 2010 are provided in the following table.

Source	Texture	Organic matter (%)	pH	EC (ds/m)	Phosphate phosphorus (mg/kg)	Nitrate nitrogen (mg/kg)	Potassium (mg/kg)	Iron (mg/kg)	Zinc (mg/kg)
Control	Clay	3.96	6.83	0.86	107	21	376	19.32	4.15
1/2 rate traditional	Clay	2.63	7.35	0.56	35	19	305	8.78	0.83
1/2 rate organic	Clay	2.45	7.23	0.66	20	5	296	9.72	0.43
Full rate traditional	Clay	4.23	6.71	0.62	108	22	41	26.52	6.30
Full rate organic	Clay	4.59	6.98	0.55	114	31	414	19.38	5.06

All pH and electrical conductivity (EC) levels are reasonable, but there are large disparities in the other parameters. The full-rate traditional plots were low in potassium, which may have contributed to somewhat lower yields. Although iron levels in both traditional and organic full-rate plots were higher than the 1/2-rate plots, this should not have led to nutrient toxicities, especially at the pH levels of about 7 in both cases. It appears that even at the moderate levels of

fertilization used in this study, differences in soil fertility led to differences in yield. In many cases, the full-rate fertilization levels were not superior in yield or nutritional content; 1/2 rate may be sufficient. For unknown reasons, the soil fertility levels in the controls were similar to the full-rate fertilization levels, possibly leading to yields being similar or even superior to the 1/2-rate fertilization plots.

Since the fertilization studies were conducted in two different ways in 2009 and 2010, comparisons cannot be made between years. However, the basic yields as well as nutritional information gained from laboratory analyses of total phenols, total flavonoids, and antioxidant activity will be valuable to vegetable producers and consumers alike.

Concerning production, we recommend 'Paragon', 'Super Fantastic', and 'Yellow Perfection' of the tomato varieties tested; 'Sweet Chocolate' and 'Better Belle' peppers; 'Cylindra' and 'Kestral' beets; and 'Little Finger' and 'Danvers Half Long' carrots.

Nutritionally-speaking, 'Early Red Chief' tomato, 'California Wonder' pepper (although none stood out dramatically from the other varieties), 'Cylindra' beet, and 'Danvers Half Long' carrot (again, none stood out) showed moderate to high total phenols, total flavonoids, and antioxidant activity in 2009. In 2010, 'Yellow Perfection' tomato, 'Better Belle' pepper, 'Lutz' beet, and 'Little Finger' carrot showed highest levels of nutritional qualities tested.

When considering yield and nutritional content together, 'Cylindra' beet, 'Danvers Half Long' carrot, 'Yellow Perfection' tomato, and 'Better Belle' pepper ranked higher than the other varieties.

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