Organic Greenhouse Crop Production

Mary Peet

NC STATE UNIVERSITY

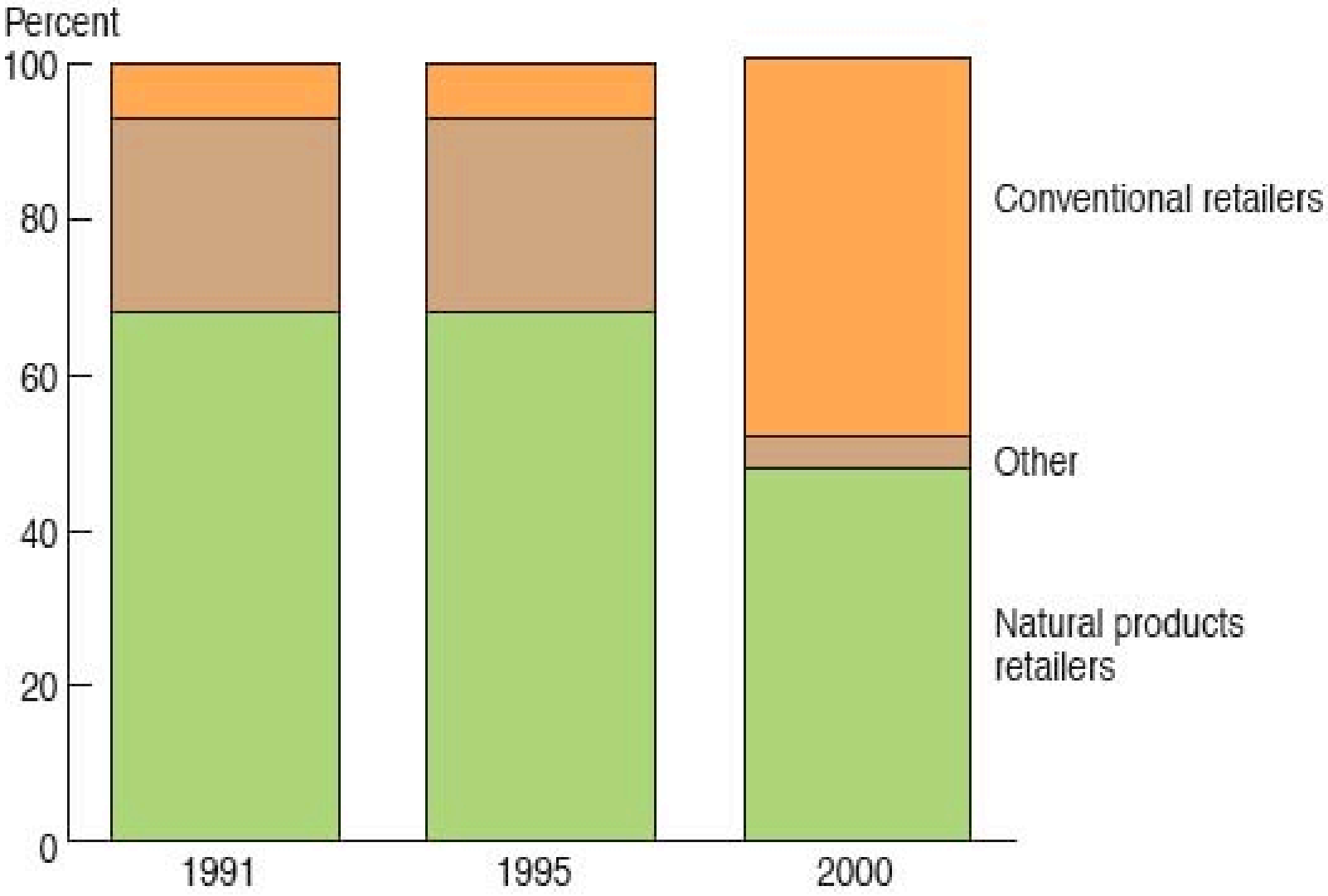
www.ces.ncsu.edu/greenhouse_veg

Don't panic- go Organic!

World Markets
Retail Sales of Organic Products, 2000

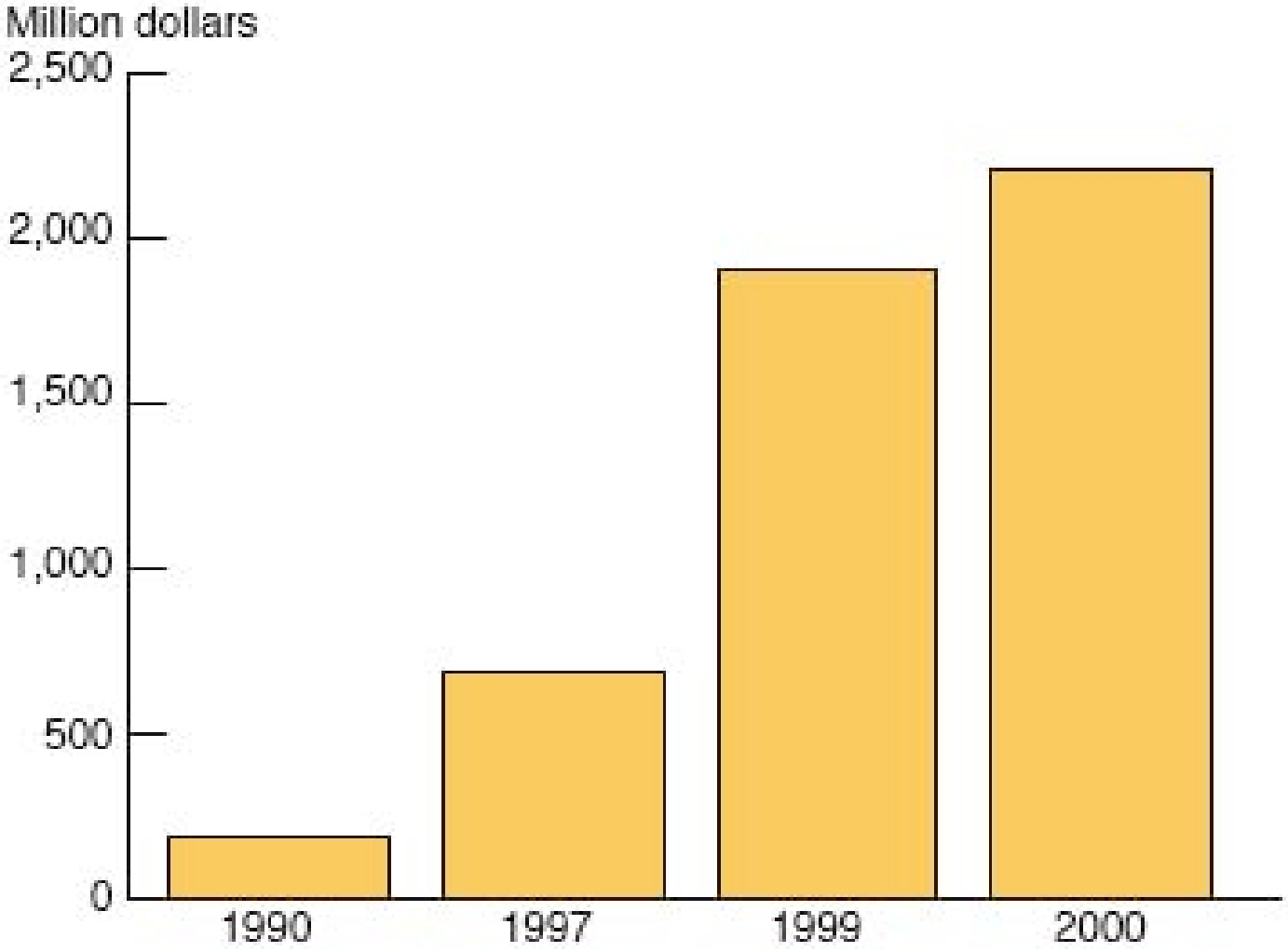
- **U.S. - $7.8B** (15-20% expected growth - medium term)
  - 20-percent annual increase, 1990-2000*
- Germany - $2.2-2.4B (10-15% expected growth)
- Japan - $2.5B**
- Italy - $1-1.1B (15-20% expected growth)
- U.K - $1-1.1B (25-30% expected growth)
- France - 0.75-0.8B (15-20% expected growth)
- ***SOURCE:*** *International Trade Center UNCTAD/WTO and *Packaged Facts*
- ***Includes "green products"*

Figure 1—Share of organic sales by venue



Notes: Other is direct sales and exports.
Source: *Natural Foods Merchandiser*, Packaged Facts.

Figure 3—Sales of organic fruits and vegetables: 1990, 1997, 1999, and 2000



Source: 1997 data. Food Industrial Management Program at Cornell University; 1999, 2000, *Nutrition Business Journal*.

Price Differentials are Possible!

Marketing Organics

Package differently from large commercial growers- No shrink-wrap on these organic cucumbers and flower is still attached!

USDA Resources on Organic Farming & Marketing

Organic Farming & Marketing Briefing Room

www.ers.usda.gov/briefing/Organic/

Organic Perspectives Newsletter

www.fas.usda.gov/htp/organics/organics.html

National Organic Program

www.ams.usda.gov/nop/

Source: Catharine Greene, USDA, Economic Research Service.

Organic Certification in the U.S.

- Greenhouse standards available at: http://www.ams.usda.gov/nop/.
  - Soilless not prohibited.
  - No special standards for greenhouses
- Certification conducted by approved groups that have lists of allowed, restricted or prohibited materials.
  - See list of certifiers in handout
  - Some certifiers more open to soilless production
    - NOFA not very receptive

61 pages of The Rule!

USDA NATIONAL ORGANIC PROGRAM STANDARDS

SUBPART A - TERMS

§ 205.1 Meaning of words For the purpose of the regulations in this subpart, words in the singular form shall be deemed to impart the plural and vice versa, as the case may demand.

§ 205.2 Terms defined

Accreditation. A determination made by the Secretary that authorizes a private, foreign, or State entity to conduct certification activities as a certifying agent under this part.

Act. The Organic Foods Production Act of 1990, as amended (7 U.S.C. 6501 et seq.).

Action level. The limit at or above which the Food and Drug Administration will take legal action against a product to remove it from the market. Action levels are based on unavoidability of the poisonous or deleterious substances and do not represent permissible levels of contamination where it is avoidable.

Administrator. The Administrator for the Agricultural Marketing Service, United States Departure of Agriculture, or the representative to whom authority has been delegated to act in the stead of the Administrator.

Agricultural inputs. All substances or materials used in the production or handling of organic agricultural products.

Agricultural product. Any agricultural commodity or product, whether raw or processed, including any commodity or product derived from livestock, that is marketed in the United States for human or livestock consumption.

Allowed synthetic. A substance that is included on the National List of synthetic substances allowed for use in organic production or handling.

Agricultural Marketing Service (AMS). The Agricultural Marketing Service of the United States Department of Agriculture.

Animal drug. Any drug as defined in section 201 of the Federal Food, Drug, and Cosmetic Act, as amended (21 U.S.C. 321), that is intended for use in livestock, including any drug intended for use in livestock feed but not including such livestock feed.

Annual seedling. A plant grown from seed that will complete its life cycle or produce a harvestable yield within the same crop year or season in which it was planted.

Examples of Restrictions on Greenhouse Construction

General	Allowed	Restricted	Prohibited
Transition period may be required if taking over existing conventional greenhouse Whole house must be certified, but can have uncertified houses on same farm if product distinguishable	Proper ventilation required, but emergency use of portable heaters allowed	Pressure treated lumber only allowed on foundations and end walls (must be isolated from growing media and plants) Artificial light and shade	No asbestos, urea, or formaldehyde

Seeds, Containers, Substrates

General	Allowed	Restricted	Prohibited
Organic transplant production, Organic, untreated seed, no GMOs	Perlite, coir, sawdust, Peat allowed but compost preferred;	Fiber containers with no prohibited material (NOFA, FOG);	No synthetic fertilizers, fungicides, wetting agents, or sterilants in potting mix, rockwool,

Transplant Production

Soil blocks for transplant production

Commercial transplant mixes (left to right):

coir, Fafard, Intervale, Premier, Sungro

Fertilization

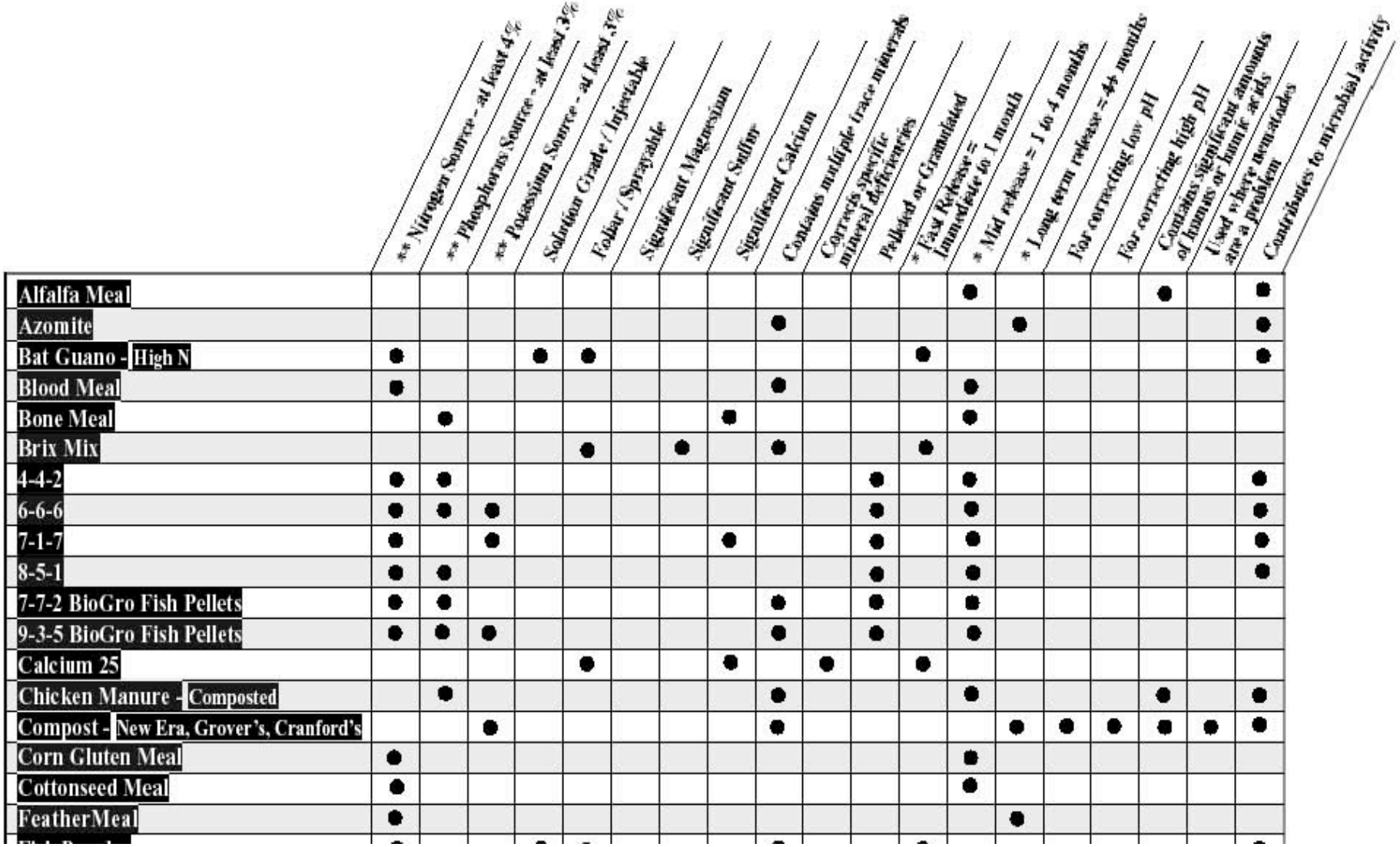
Allowed	Restricted	Prohibited
Compost (N, K, Micros); Citric acid for pH correction Colloidal soft rock and hard rock phosphate (P); Guano (P); Wood ash (K); Rock dusts [granite, feldspar, greensand] (K); Natural potassium sulfate (K); Limestone, gypsum, calcium oxide, (Ca); Dolomitic limestone, Kierserite (Mg); Kelp meal, liquid or powdered seaweed extract, rock powders (Micros); Commercial products on OMRI list	Sodium Nitrate (N); Fish emulsion (N, P); Bone Meal (N, P); Calcium Chloride (Ca); Epsom salts (Mg); Chelate, acid treated sulfate, or oxide materials (Micros)	Synthetic Sources; Muriate of potash; Quick lime, or hydrated lime

Good Source of Organic Fertilizers:

Peaceful Valley Farm Supply

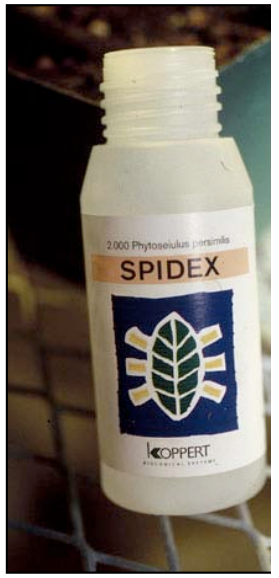
http://www.groworganic.com

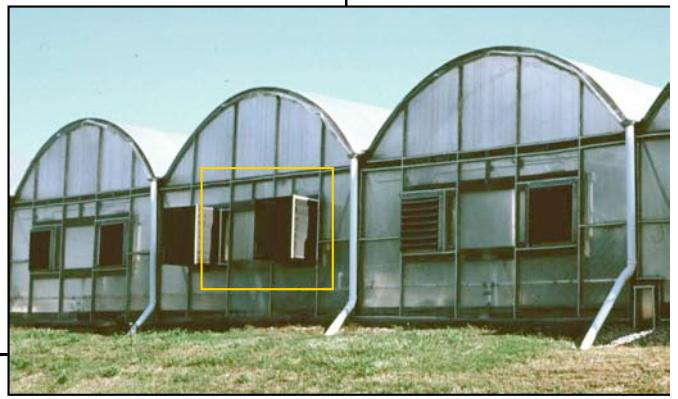
FERTILIZER SOLUTIONS CHART



Pest Control

Allowed	Restricted	Prohibited
Insect Traps; Insect Barriers; Hand, Mechanical, or Hydraulic Removal; Biological Controls; Alcohol to disinfect benches, pots, tools Steam sterilization, hot water seed treatment, low temperature baking Resistant cultivars; Roguing or destroying infected plants; Herbal sprays	Oil Sprays; Insecticidal Soaps; non-GMO types of BT; kaolin, Surround, Spintor, Cinnamite Copper; Sulfur; Approved Non-synthetic Fungicides; Bleach, hydrogen peroxide, quantenary ammonium salts and oxalic acid for disinfection, probably UV and ozone disinfection systems	Synthetic Pesticides, Fungicides, and Nematicides

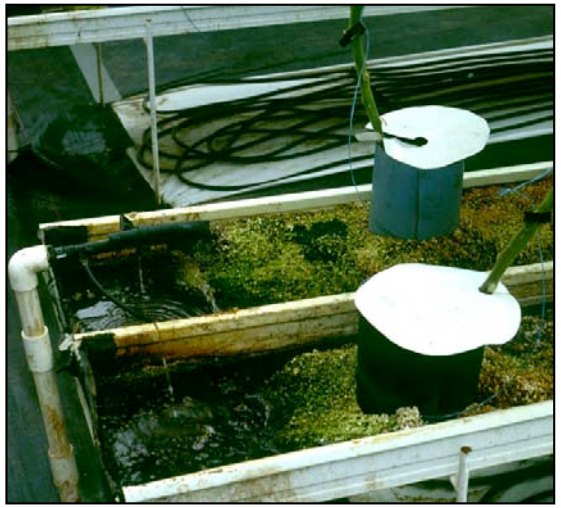




Water-based Organic Production Systems-

NFT, pipe systems or float trays

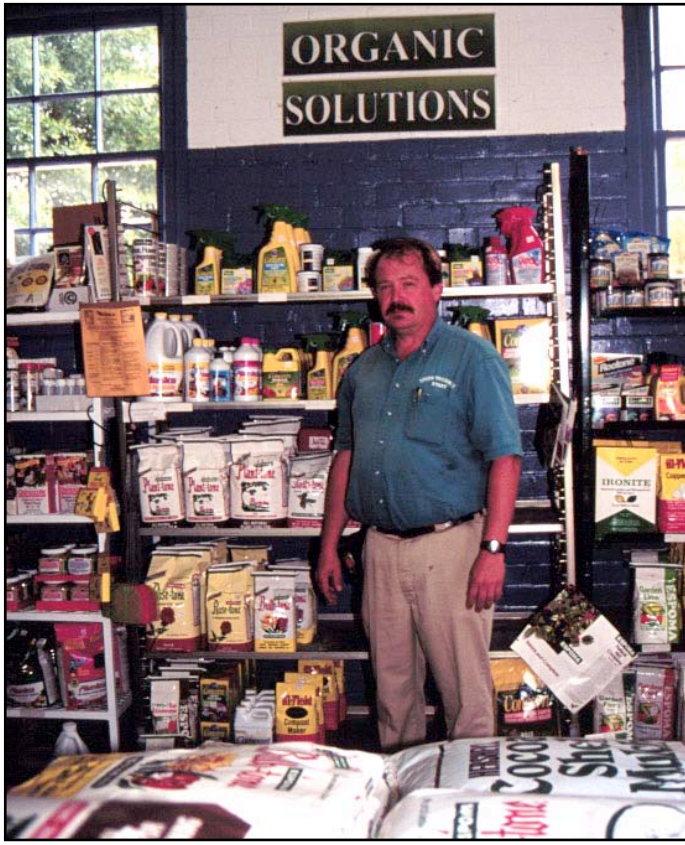
- Least common type
- Unstable
- Most complicated and expensive
- Allowed in NOP, but may not be accepted by particular certification programs e.g Northeastern Organic Farming Association



ValleyFresh, Colorado, gravel in pots

Typical Problems using Organic Fertilizers in Hydroponic Systems

- Lack of sterility in system
  - Diseases
  - Clogging from algae and other free-living organisms
- Deciding when to replace recirculating water
  - Relationship of EC (salt readings) to available plant nutrients
- Local, affordable sources of organically certified mixes and fertilizers
- Balancing fertilizers



Soil-based Organic Production

- Most common and widely accepted
- Add composts and dry organic fertilizers to soil
- Yields generally 20-25 lbs/plant or less
- Use root grafting to compensate for nematodes and root diseases
- May use cover crops or some rotation

Quebec & New England Grower Groups

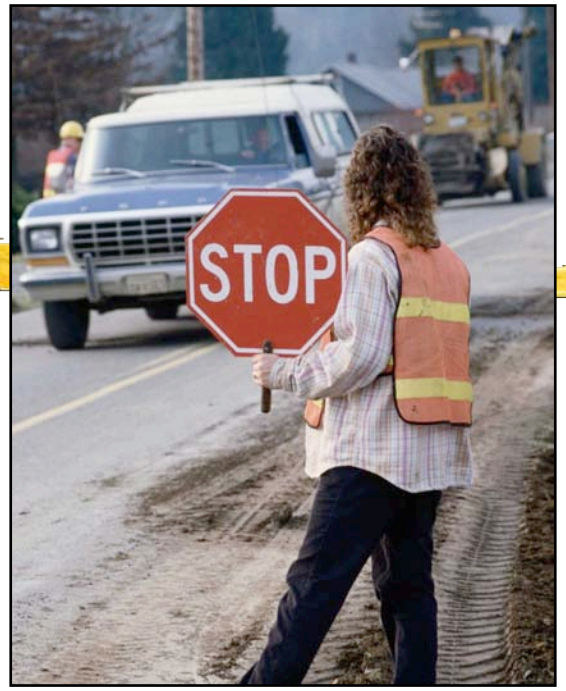
10 acres in Vermont

Ferme Pleine Terre, Saint-Joseph-de-Beauce, Quebec, Prop. Serge Lessard & Sylvie Lambert

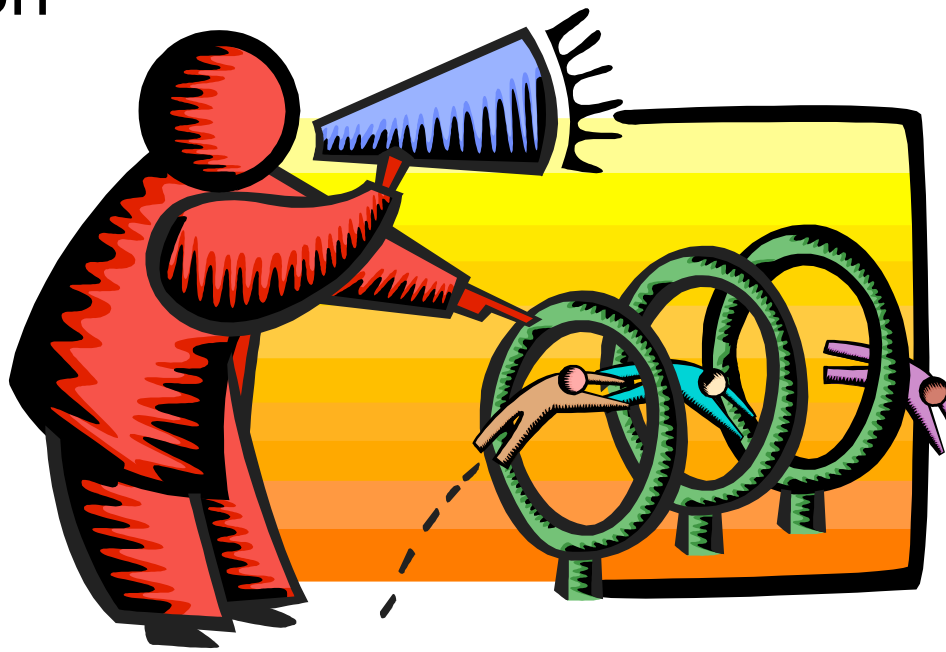
California & Florida

John van Diepen,
Felton, Ca.

Issues before starting commercial organic crop



- Is certification necessary to sell to your market?
- Can't use word 'organic' after October 2002 without certification unless gross under $5,000
- Is certifying agency receptive?
- Will the market pay a premium?
- Is your philosphy compatible?
  - How do you feel about jumping through a lot of hoops?



Our Approach to Organic Hydroponics:

- Soilless media with higher water and nutrient retention than perlite and rockwool (peat, pinebark, coir) with added compost
- Organically certifiable media ingredients & fertilizers
- Biocontrols for pests
- For description, see www.ces.ncsu.edu/greenhouse_veg/

Substrate:

- Fafard special blend of 4-P to omit wetting agents, nutrient charge and micronutrients (85% by volume)
- 15% by volume Vermicycle (worm compost: 1.8-1.6-0.3)
- 1.5 lbs/cubic yard each of:
  - Blood meal
  - Bone meal
  - Potassium sulfate
- OMRI-approved wetting agent “Natural Wet” at 2 tablespoons/gal
- 0.5 lbs/cubic yard sulfur
- For other suggested potting mixes, visit www.attra.org website.

Appropriate Technology Transfer for Rural Areas

Main Study

- Three growing seasons

Season	Transplant Date
Fall 1998 (F98)	August 27, 1998
Spring 1999 (S99)	January 14, 1999
Fall 1999 (F99)	November 4, 1999

Organic Growing Media (F98)

OM	= Substrates	+ Amendments
OM1	85% P/PB	6.0 kg·m^{-3} dolomite
	15% worm compost	1.5 kg·m^{-3} blood meal
	wetting agent	1.5 kg·m^{-3} bone meal
OM2	63% coconut coir	1.5 kg·m^{-3} K_2SO_4
	22% pine bark	
	15% worm compost	

Organic Growing Media (S99)

OM	= Substrates	+ Amendments	
OM3	85% P/PB	1.79 $kg \cdot m^{-3}$	dolomite
	15% worm compost	0.89 $kg \cdot m^{-3}$	blood meal
	wetting agent	0.89 $kg \cdot m^{-3}$	bone meal
OM4	63% coconut coir	0.89 $kg \cdot m^{-3}$	K_2SO_4
	22% pine bark		
	15% worm compost		

Organic Growing Media (F99)

OM	= Substrates	+ Amendments
OM5	85% P/PB	0.30 kg·m^{-3} sulfur
	15% worm compost	0.89 kg·m^{-3} blood meal
	wetting agent	0.89 kg·m^{-3} bone meal
OM6	100% P/PB	0.89 kg·m^{-3} K_2SO_4
	wetting agent	

Organic Fertilizers

- Earth Juice® (EJ)
  - "Grow" (2-1-1)
  - "Bloom" (0-3-1)
  - "Catalyst" (0.03-0.01-0.1)
  - "Micro-Burst" (supplies Mg, B, Cu, Fe, Mn, Zn)
  - "Meta-K" (0-0-10)
- Magna Gro® (MG)
  - "Hydroponic Base Mix (HBM)" (2-3-6)
  - "19% N" (19-0-0)
  - "K-9" (0-0-9)

Fertilization-

- **Magna Gro** brand fertilizer consists of:
  - Hydroponic Base Mix - analysis 2-3-6
    - ingredients: poultry compost tea, pasteurized blood meal, calcium phosphate, and seaweed. This also contains trace minerals with fermented molasses in the form of Zn SO_4, Mg SO_4, and Fe SO_4.
  - 19%N from poultry compost tea and pasteurized blood meal
  - K-9 - 9% K_2O from seaweed
  - Organic forms of trace minerals supplied as 6% B, 6% Fe, 6% Mg, and 6% Ca added, as needed based on tissue analysis.
- For exact receipe, consult www.ces.ncsu.edu/greenhouse_veg/
- For other fertilizer sources, consult www.attra.org website

Earth Juice brand fertilizer consists of 5 separate formulations:(N-P-K)

- ‘Grow’ (2-0.44-0.83): bat guano, Norwegian sea kelp, natural sulfate of potash, feather meal, oat ran, blood meal and steamed bone meal
- ‘Bloom’ (0-1.3-0.83): bat guano, Chilean sea bird guano, Norwegian sea kelp, natural sulfate of potash, steamed bone meal, oat bran and rock phosphate
- ‘Catalyst’ (0.03-0.0044-0.083): oat bran, kelp, wheat malt, molasses, yeast
- ‘Micro-burst’(5% Mg, 0.02% B, 0.05% Cu, 0.2% FE, 0.1% Mn and 0.15% Zn): kelp meal, magnesium sulfate, borax, copper sulfate, iron sulfate, manganese sulfate, and zinc sulfate.
- ‘Meta-K’(10%K): from seaweed

Conventional System

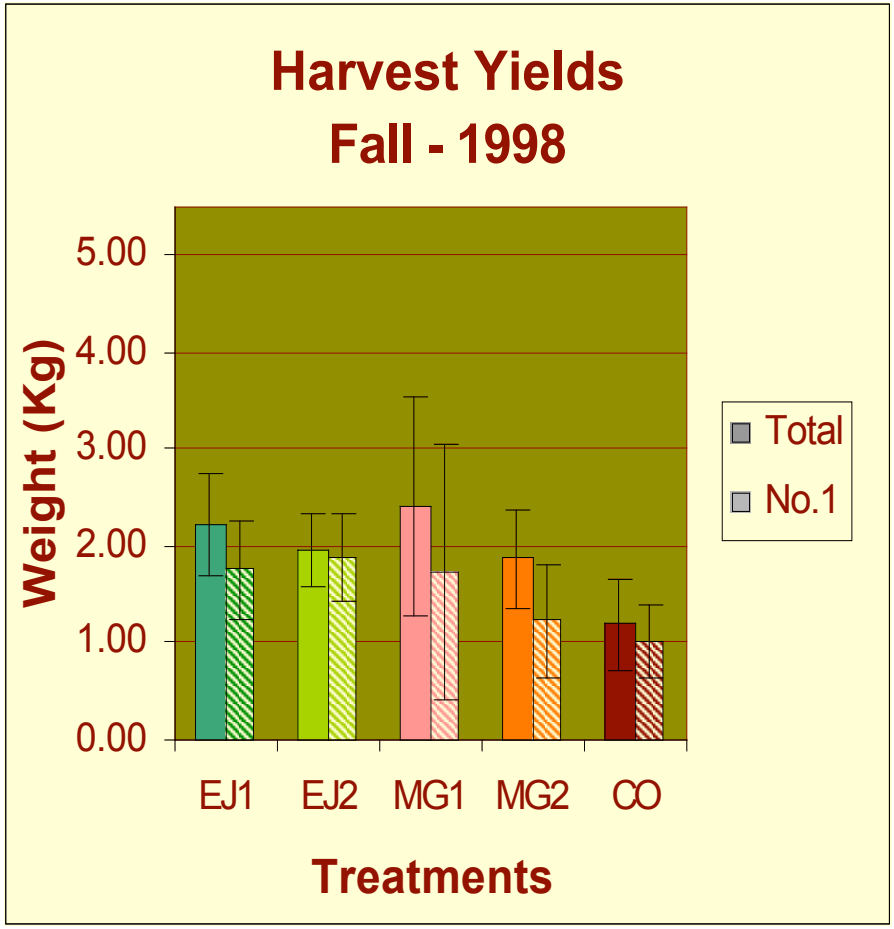
- Substrate:
  - 50% Southland SI-1®
    - peat moss
    - perlite
    - vermiculite
    - starter nutrient charge
  - 50% composted pine bark
- Fertilizer:
  - Chem-Gro® from HydroGardens

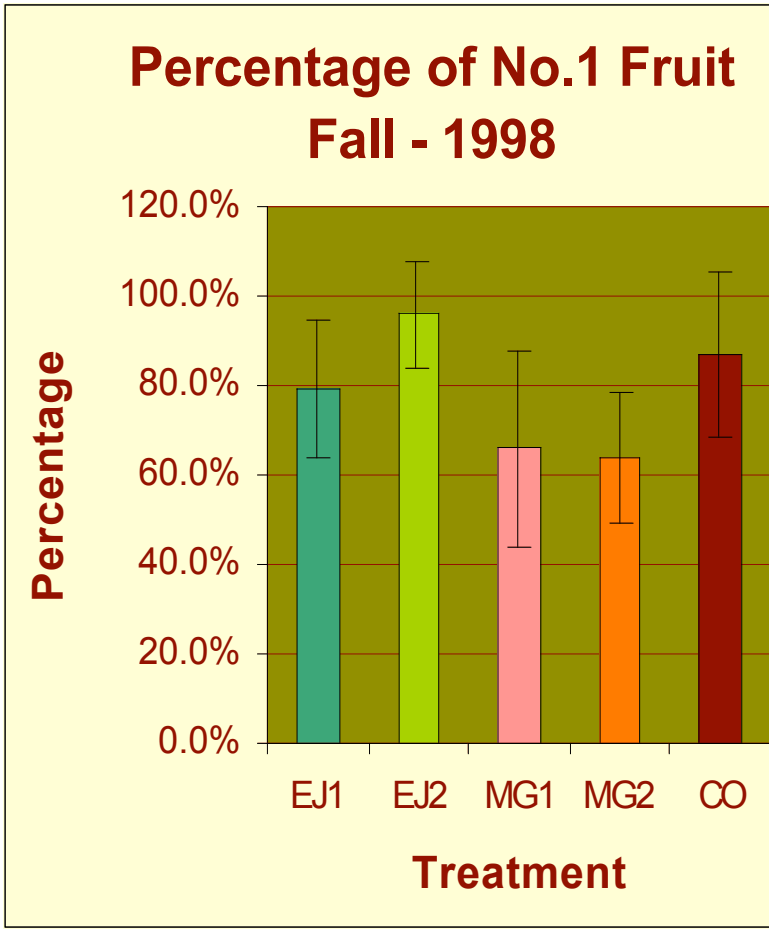
Fertilizers

- All fertilizers formulated to provide:

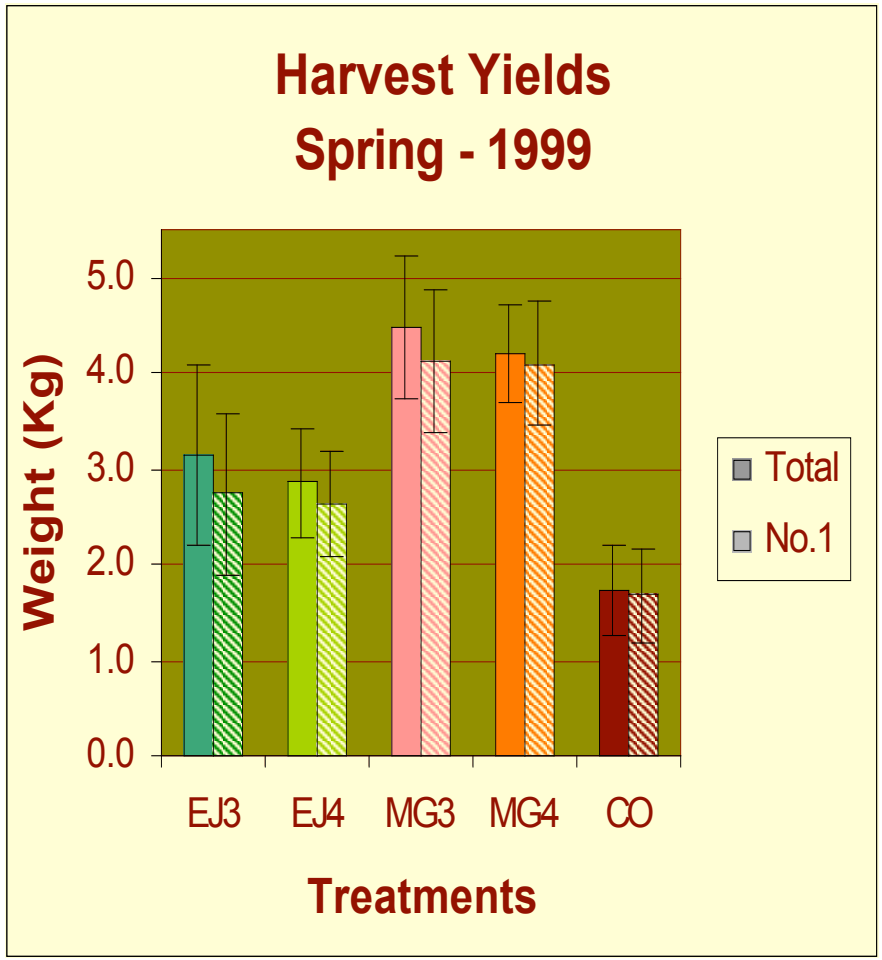
	ppm N	ppm P	ppm K
Stage 1:	90	45	195
Stage 2:	125	45	195
Stage 3:	165	45	310

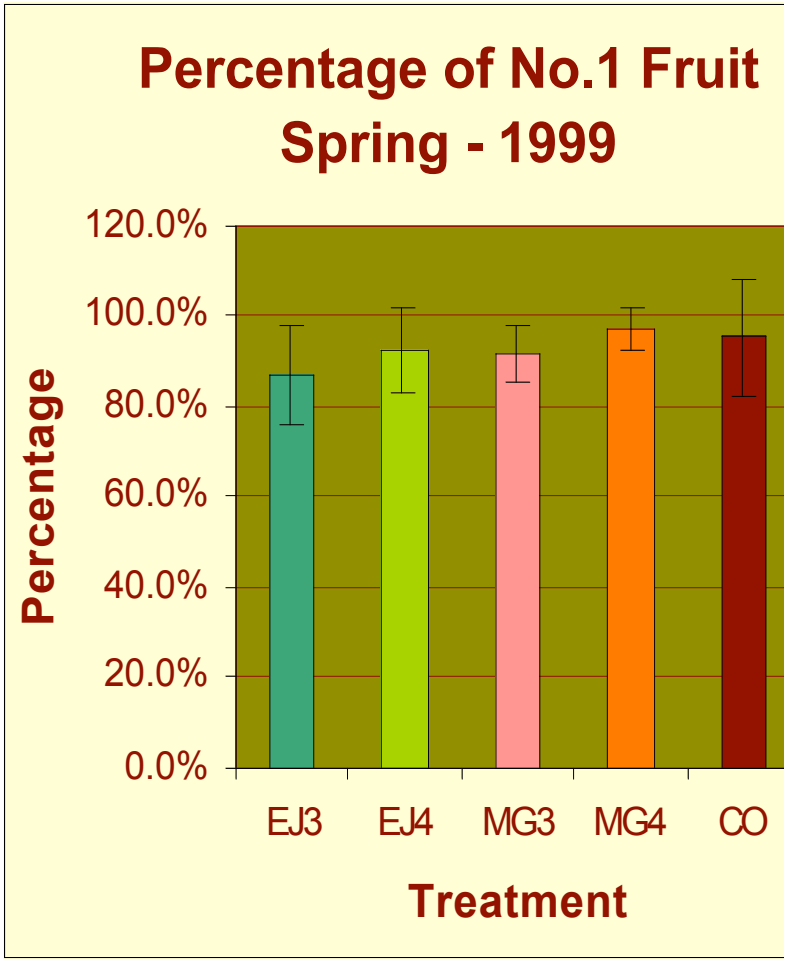
Harvest Yields - F98



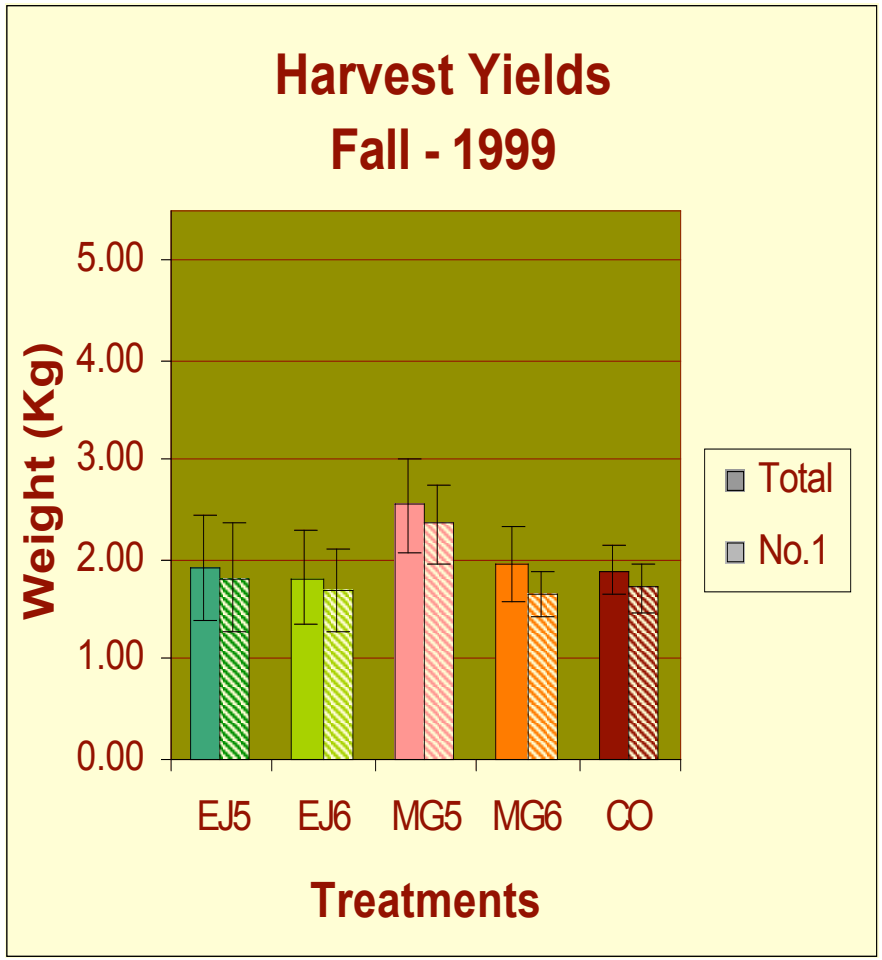


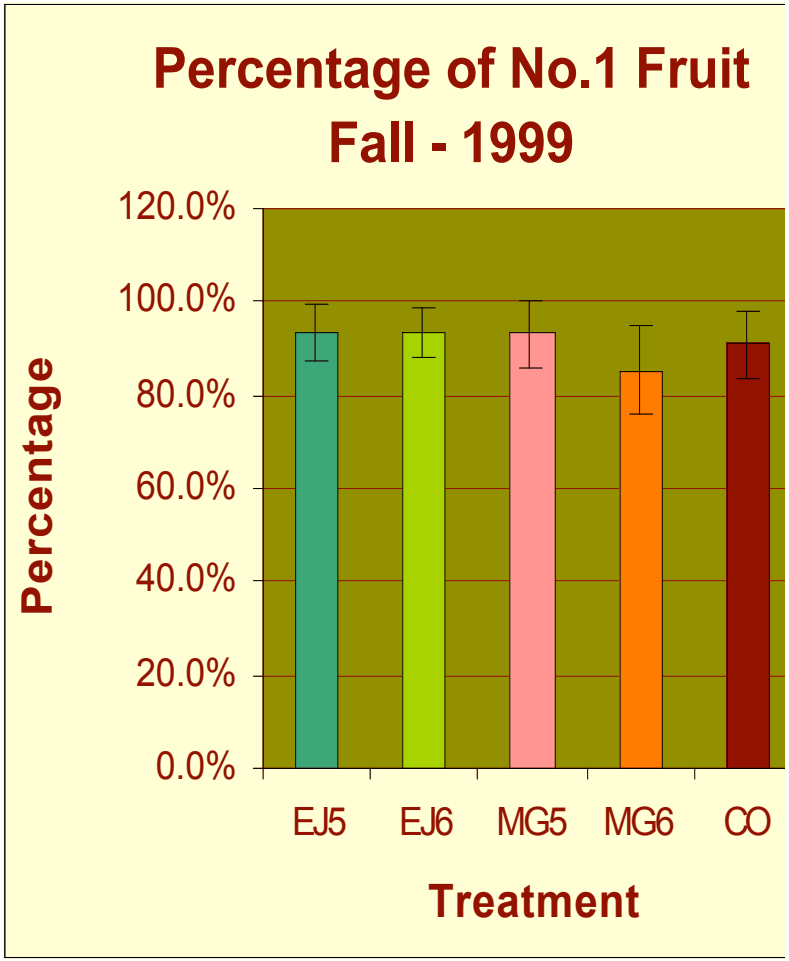
Harvest Yields - S99





Harvest Yields - F99





Harvest Yields

- No significant OR fertilizer effects on
  - total yields (p=0.2668)
  - yield of No. 1 fruit (p=0.4847)

- Yields were comparable among all treatments

Observations

- Substrates
  - coconut coir produced highest percentage of No.1 fruit
  - peat with compost produced higher yields with MG than peat without compost (F99)
  - The addition of compost made little difference with EJ (F99)

New Materials Available, But Untested in First Study

- Soluble Fertilizers
  - Natural Organic Grow 3-3-0.3 from Jedwards International (organic fish hydrolysate, Organic GEM, OMRI certified)
  - Harmony Farms Omega 6-6-6 (certification status unknown)
- Potting soils
  - McEnroe Organics
  - Southland Organic Mix (10% chicken litter compost)
  - SunGro has a number of organic mixes
- Others: select the database on Organic Amendments at www.ncsu.edu/organic_farming_systems/, search on www.attra.org, or Peaceful Valley Farm Supply http://www.groworganic.com/ list of fertilizers

Method of addition

- Injected into lines during daily waterings (flush on weekends)
- Fertilizers agitated by aquarium pumps
- Filtered to remove some, but not all solids
- Pump adjusted to low dilution rate (1:20)
- Drain to waste system

Recmmendations for Organic Fertilization of Soilless Media (peat/pinebark):

- Constant provision of fertilizers at levels comparable to conventional mix (receipes on website & in newsletter)
- pH and salts adjustment to prevent burning
- Precautions with drip injection:
  - Low dilution rates (1:50 or 1:20)
  - Agitate with pump to prevent settling
  - Weekly water flush
  - Emitters which resist clogging
  - Need some filtration, but nutrients not completely soluble
- Processed fertilizers rather than fishmeal (too smelly!)

Unresolved issues in organic fertilization in our system:

- Is flavor and quality different?
- How do you reduce pH and salts?
- Would our recommendations also work on inert substrates such as perlite and sawdust with low CEC and in recirculating systems?
- How do you increase potassium and calcium?
- Are there more affordable alternatives?
- Will animal waste products work and be allowed?

Overall conclusions from study:

- The basics are still important (like good transplants!)
  - transplant mixes can be shipped in or made on site.
  - Much ‘hype’ on biocontrols, biorationals, organic fertilizers--but little data
  - New products are emerging rapidly
- With proper management and experience, system differences will not be great

Follow-up Study: Spring 2001

- Funded by Organic Farming Research Foundation
- Three organic fertilizers, including 2 commercial mixes and a N-P-K balanced ‘in-house blend’, were compared to a conventional fertilizer for production of greenhouse tomatoes in containers.
- All fertilizers were applied to a peat/perlite substrate using a drip irrigation system.
  - No compost was added.
  - Some lime addition-less than in previous study

Table 1. Fertilizer rates and formulas for organic and conventional fertilizers. For all fertilizers, N levels were matched at each stage of grow to ppm N in conventional fertilizer formula. Other nutrients were not match in the OM and NOG mixes, but N-P-K were matched in the NCS formulation using a combination of blood meal, Micro Phos and Maxicrop. Some additional nutrient were provided by Maxicrop, as describe the footnotes.

Conventional N-P-K rates for each growth stage[z]		
Stage 1	**Stage 2**	**Stage 3**
90 ppm N	125 ppm N	165 ppm N
45 ppm P	45 ppm P	45 ppm P
195 ppm K **K:N 2.2**	195 ppm K **K:N 1.56**	310 ppm K **K:N 1.89**

Fertilizer Formulas			
Fertilizer	**Stage 1**	**Stage 2**	**Stage 3**
Omega (OM) [y]	9.99 fl. oz. (299.7 mL)	13.88 fl. oz. (416.3 mL)	18.32 fl. oz. (549.6 mL)
Natural Organic-Grow (NOG)[x]	27.97 fl. oz. (839.0 mL)	38.85 fl. oz. (1165.4 mL)	51.63 fl. oz. (1540.8 mL)
NCSU Blend (NCS)[w, v]	1.34 oz. (38.0 g) Blood Meal	2.00 oz. (56.9 g) Blood Meal	2.55 oz. (72.3 g) Blood Mea
	13.33 oz. (377.8 g) Micro Phos	13.33 oz. (377.8 g) Micro Phos	13.16 oz. (373.1 g) Micro Pho
	5.19 oz. (147.3 g) Maxicrop	5.19 oz. (147.3 g) Maxicrop	8.25 oz. (234.1 g) Maxicrop

[z] Stage 1: the period from transplanting to the first fruit set; Stage 2: the period of fruit set from first through sixth clusters; Stage 3: th period from fruit set on the sixth cluster until the end of the crop. Levels based on Carpenter (1982).

[y] Omega (OM). Analysis: 6-6-6 (6N-2.64P-4.98K). For 1 gallon (3.79 L) of stock injected at a rate of 50:1. K:N ratio 0.83.

[x] Natural Organic-Grow (NOG). Analysis: 3-2-0.3 (3N-0.88P-0.25K). For 1 gallon (3.79 L) of stock injected at a rate of 70:1. K:N ratio 0.083.

[w] NCSU Blend (NCS) is comprised of three products: Blood Meal – Analysis: 14-0-0 (14N-0P-0K); Micro Phos – Analysis: 0-2-0 (0N-0.88P-0K); and Maxicrop – Analysis: 1-0.11-12 (1N-0.05P-10K). Additional nutrients in Maxicrop: 12,000 ppm Ca; 8,000 ppm Mg; 37,000 ppm S; 80 ppm B; 5 ppm copper; 1200 ppm Fe; 12 ppm Mn; 100 ppm Zn. Formulated for 1 gallon (3.79 L) of stock injected a rate of 20:1. K:N ratios similar to those in conventional mix.

[v] Since blood meal is insoluble, the nitrogen was extracted by soaking overnight the amount required in 1 gal. (3.79 L) of hot water to which 1 oz. (28.3 g) of citric acid was added. The supernatant was then strained into the stock tank and the remaining ingredients we added.

Table 2. Nutrient content of tomato leaves analyzed by The NCDA. Each sample consisted of the fifth leaf from the apex of each plant in each treatment.

Nutrient/ Adequate range[y]	Unit	Date	Fertilizer: Omega	Natural Organic-Grow	NCSU	Conventional
N	%	27-Feb	6.47 a[z]	5.44 a	5.72 a	5.84 a
3.5-5%		23-Mar	5.10 a	3.48 b	2.46 c	3.18 b
P	%	27-Feb	1.11 a	1.08 a	0.92 b	1.03 a
0.3-.65%		23-Mar	0.72 b	0.83 a	0.68 b, c	0.59 c
K	%	27-Feb	3.41 a, b	3.63 a	2.93 b	3.10 a, b
3.5-4.5%		23-Mar	3.87 a	2.50 b	4.25 a	4.09 a
Ca	%	27-Feb	0.78 a	0.86 a	1.00 a	0.94 a
1-3%		23-Mar	0.38 b	1.06 a	1.17 a	1.09 a
Mg	%	27-Feb	0.56 b	0.63 a	0.60 a, b	0.61 a, b
0.35-1%		23-Mar	0.31 c	0.57 a	0.61 a	0.50 b
S	%	27-Feb	0.79 b	0.91 a, b	0.94 a	0.85 a, b
0.2-1%		23-Mar	0.40 b	0.53 b	0.89 a	0.78 a
Na	%	27-Feb	0.06 a	0.06 a	0.06 a	0.05 a
		23-Mar	0.10 b	0.20 a	0.22 a	0.07 b
Fe	ppm	27-Feb	101.65 b	99.20 b	93.00 b	121.33 a
50-300 ppm		23-Mar	94.80 a	53.57 c	51.32 c	77.43 b
Mn	ppm	27-Feb	116.17 a	121.30 a	125.00 a	122.17 a
25-200ppm		23-Mar	83.42 c	160.00 b	199.17 a	138.00 b
Zn	ppm	27-Feb	61.27 a	61.72 a	55.40 a, b	49.35 b
18-80 ppm		23-Mar	50.90 a	19.22 b	19.05 b	16.15 b
Cu	ppm	27-Feb	8.95 b	10.72 a, b	9.17 b	12.57 a
5-35 ppm		23-Mar	10.25 b	8.28 c	7.87 c	14.00 a
B	ppm	27-Feb	70.17 b	77.12 a, b	85.75 a	69.42 b
30-75 ppm		23-Mar	50.48 c	83.17 b	100.80 a	77.67 b

[y]Reference sufficiency ranges for greenhouse tomatoes. In sufficiency ranges for plant analysis (Campbel

[z] Different letters denote significant differences (alpha=0.05) among treatments.

Table 3. Substrate pH, cation exchange capacity and nutrient content. Soil cores from four gro-bags of each treatment were combined for each analytical sample.

Soil Property or Nutrient	Type of Unit	Date	Fertilizer			
			Omega	Natural Organic-Grow	NCSU	Conventional
pH		27-Feb	5.53 a, b[y]	5.43 b	5.63 a	5.10 c
		23-Mar	5.53 a	5.37 a	5.57 a	5.33 a
		25-May	5.20 b	5.13 b	6.10 a	5.00 b
Cation Exchange Capacity (CEC)		27-Feb	7.13 b	6.90 b	7.30 b	8.07 a
		23-Mar	8.67 b	8.37 b	8.93 a, b	9.93 a
		25-May	6.43 b	7.60 a, b	7.43 a, b	8.83 a
Nitrate-N (NO_3)		27-Feb	9.00 b	3.67 b	8.00 b	25.67 a
		23-Mar	18.67 a	2.00 a	2.67 a	4.00 a
		25-May	16.33 a	3.33 b	2.33 b	2.00 b
Phosphorous (P)	Index[z]	27-Feb	16.00 a	16.67 a	12.00 a	16.33 a
		23-Mar	22.67 a	21.00 a, b	19.67 a, b	15.33 b
		25-May	18.00 b, c	30.00 a	26.00 a, b	9.33 c
Potassium (K)	Index	27-Feb	62.67 a	35.00 c	48.67 b	55.00 a, b
		23-Mar	61.00 a	8.33 b	52.67 a, b	31.67 a, b
		25-May	80.67 a	13.33 b	79.67 a, b	19.00 b
Calcium (Ca)	%	27-Feb	35.33 a	35.67 a	36.33 a	36.33 a
		23-Mar	33.00 b	32.33 b	34.33 b	41.00 a
		25-May	31.67 b	33.33 a, b	42.67 a	42.00 a
Magnesium (Mg)	%	27-Feb	27.33 a	27.33 a	25.67 a	25.33 a
		23-Mar	23.67 a	26.00 a	23.33 a	23.00 a
		25-May	13.67 c	21.33 b	24.67 a	20.00 b
Sulfur (S)	Index	27-Feb	23.00 b	36.67 b	27.00 b	113.00 a
		23-Mar	18.67 b	25.33 b	44.67 a	29.67 b
		25-May	27.67 b	32.67 b	74.33 a	91.67 a
Manganese (Mn)	Index	27-Feb	24.67 b	26.33 b	26.00 b	34.67 a
		23-Mar	25.67 b	27.33 b	25.00 b	40.33 a
		25-May	18.67 a	24.67 a	20.00 a	25.00 a
Zinc (Zn)	Index	27-Feb	87.33 a	86.67 a	77.67 a	79.67 a
		23-Mar	102.67 a	98.67 a	81.67 a	83.33 a
		25-May	91.67 a	87.67 a	90.33 a	81.33 a
Copper (Cu)	Index	27-Feb	15.00 a	15.67 a	16.00 a	14.33 a
		23-Mar	29.33 a	17.00 b	17.33 b	28.00 a
		25-May	23.67 a	15.67 a	16.00 a	18.00 a
Sodium (Na)	%	27-Feb	0.20 b	0.20 b	0.27 a	0.20 b
		23-Mar	0.33 b	0.33 b	0.67 a	0.27 b
		25-May	0.40 c	0.37 c	1.07 a	0.50 b

[z] Different letters denote significant differences (alpha=0.05) among treatments.

[z] NCDA index based on soil test index: 0-10 very low; 11-25 low; 26-50 medium; 51-100 high; >100 very high.

Table 4. Weight per cluster (g) of total and marketable (No. 1) tomato fruit harvested per plant using 3 organic fertilizers and a conventional fertilizer.

Harvest Yields - Tomatoes Spring - 2001 By Cluster				
	Average Wt. (g) / Plant			
	Cluster 1		Cluster 2	
Treatment	All Fruit	No. 1 Fruit	All Fruit	No. 1 Fruit
OM [z]	742.59	505.46	559.78	212.55
NOG	884.19	670.94	610.49	558.67
NCS	766.38	708.79	476.03	396.43
CV	1300.93	1011.47	932.42	837.53

[z] OM = Omega; NOG = Natural Organic Grow; NCS = North Carolina State Formula; CV = Conventional

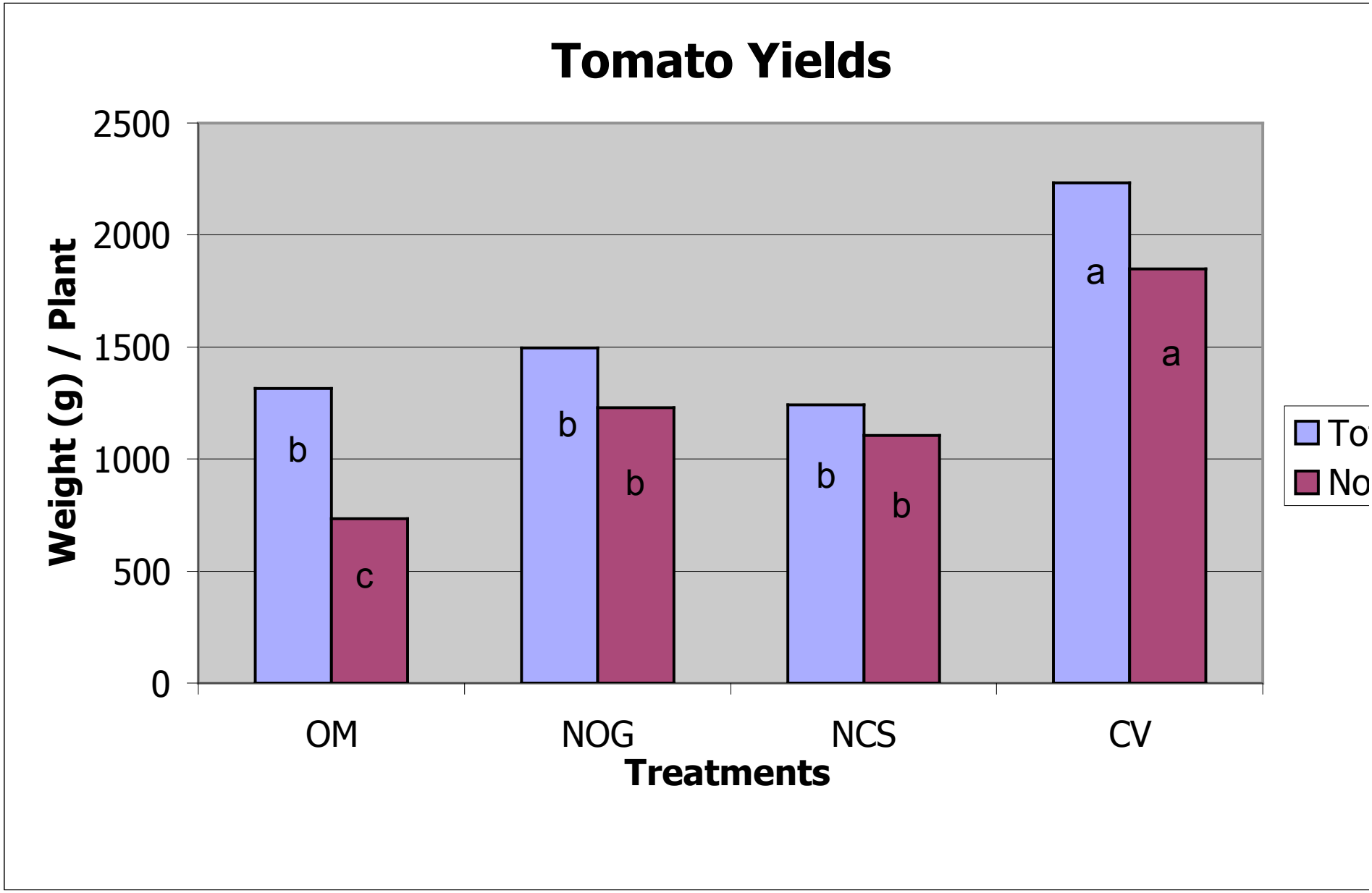


Figure 3. Total and No. 1 tomato yields. Letters designate significance of treatment differences.

Results of Follow-up Study

- There were no differences between any of the treatments in the rate of plant development over the course of this experiment, but by the end of the experiment, plant vigor was excessive in one organic fertilizer treatment (6-6-6) and low in another (NOG).
- Two of the three organic fertilizers tested had a similar percentage of marketable fruit to the conventional fertilizer, but all had significantly lower yields than the conventional fertilizer.
- Our ‘in-house blend’, which most closely resembled the conventional fertilizer in N-P-K, had comparable vigor to conventionally grown plants and good pH and CEC characteristics. The nitrogen source (bloodmeal) had the disadvantage of being difficult to keep in solution, however, and lower yields compared to conventional may have been a result of initial difficulties in getting N into solution and associated emitter clogging.
- Substrate pH levels were lower than in our previous study (Miles, 2000), in which above-optimal pH levels were experienced in an organically fertilized substrate containing 15% vermicompost. This demonstrates the difficulty of predicting pH in organically fertilized container-grown plants.

Future Work

- Better prediction of fertilizer & substrate pH & EC
- Better N source for NCS blend
- Combination of low-K material (NOG) with K supplement
- Explore microbiology and mineralization rates

Conventional System

- Substrate:
  - 50% Southland SI-1®
    - peat moss
    - perlite
    - vermiculite
    - starter nutrient charge
  - 50% composted pine bark
- Fertilizer:
  - Chem-Gro® from HydroGardens

Problems with Commercial Implementation

- Cost of fertilizers
- Convenience of mixing
- Local availability and lack of current certification (Magna-Gro)
- pH and salts too high
- Level of pH and salts varied throughout experiment

Follow-up Study: Spring 2001

- Three organic fertilizers
  - 2 commercial mixes (6-6-6 and 3-3-0.3)
  - N-P-K balanced ‘in-house blend’
    - Bloodmeal (14-0-0)
    - Micro-phos (0-2-0)
    - Magna-Gro (1-0.1-12)
- All fertilizers were applied to a peat/perlite substrate using a drip irrigation system.
  - No compost added
  - Some lime addition-less than in previous study to reduce high pH problems

Objectives

- Separate out substrate and organic fertilizer pH and EC characteristics by utilizing the same substrate in conventional and organic treatments.
  - Omitted 15% vermicompost addition
  - Lowered lime addition to reduce pH
- Try to streamline organic fertilizer additions
  - Matched on the basis of N only rather than NPK

Table 1. Fertilizer rates and formulas for organic and conventional fertilizers. For all fertilizers, N levels were matched at each stage of gr to ppm N in conventional fertilizer formula. Other nutrients were not match in the OM and NOG mixes, but N-P-K were matched in the N(formulation using a combination of blood meal, Micro Phos and Maxicrop. Some additional nutrient were provided by Maxicrop, as descri the footnotes.

Conventional N-P-K rates for each growth stage[z]		
Stage 1	**Stage 2**	**Stage 3**
90 ppm N	125 ppm N	165 ppm N
45 ppm P	45 ppm P	45 ppm P
195 ppm K **K:N 2.2**	195 ppm K **K:N 1.56**	310 ppm K **K:N 1.89**

Fertilizer Formulas			
Fertilizer	**Stage 1**	**Stage 2**	**Stage 3**
Omega (OM) [y]	9.99 fl. oz. (299.7 mL)	13.88 fl. oz. (416.3 mL)	18.32 fl. oz. (549.6 mL)
Natural Organic-Grow (NOG)[x]	27.97 fl. oz. (839.0 mL)	38.85 fl. oz. (1165.4 mL)	51.63 fl. oz. (1540.8 mL)
NCSU Blend (NCS)[w, v]	1.34 oz. (38.0 g) Blood Meal	2.00 oz. (56.9 g) Blood Meal	2.55 oz. (72.3 g) Blood Me
	13.33 oz. (377.8 g) Micro Phos	13.33 oz. (377.8 g) Micro Phos	13.16 oz. (373.1 g) Micro Ph
	5.19 oz. (147.3 g) Maxicrop	5.19 oz. (147.3 g) Maxicrop	8.25 oz. (234.1 g) Maxicrop

[z] Stage 1: the period from transplanting to the first fruit set; Stage 2: the period of fruit set from first through sixth clusters; Stage 3: period from fruit set on the sixth cluster until the end of the crop. Levels based on Carpenter (1982).

[y] **Omega (OM). Analysis: 6-6-6** (6N-2.64P-4.98K). For 1 gallon (3.79 L) of stock injected at a rate of 50:1. K:N ratio 0.83.

[x] **Natural Organic-Grow (NOG). Analysis: 3-2-0.3** (3N-0.88P-0.25K). For 1 gallon (3.79 L) of stock injected at a rate of 70:1. K:N 0.083.

[w] NCSU Blend (NCS) is comprised of three products: **Blood Meal – Analysis: 14-0-0 (14N-0P-0K); Micro Phos – Analysis: 0-2- (0N-0.88P-0K); and Maxicrop – Analysis: 1-0.11-12 (1N-0.05P-10K). Additional nutrients in Maxicrop: 12,000 ppm C 8,000 ppm Mg; 37,000 ppm S; 80 ppm B; 5 ppm copper; 1200 ppm Fe; 12 ppm Mn; 100 ppm Zn**. Formulated for 1 gallo (3.79 L) of stock injected at a rate of 20:1. K:N ratios similar to those in conventional mix.

[v] Since blood meal is insoluble, the nitrogen was extracted by soaking overnight the amount required in 1 gal. (3.79 L) of hot water to which 1 oz. (28.3 g) of citric acid was added. The supernatant was then strained into the stock tank and the remaining ingredients w added.

Table 2. Nutrient content of tomato leaves analyzed by The NCDA. Each sample consisted of the fifth leaf from the apex of each plant in each treatment.

Nutrient/ Adequate range[y]	Unit	Date	Fertilizer: Omega	Natural: Organic-Grow	NCSU	Conventional
N	%	27-Feb	6.47 a[z]	5.44 a	5.72 a	5.84 a
3.5-5%		23-Mar	5.10 a	3.48 b	2.46 c	3.18 b
P	%	27-Feb	1.11 a	1.08 a	0.92 b	1.03 a
0.3-.65%		23-Mar	0.72 b	0.83 a	0.68 b, c	0.59 c
K	%	27-Feb	3.41 a, b	3.63 a	2.93 b	3.10 a, b
3.5-4.5%		23-Mar	3.87 a	2.50 b	4.25 a	4.09 a
Ca	%	27-Feb	0.78 a	0.86 a	1.00 a	0.94 a
1-3%		23-Mar	0.38 b	1.06 a	1.17 a	1.09 a
Mg	%	27-Feb	0.56 b	0.63 a	0.60 a, b	0.61 a, b
0.35-1%		23-Mar	0.31 c	0.57 a	0.61 a	0.50 b
S	%	27-Feb	0.79 b	0.91 a, b	0.94 a	0.85 a, b
0.2-1%		23-Mar	0.40 b	0.53 b	0.89 a	0.78 a
Na	%	27-Feb	0.06 a	0.06 a	0.06 a	0.05 a
		23-Mar	0.10 b	0.20 a	0.22 a	0.07 b
Fe	ppm	27-Feb	101.65 b	99.20 b	93.00 b	121.33 a
50-300 ppm		23-Mar	94.80 a	53.57 c	51.32 c	77.43 b
Mn	ppm	27-Feb	116.17 a	121.30 a	125.00 a	122.17 a
25-200ppm		23-Mar	83.42 c	160.00 b	199.17 a	138.00 b
Zn	ppm	27-Feb	61.27 a	61.72 a	55.40 a, b	49.35 b
18-80 ppm		23-Mar	50.90 a	19.22 b	19.05 b	16.15 b
Cu	ppm	27-Feb	8.95 b	10.72 a, b	9.17 b	12.57 a
5-35 ppm		23-Mar	10.25 b	8.28 c	7.87 c	14.00 a
B	ppm	27-Feb	70.17 b	77.12 a, b	85.75 a	69.42 b
30-75 ppm		23-Mar	50.48 c	83.17 b	100.80 a	77.67 b

[y]Reference sufficiency ranges for greenhouse tomatoes. In sufficiency ranges for plant analysis (Campbel

[z] Different letters denote significant differences (alpha=0.05) among treatments.

Plant Growth Rates Similar

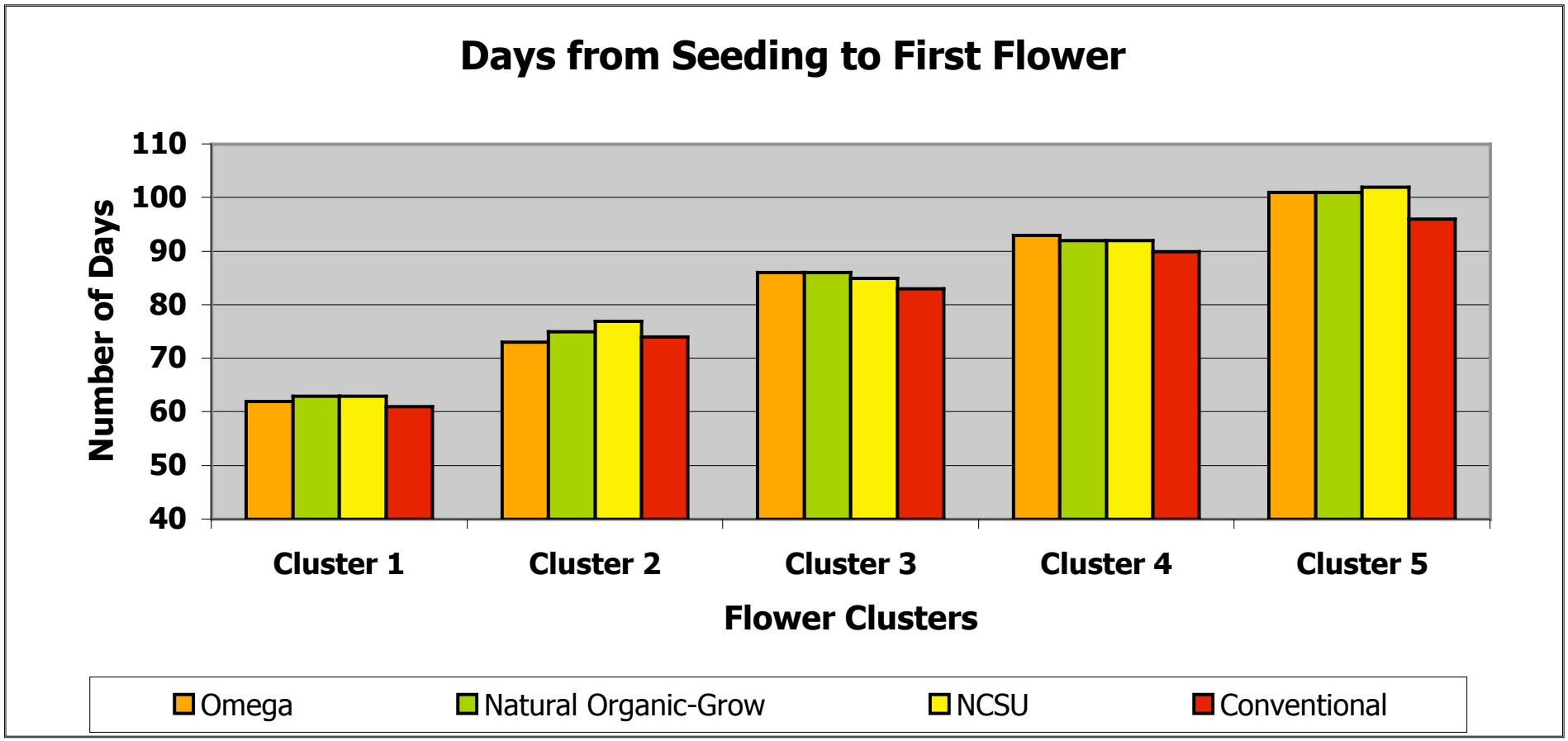


Table 3. Substrate pH, cation exchange capacity and nutrient content. Soil cores from four gro-bags of each treatment were combined for each analytical sample.

Soil Property or Nutrient	Type of Unit	Date	Fertilizer			
			Omega	Natural Organic-Grow	NCSU	Conventional
pH		27-Feb	5.53 a, b[y]	5.43 b	5.63 a	5.10 c
		23-Mar	5.53 a	5.37 a	5.57 a	5.33 a
		25-May	5.20 b	5.13 b	6.10 a	5.00 b
Cation Exchange Capacity (CEC)		27-Feb	7.13 b	6.90 b	7.30 b	8.07 a
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		25-May	16.33 a	3.33 b	2.33 b	2.00 b
Phosphorous (P)	Index[z]	27-Feb	16.00 a	16.67 a	12.00 a	16.33 a
		23-Mar	22.67 a	21.00 a, b	19.67 a, b	15.33 b
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		25-May	91.67 a	87.67 a	90.33 a	81.33 a
Copper (Cu)	Index	27-Feb	15.00 a	15.67 a	16.00 a	14.33 a
		23-Mar	29.33 a	17.00 b	17.33 b	28.00 a
		25-May	23.67 a	15.67 a	16.00 a	18.00 a
Sodium (Na)	%	27-Feb	0.20 b	0.20 b	0.27 a	0.20 b
		23-Mar	0.33 b	0.33 b	0.67 a	0.27 b
		25-May	0.40 c	0.37 c	1.07 a	0.50 b

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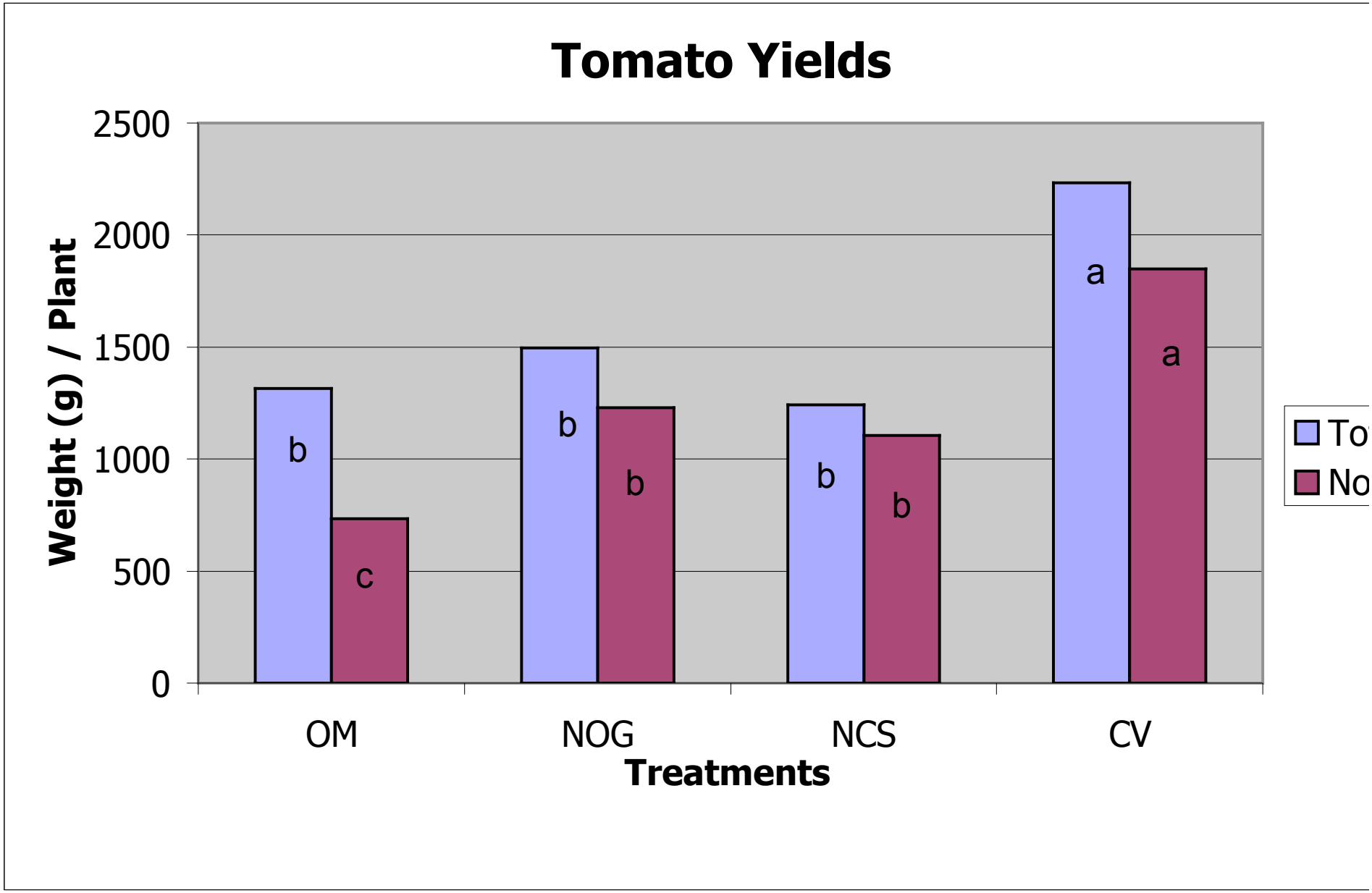
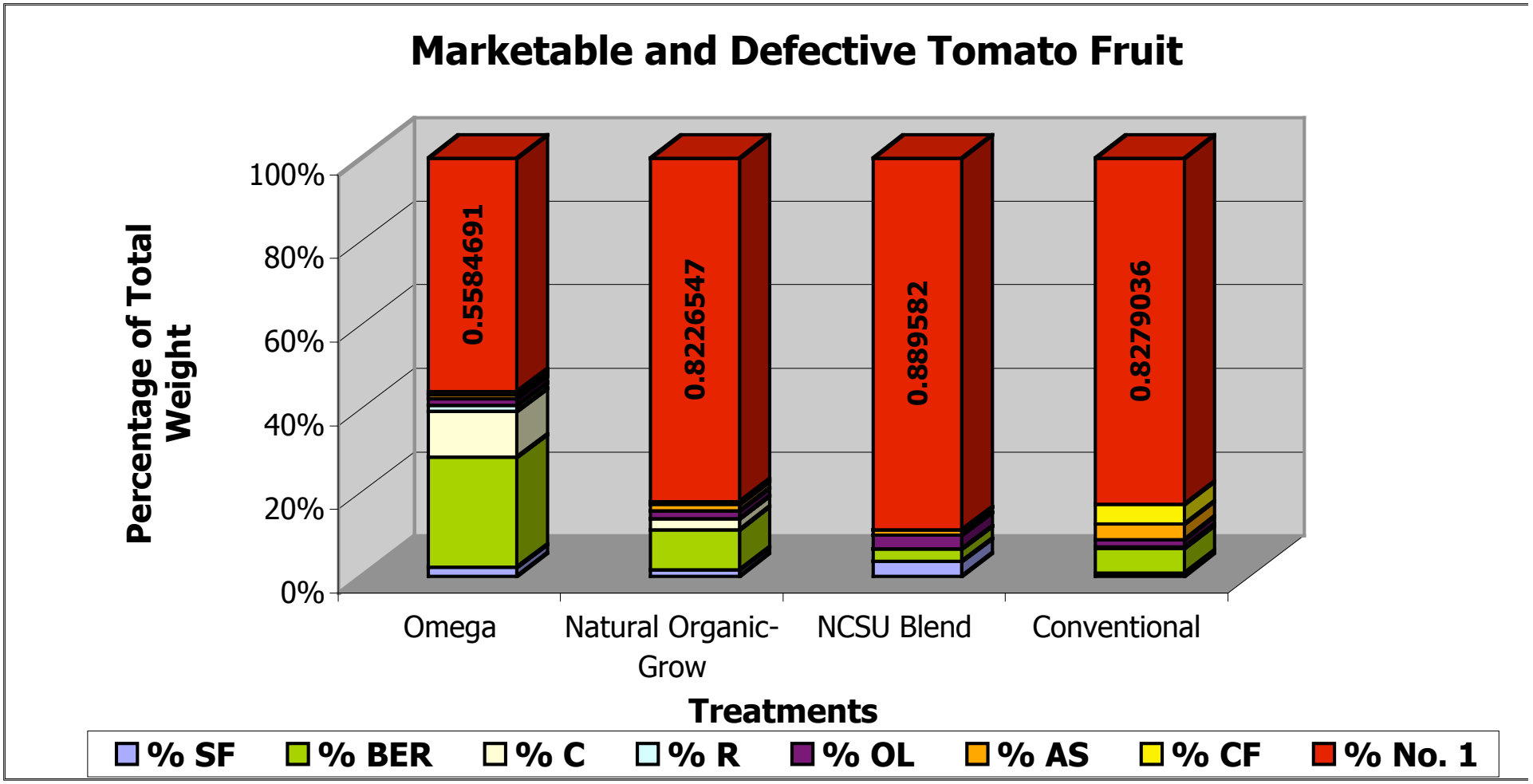


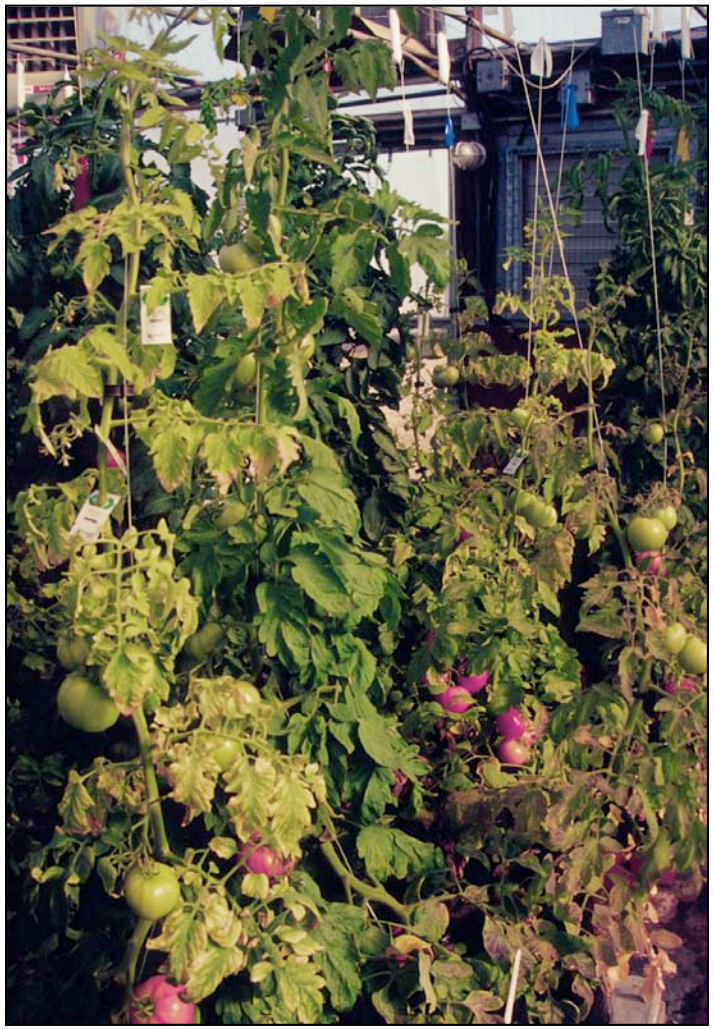
Figure 3. Total and No. 1 tomato yields. Letters designate significance of treatment differences.

Fruit Quality Highest in NCSU Blend



Growth and Yields in Follow-up Study

- No differences between any of the treatments in the rate of plant development
- Plant vigor
  - excessive in 6-6-6 organic fertilizer treatment
  - low in 3-3-0.3 organic fertilizer treatment
- Two of the three organic fertilizers tested had a similar percentage of marketable fruit to the conventional fertilizer, but all had significantly lower yields than the conventional fertilizer.



Nutrition in Follow-up Study

- NCSU blend', which most closely resembled the conventional fertilizer in N-P-K, had comparable vigor to conventionally grown plants and good pH and CEC characteristics.
  - The nitrogen source (bloodmeal) had the disadvantage of being difficult to keep in solution, however, and lower yields compared to conventional may have been a result of initial difficulties in getting N into solution and associated emitter clogging.
- Blend of 3-3-0.3 and Maxicrop (0-0.11-12) potentially balanced

Future Work

- Better prediction of fertilizer & substrate pH & EC
- Better N source for NCSU blend
- Combination of low-K material (NOG) with K supplement
- Explore microbiology and mineralization rates and utilization of composts