Table 4. Vase-life of 'May Shoesmith' chrysanthemums as influenced by flower source, water quality and preservative.[z]

Flower source	Preservative	Water source: Grower A	Grower B	Grower C	De-ionized	Mean
A	–	3.0	2.8	2.5	5.5	3.5
A	+	9.7	5.8	8.0	12.7	9.1
B	–	3.8	3.7	2.0	8.8	4.6
B	+	9.5	15.2	3.2	10.5	9.6
C	–	6.3	7.5	4.5	14.7	8.3
C	+	19.5	23.3	23.0	19.5	21.3
Mean		8.6	9.7	7.2	12.0	

[z]$S_{\bar{x}} = 2.33$ and $HSD_{5\%} = 12.1$

A and B by 128 and 107% for the plus and minus preservative treatments, respectively, regardless of the water source. A final example is that DI water alone extented vase-life for the flowers from sources B and C but not for A, however, the combination of preservative and DI water was always better than any tap water source minus preservative.

As a result of previous work (Table 1) and that presented in Table 3, it has been and can be generally recommended that the use of preservative and/or DI or Dist water will extend cut flower vase-life. However, when various water and flower sources are analyzed (Table 4), such clear-cut recommendations should not be made. Also, by just examing the TDS of a water source one cannot conclusively predict the effect on cut flower vase-life. For example, the lowest TDS of the 3 tap water sources was C but the vase-life in this water source was not better compared to sources A and B and in fact was detrimental (viz. induced leaf phytotoxicity) when containing preservative using flowers from source B. Finally, possible particulate constituents indigenous to the various water sources were not quantified as to their possible role in determining flower vase-life. Such particulates are known to react with quinoline compounds (i.e. HQC) in various fashions (7, 8, 11) which could greatly influence vase-life. Also, differences in pH among water sources could also influence the effectiveness of HQC (11) and hence the preservative solution.

In conclusion, each water quality, preservative, and production practice situation encountered should be investigated individually where cut flowers are being handled to determine the cultural advantages and costs of implementing any heretofore described methods in extending vase-life. More research is needed to determine the effects of various water constituents on the vase-life of cut flowers and on preharvest factors that may potentially affect vase-life. Finally, a systems approach is needed where a relatively standard water quality is used with known perservatives so that potential detrimental interactions between these 2 constituents can be reduced.

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Factors Affecting the Acidity of Tomatoes[1]

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Abstract. **Acidity was measured on ripe and overripe samples of 16 cultivars of tomato (*Lycopersicon esculentum* Mill.) 'Ace' and 'Garden State' were the lowest in acidity. In some samples of 'Garden State', 25% of the individual ripe fruits exceeded pH 4.8. Overripe tomatoes, tomato tissue infected with *Alternaria* and anthracnose, and fruits obtained from dead vines were also abnormally high in pH.**

Acidity of tomatoes varies over a wide range due to the influence of genetic and environmental factors (1, 2, 4, 5). Research was undertaken by the USDA in 1975 to determine whether the incidence of "low acid" tomatoes (pH above 4.6) would be high enough to constitute a potential health hazard to consumers of home canned tomatoes. *Clostridium botulinum* has been shown to grow and produce toxin in foods, including tomato products, at 4.8-5.0 (9). However, very few outbreaks of botulism have been associated with home canned tomatoes, and in those incidents where pH data were obtained, the pH of the implicated samples was substantially lower than 4.8 (6).

Our 1975 studies indicated that certain cultivars, locations, and growing

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conditions tended to produce higher pH tomato fruits, although the incidence of such tomatoes was very low, and none examined in our laboratory was as high as pH 4.8. We also demonstrated the fallacy many popular beliefs about low-acid tomatoes (7).

Our 1976 research on factors affecting the occurrence of lower acid tomatoes in reported here.

Sixteen cultivars, most of which had produced higher pH tomato fruits in previous years (7), were selected for the 1976 trials. Tomatoes were planted in 5 locations: Beltsville, Md.; Doylestown, Pa.; Mississippi State, Miss.; Sodus, Mich.; and Santa Paula, Cal. All but the last location were found to yield higher pH tomatoes in 1975 (7). Samples of most cultivars were obtained from 2 or more locations. Tomatoes grown at Beltsville and Doylestown were picked table-ripe and transported by bus or automobile to our laboratory, a trip requiring only a few hours. Tomatoes obtained from more distant locations were picked when less ripe (light to dark pink stage) and were shipped by air freight, arriving within 1-2 days after harvest, at which time they were usually ripe. Each lot of tomatoes was sampled when table or canning ripe. The remaining tomatoes were stored at about 25°C in a dimly-lit room and were resampled when overripe, as judged by firmness and color, the fruits still being considered edible.

About 15 washed tomatoes from each sample were individually blended and analyzed for pH and titratable acidity as described previously (7). A combination electrode was used to measure the end point for the determination of titratable acidity; standard glass electrodes and calomel reference electrodes (fiber junction) and an expanded scale pH meter were used for all other pH measurements.

The effects of three fungal diseases on tomato acidity were determined with 'Ace 55 VF' tomatoes grown in Doylestown. Uniformly ripe and unblemished fruits were washed, air-dried, and inoculated with pure cultures of *Alternaria tenuis, Colletotrichum coccodes* (anthracnose), and *Geotrichum candidum* (sour rot), by applying a droplet of inoculum to the surface and puncturing the skin under the droplet with a sterile needle for the former 2 organisms and with a sterile knife for the last organism. Controls were inoculated with a droplet of sterile water. The inoculated tomatoes were incubated at about 25°C, and samples were analyzed for titratable acidity after 2, 6, and 13 days. At the same time, the infected portions of similar appearing tomatoes were excised and blended in a stainless steel semi-micro blending container for 1 min; the remaining portions of each tomato were blended in a standard blendor jar for 2 min. The pH of each homogenate was then measured.

The effect of bruising on tomato pH was determined by subjecting 'Ace 55 VF' fruits to a sharp blow applied with a Magness-Taylor pressure tester. The probe was retracted to a force reading of 2.2 kg (6 lb.), placed against the tomato, and suddenly released. This blow permanently dented but did not puncture the skin of the fruit. The dented portion and remainder of each fruit were separated, homogenized and analyzed for pH after incubation for as long as 13 days, as with the tomatoes inoculated with spoilage fungi.

Cultivar differences in tomato acidity. 'Ace', 'Ace 55 VF', 'Cal Ace', and 'Garden State' were substantially lower in acidity than the other cultivars examined (Table 1), and individual fruits with pH values exceeding pH 4.8 were found. In some ripe 'Garden State' samples, the incidence of such tomatoes exceeded 25%. Similarly high pH values for these cultivars have been reported previously by Wishnetsky (personal communication, 1976) and others (2, 3); 'Ace' and 'Garden State' had higher pH in our samples (7).

None of the ripe samples of the other 12 cultivars ('Big Girl', 'Fireball', 'Jet Star', 'Jubilee', Md 122, 'Oxheart', 'San Marzano', 'UC 105J', 'Valiant', and 'VF 10') contained many fruits exceeding pH 4.6, although some samples were low in titratable acidity. We obtained slightly higher pH values with 'Big Girl', 'Fireball', 'San Marzano', and 'Valiant' in 1975 (7).

All populations of tomato fruits exhibit a certain degree of variability in pH. In our study, standard deviations for pH between 0.14 and 0.17 were obtained with 'Ace' and 'Garden State'. The pooled standard deviation for pH was 0.16 for all 16 cultivars. Farrow (2) reported pH standard deviations of 0.16 and 0.15 for very large tomato samples surveyed in 1959 and 1961, respectively. Our data suggest that any tomato population having a mean pH above 4.5–4.6 is likely to contain individual fruits exceeding pH 4.8. Cultivars which produced appreciable amounts of such fruit would not be suitable for home canning. However, National Canners Association data (2, 6) as well as our earlier data (7) demonstrate that tomatoes having pH values above 4.8 are found very infrequently and therefore represent a minimal risk to home canners.

Acidity of overripe tomatoes. All cultivars were higher in pH and/or decreased in titratable acidity when overripe (Table 1). 'Garden State' and 'Cal Ace', which are very high in pH when ripe, show an even higher incidence of fruits with pH values exceeding 4.8 when overripe. However, 'Nova' which was relatively low in pH when ripe, also became very high in pH when overripe. Home canners have been cautioned against using overripe tomatoes because of their tendency to be higher in pH (10, 11).

Acidity of tomatoes from dead vines. 'San Marzano' and 'Fireball' grown in Doylestown, which remained attached to dead vines at the end of the season were considerably less acid than when sampled 42-48 days previously and in the case of 'Fireball' yielded a high proportion of fruits exceeding pH 4.8 (Table 2). No observations vine or fruit condition were made between the 2 harvests, but the fruits obtained from the dead vines were firm and normal in appearance, suggesting that the pH increase did not result from over-ripening. Such atypical tomatoes also are not suitable for home canning.

Acidity of decayed and bruised tomatoes. We observed exceptionally high pH values (pH 5.27) in tomatoes having soft and decayed areas resembling anthracnose and *Alternaria* infections. Subsequently, we inoculated 'Ace 55 VF' tomatoes with the fungi which produce these diseases and also sour rot. Over a 13-day period, tomatoes inoculated with *A. tenuis (Alternaria)* and *C. coccodes* (anthracnose) showed an increase in pH ac-

Table 1. Acidity of ripe and overripe fruits for five low-acid tomato cultivars.

Cultivar	Ripeness[z]	No. fruits analyzed	Mean pH	Sample distribution (%)			Mean titratable acidity (%)[y]
				pH ≥4.6	pH ≥4.7	pH ≥4.8	
Ace	R	30	4.52	47	27	10	0.326
	OR	29	4.57	55	28	7	0.234[x]
Ace 55 VF	R	60	4.50	40	13	2	0.296
	OR	59	4.52	36	15	7	0.299
Cal Ace	R	58	4.52	38	10	2	0.336
	OR	45	4.57	47	22	16	0.286[x]
Garden State	R	30	4.58	63	37	20	0.330
	OR	41	4.70[x]	93	66	29	0.323
Nova	R	10	4.26	0	0	0	0.439
	OR	15	4.53[x]	53	13	7	0.279[x]

[z]R = ripe, OR = overripe.

[y]Calculated as citric acid.

[x]Difference between overripe and ripe is statistically significant at the .05 level.

companied by a decrease in titratable acidity (Table 3). The infected portions of these tomatoes attained pH values as high as 6.37 *G. candidum* (sour rot) had no effect on tomato acidity. Schlösser (8) observed a pH shift from 4.5 to 5.7 in wounded but not infected tomatoes. Subsequent fungus infections by *Corticium rolfsii, Botrytis cinerea,* and *Monilia fructigena* lowered the pH while infection by *Gloeosporium fructigenum* increased the pH to 6.4.

We observed a small elevation (no more than 0.2 unit) in the pH of bruised portions of tomato fruits. However, since this effect was highly localized and did not progress with time, we do not consider it to be relevant to the safety of home canned tomatoes. Home canners have been advised to avoid soft and decayed tomatoes (10).

Table 2. Acidity of ripe tomato fruits from dead vines.

Cultivar	Harvest date	No. fruits analyzed	Mean pH	Sample Distribution (%) pH >4.6	pH >4.7	pH >4.8	Mean titratable acidity (%)[z]
Fireball	Aug 3	15	4.40	0	0	0	0.386
	Sept 20[y]	16	4.68[x]	81	62	38	0.221[x]
San Marzano	Aug 9	15	4.40	0	0	0	0.444
	Aug 20[y]	14	4.50[x]	36	7	0	0.289[x]

[z]Calculated as citric acid.
[y]Vines dead at time of second harvest.
[x]Difference between harvests is statistically significant at .05 level.

Table 3. Acidity of 'Ace 55 VF' tomatoes inoculated with spoilage organisms.

Inoculum[z]	Incubation time (days)	pH of excised portions: Inoculated	Remainder	Titratable acidity (%)[y]
Alternaria tenuis	2	4.39	4.38	0.268
	6	4.69	4.55	0.250
	13	6.37	4.62	0.217
Colletotrichum coccodes	2	4.45	4.40	0.314
	6	4.53	4.32	0.342
	13	5.28	4.75	0.226
Geotrichum candidum	2	4.52	4.56	0.256
	6	4.52	4.52	0.268
	13	4.57	4.51	0.269
Control	2	4.35	4.28	0.266
	6	4.40	4.45	0.306
	13	4.48	4.47	0.295

[z]Inoculum applied by puncturing skin with sterile needle; control inoculated with sterile H_2O.
[y]Calculated as citric acid; determined on duplicate whole tomatoes, similar to those analyzed for pH.

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The Effect of Ethylene-induced Ripening on Tomatoes of Different Genotypes[1]

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Abstract. **Mature green 'Homestead' tomatoes (*Lycoperiscon esculentum* Mill.) and 3 advanced breeding lines were treated with ethylene gas and some compositional parameters of the treated fruit were compared with those of control fruit. Tomato breeding line T3702 j_2 showed a greater response to ethylene treatment than 'Homestead' and other advanced breeding lines carrying the crimson (og^c) and high pigment-crimson (hp og^c) genotypes. Ethylene treatment had negligible effects on the levels of soluble solids, dry matter, ascorbic acid, β-carotene, and lycopene in the genotypes studied. The mean pH of the treated samples was slightly higher than that of the control, but was not statistically significant in all cultivars or breeding lines every year. The data suggest that breeders should pay attention to the response of breeding lines and potential cultivars to ethylene-induced ripening.**

Fresh market tomatoes are commonly picked mature green and ripened by exposure to ethylene, either before transit or at repacking facilities near the major markets. Ethylene treatment induces the mature green fruit to ripen earlier and more uniformly (3, 9, 11, 12). However, tomato cultivars vary in ripening rate whether ripened with (1), or without (14), ethylene treatment. Changes in the final composition of fruits as a result of ethylene treatment have been studied (13)[3], but direct comparisons among different cultivars have not been made.

The purpose of this study was to determine if our advanced breeding lines respond differently from established cultivars when treated with ethylene gas. For these experiments we used: 'Homestead', a widely grown cultivar for the fresh market; T3702, a breeding line with the jointless (j_2) allele; T3790, a breeding line with a combination of the high pigment (hp) and crimson (og^c) alleles; and T3810, a breeding line with the crimson allele.

Tomato fruit were produced in the field for the 1974 experiment and in the greenhouse for the 1975 and

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