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Growth, Free Amino Acids, and Mineral Composition of Tomato Plants in Relation to Nitrogen Form and Growing Media

Jose R. Magalhaes[1] and G.E. Wilcox
Department of Horticulture, Purdue University, West Lafayette, IN 47907

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Abstract. **Tomato plants 'Campbell 1327' grown in peat with NH_4 nutrition had no visible symptoms of NH_4 toxicity, while severe symptoms of NH_4 toxicity were displayed in solution or sand culture. Growth of plants was much better with NO_3-N than NH_4-N in sand, vermiculite, or solution culture; but in peat, growth of NH_4-treated plants equalled or exceeded that of NO_3-treated plants in sand, vermiculite, and peat. The total dry weight of NH_4-treated plants grown in peat was 2, 2.5, and 3.4 times higher than plants grown in vermiculite, sand, and solution culture, respectively. Content of uncomplexed NH_4^+ in NH_4-treated plants grown in peat was reduced markedly compared with other media. NH_4-treated plants grown in sand, vermiculite, and solution culture, displaying NH_4 toxicity symptoms, had a total amino acid:free NH_4^+ molar ratio < 2, compared to 6–8 with NO_3. For NH_4-treated plants grown in peat the ratio was similar to that of NO_3-treated plants. Asparagine and glutamine in NH_4-treated plants grown in peat were 3.5 and 11.3 times higher than with NO_3-N, indicating a high efficiency in detoxification of NH_4 through incorporation into these amino acids. The medium on which a plant is grown can have a marked influence on the plant response to N form.**

N is often the most limiting of factors influencing plant growth in many cropping systems. Less than 50% of the N fertilizer applied may be utilized by the crop (1) due to loss by leaching and denitrification. Application of NH_4-N fertilizer could increase N utilization efficiency because NH_4^+ is not as readily leached nor denitrified. Inhibitors of nitrification have been used to prevent conversion of NH_4^+ to NO_3^- and to increase the utilization efficiency when losses of N by leaching or denitrification were high (19, 26, 27).

Although growing plants assimilate N in fully reduced form, NH_4-N ions are toxic to many plants (8, 21, 22). The toxicity of NH_4-N to higher plants generally has been demonstrated in experiments carried out in sand or solution cultures. The physical and chemical properties of soil and soilless media used as horticultural substrates can differ from solution or sand in their influence on plant growth (20, 28). Water and sand culture have little or no buffering power or cation exchange capacity. In contrast, peat, the main ingredient in soilless mixes, and soil have high cation exchange capacity (28). Therefore, this high cation exchange capacity could influence response to N forms by plants growing in these substrates.

The objective of this study was to determine the effects of N forms (NO_3-N and NH_4-N) on growth, N metabolism, and nutrient uptake by tomato plants growing in different media.

Material and Methods

'Campbell-1327' was seeded in flats of vermiculite, and seedlings were transplanted 8 days after emergence into 2.8-liter, black, plastic pots filled with silica sand, vermiculite, sphagnum peatmoss, or aerated solution culture. The peat used was pH 3.5 with 120 mg/100 g extracted acid, 133 mg/100 g CEC, and a 9.3% base saturation. The peat substrate received 5 g/pot $CaCO_3$ before transplanting to adjust the pH. The seedlings in all media received 500 ml · pot^{-1} · day^{-1} modified Hoagland's solution at 112 ppm N as NO_3 for 10 days prior to the initiation of the N form treatments.

Prior to starting the treatments, the sand-, vermiculite-, and peat-filled pots were leached with dionized water at 2 liters pot^{-1}. The solution culture pots were refilled with a new solution. The N form treatment solutions contained 112 ppm N as either NO_3 or NH_4 with KH_2PO_4 at 2 mM for both solutions. The solutions for both treatments were adjusted to pH 5.7.

Two, 120-liter, black, plastic tanks were used as reservoirs for the NO_3 and NH_4 solutions, respectively. A Little Giant water pump delivered each nutrient solution to the pots through a spaghetti-tube system. The solutions were pumped for 5 min every 30 min for 12 hr a day at a flow rate of 10 ml min^{-1} per tube, 1200 ml · pot^{-1} · day^{-1}. The nutrient solutions were not recirculated to the respective reservoirs but were leached through the pots, including those filled with solution culture. Leachate was collected every 4 days for pH and NO_3 analysis.

This experiment was conducted in the greenhouse during Oct. and Nov., 1982. Plants were grown in normal daylight supplemented with 12 hr of fluorescent light daily at 24° to 28°C temperatures. The experimental design was a completely randomized design with 4 growing media (sand, vermiculite, peat, and water) and two N forms (NO_3 and NH_4) with 5 replications and 1 plant per pot.

Plants were harvested 12 days after starting treatments. Shoots and roots were taken as separate samples, and their fresh and dry weights were obtained. Root length (L) was measured by using the Tennant method (25). The mean root radius, ro, was calculated as: ro = (FW/L)1/2, where FW was root fresh weight in g and L was the root length in cm. This formula assumes root specific gravity of 1.0 and that the root is cylindrical in shape, according to Classen and Barber (5). The root surface, RS, was calculated from: RS = 2 roL, with ro and L as defined previously.

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[1]C.P.H. EMBRAPA, C. Postal (11) 1316, 70.000 Brasilia DF, Brazil.

Table 1. pH change and N as NO_3 in the leached solution for tomato growing on different media and N forms.

Day of sample	Leachate composition[z]							
	Solution		Sand		Vermiculite		Peat	
	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4
	pH							
4	6.0	5.7	6.0	5.7	6.6	6.0	4.6	4.5
8	6.2	5.7	6.2	5.6	6.6	6.0	4.3	4.0
12	6.2	5.7	6.2	5.6	6.6	5.9	4.2	4.0
	N as NO_3 ppm							
8	114	0.0	114	0.0	110	0.0	105	0.0
12	114	0.0	113	0.0	108	0.0	100	0.0

[z]Leachate a composite of replicates at each sampling.

Tissue samples were dried in a forced-air oven at 70°C and ground to pass a 20-mesh screen in a Wiley Mill. Ground tissue samples (100 mg) were digested in 1.0 ml of concentrated H_2SO_4, oxidized with H_2O_4, and diluted to 50 ml with distilled water. The solutions were analyzed for N, P, K, Ca, and Mg. The K, Ca, and Mg concentrations were determined with a Unicam SP-90 AA spectrophotometer. N was determined by Nesslerization and P was determined by an ammonium molybdate-amino naphthol sulfonic acid reduction procedure, using a Bausch and Lomb Spectronic-20. Nitrate and NH_4-N determinations were made from 500 mg of dried ground tissue shaken 30 min in 50 ml of distilled water and filtered with No. 1 filter paper. NO_3-N was determined with an Orion Nitrate Electrode Model 92-07 and NH_4-N was determined with an Orion Ammonia Electrode Model 90-10 using Ionanalyzer Specific Ion Meter Model 401.

For amino acid analysis, 500 mg of ground tissue were homogenized in 12 ml 3.5% sulfosalicylic acid using a polytron. The homoginate was centrifuged for 20 min at 5000 rpm in an automatic, refrigerated centrifuge at 3°C. The clear supernatent was diluted 3 times with citrate buffer, and the amino acid was determined using a Beckman 119 CL Amino Acid Analyzer. The method used was single-column physiological analysis, W3P type resin (from Beckman) with 22 cm resin bed height and column temperatures from 40° to 65°, starting at 20 min.

The elution profile was made for 66 min of pH 2.83, 0.20 N Lithium citrate (A); followed by 99 min of pH 3.70, 0.20 N Lithium citrate (B); followed by 102 min of pH 3.75, 1.00 N Lithium citrate (C); followed by 5 min of 0.30N LiDH (D); followed by 15 min of pH 2.83, 0.20 N Lithium citrate (A) for re-equilibration.

All buffers were purchased from Beckman Instrument Bioproducts Division and prepared as per instructions, except for buffer C (pH 3.75, 1.00 N Lithium citrate) which was made with 3% 2-Propanol.

The developing reagent was Ninhydrin reagent prepared as per Beckman's instructions using Peirce brand Crystal Ninhydrin reagent.

Results

Leachate composition. The nutrient feed system used in this experiment avoided pH change and nitrification in the substrate media (Table 1). The NO_3-N level in NH_4-N leaching solutions was nil, while in NO_3-N leaching solutions it was about the same as the source solution during the course of the experiment. The pH of the leaching solution did not vary during the experimental period for any treatment, although the pH of the leaching solutions reflected the effect of N source and media.

Growth. Growth of plants in solution, sand, and vermiculite culture was much better with N supplied as NO_3 than with NH_4 (Table 2). However, growth of NH_4-treated plants in peatmoss equalled or exceeded that of those with NO_3-N treatment in sand, vermiculite, or peat. The total dry weight of NH_4-treated plants

Table 2. Tomato growth as influenced by N form and growing media.

Unit of measurement	Growth								LSD[z] 5%
	Solution		Sand		Vermiculite		Peat		
	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	
	g per plant								
Shoot fresh wt	25.20	8.10	16.60	4.53	12.47	9.80	16.93	18.13	2.07
Shoot dry wt	1.47	0.39	1.00	0.28	0.73	0.51	1.00	1.06	0.12
Root dry wt	0.18	0.08	0.12	0.06	0.07	0.06	0.10	0.11	0.02
Total dry wt	1.65	0.47	1.12	0.34	0.80	0.57	1.10	1.17	0.12
	m								
Root length	38.27	11.03	16.60	6.91	12.83	9.26	26.97	29.84	3.98
	cm^2								
Root area	368	122	215	93	124	90	200	217	28

[z]All interactions significant.

Table 3. N fraction in different parts of tomato plants as influenced by N form and growing media.

N fraction	Plant part	Tissue composition: Solution NO_3	Solution NH_4	Sand NO_3	Sand NH_4	Vermiculite NO_3	Vermiculite NH_4	Peat NO_3	Peat NH_4	LSD[z] 5%
		Micromoles per g dry wt								
NO_3	Root	0.29	0.25	0.49	0.07	0.45	0.08	0.41	0.05	0.07
Free NH_4	Shoot	35	500	35	270	39	197	53	113	45
	Root	25	123	35	141	27	85	17	46	10
Total amino acid	Shoot	227	300	219	325	202	311	235	553	31
		Ratio								
Total amino acid / Free NH_4		7.79	0.60	6.53	1.44	6.55	1.73	6.57	5.55	2.25

[z]All interactions were significant for N fractions except for Total N (shoot and root) and NO_3 (shoot). Total N (shoot) media means: solution 5.18; sand 5.21; vermiculite 5.31; peat 5.93; LSD p = 5%, 0.22. N form means total N shoot: NO_3 5.32; NH_4 5.49; LSD p = 5%, 0.16. Total N (root) media means: solution 3.31; sand 3.42; vermiculite 3.32; peat 3.58; LSD p = 5%, 0.14. N form means, total N (root): NO_3 3.28; NH_4 3.54; LSD p = 0.10. NO_3 (shoot) media means—NS. N form means, NO_3 (shoot): NO_3 1.90; NH_4 0.22; LSD p = 5%, 0.05.

grown in peat was 2, 2.5, and 3.4 times higher than NH_4-treated plants grown in vermiculite, solution culture, and sand, respectively. NH_4-N treatment tended to decrease root length and root surface area in all media except peat.

N fractions. NH_4-treated plants tended to have a slightly higher reduced nitrogen content in shoots and roots than with NO_3-N nutrition, regardless of the growing medium (Table 3). N content in tissue was highest for plants grown in peat. The content of free NH_4 in shoots and roots of NH_4-treated plants grown in peat was much less than that of plants grown in solution culture, sand, and vermiculite, respectively; whereas, NO_3-treated plants had very low levels of free NH_4 in shoots and roots, with little effect of growing media.

The sum of free amino acid in shoots of NH_4-treated plants was significantly higher than in plants with NO_3-N nutrition, with the greatest effect of N form on plants grown in peat. NH_4-treated plants exhibiting NH_4 toxicity symptoms had a total amino acids: free NH_4 ratio in the range of 0.6 to 1.7 when grown in sand, vermiculite, or solution culture. However, for plants grown in peat with no visible NH_4 toxicity symptoms, this ratio was 5.6, which was close to that for NO_3-treated plants grown in any medium.

Table 4. Amino acid content in shoots of tomato plants as influenced by N form and growing media.

Amino acid	Amino acid content in shoot: Solution NO_3	Solution NH_4	Sand NO_3	Sand NH_4	Vermiculite NO_3	Vermiculite NH_4	Peat NO_3	Peat NH_4	LSD[z] 5%
	Micromoles per g dry wt								
Asparagine	32.50	42.00	22.50	61.50	16.00	45.50	37.00	128.00	16.14
Glutamine	8.79	26.02	8.63	49.11	7.51	25.83	8.40	95.02	3.85
Aspartate	23.41	6.02	24.09	7.46	20.81	8.91	22.14	14.62	5.70
Glutamate	3.23	2.37	3.29	3.22	3.20	4.00	2.89	8.21	0.39
GABA[y]	58.53	53.15	54.11	50.90	56.54	51.40	54.39	93.98	22.70
Glycine	2.34	3.79	2.80	3.11	2.68	6.17	2.58	6.65	0.70
Serine	9.13	27.11	9.01	22.61	8.16	26.63	9.81	34.92	1.75
Thresnine	6.45	6.19	7.07	5.96	6.91	7.10	6.30	12.01	1.38
Proline	7.18	9.76	7.38	9.20	6.49	10.78	7.84	10.10	2.60
Alanine	15.99	22.61	19.24	28.79	20.57	24.14	15.37	36.34	2.38
Valine	9.70	12.21	9.87	10.83	8.09	16.85	11.12	16.58	1.50
Leucine	10.56	13.76	11.05	11.92	9.82	18.14	12.29	18.12	1.79
Isoleucine	6.44	8.56	6.36	8.19	5.49	10.05	7.33	10.22	0.85
Arginine	4.38	20.88	4.75	16.53	4.20	13.75	5.11	21.57	0.68
Lysine	6.34	12.56	7.28	10.61	6.21	13.20	7.54	13.08	1.36
Tyrosine	3.26	6.27	3.99	5.44	3.45	5.57	4.24	6.97	0.58
Phenylalanine	6.11	6.78	5.83	6.21	5.18	8.21	6.92	9.10	0.65
Tryptophane	1.49	3.03	1.42	2.53	0.94	1.41	1.70	2.28	0.17
Ethanolamine	7.07	9.23	6.10	4.96	5.56	6.40	7.50	7.92	0.50
Histidine	1.78	4.82	1.61	3.44	1.53	2.74	2.02	3.20	0.35
Methionine	0.99	0.86	1.02	0.54	1.11	2.52	1.15	2.03	0.44
P-Serine[x]	1.49	2.75	1.48	2.22	1.47	2.41	1.34	1.71	0.33

[z]All interactions significant.
[y]GAGA = Gamma amino butyric acid.
[x]P-Serine = Phosphorous serine.

Table 5. Mineral composition of tomato plants as influenced by N form and growing media.

Element	Plant part	Nutrient content in tissue (% dry wt)								LSD[z] 5%
		Solution		Sand		Vermiculite		Peat		
		NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	
P	Shoot	1.05	1.35	0.97	1.44	1.04	1.51	0.97	1.32	0.54
	Root	0.70	1.88	0.66	1.09	0.61	0.63	0.53	0.56	0.10
K	Shoot	6.61	5.51	6.41	5.13	6.37	6.09	6.33	6.10	0.63
	Root	2.35	2.15	3.05	2.67	3.17	2.13	1.97	1.37	0.44
Ca	Shoot	3.60	1.46	3.29	1.40	2.47	1.15	3.34	2.37	0.18
	Root	0.69	0.40	1.17	0.38	0.76	0.35	0.81	0.51	0.15
Mg	Shoot	0.78	0.58	0.77	0.49	1.10	0.90	0.63	0.43	0.05
	Root	0.46	0.24	0.43	0.23	0.46	0.26	0.34	0.19	0.03

[z]All interactions significant.

Amino-acid content. Ammonium-treated plants grown in peat had higher levels of free amino acids than in other growing media. In general, amino acid content of shoots of NH_4-treated plants was higher than for NO_3-treated plants, regardless of the growing media (Table 4). An exception was noted for aspartate on all media and for GABA on all media except peat. The amino acid contents in NO_3-treated plants were not affected greatly by the growing media, with the exception of asparagine, which was markedly higher on peat than on the other media. Asparagine alone, one of the major components of amino acid pool of tomatoes, accounted for 23% of the total amino acids in NH_4-treated plants grown in peat. Asparagine and glutamine in NH_4-treated plants grown in peat were 3.5 and 11.3 times higher than with NO_3-N nutrition.

P content. P content in the shoot was higher in plants treated with NH_4 compared to NO_3 (Table 5). The growing media did not significantly affect the P content of the shoot, but in roots, P content was greatest in solution culture and least in peat.

K content. K content in the shoot of plants grown in sand and solution culture was lower with NH_4-N compared to NO_3-N, but K content was not significantly affected by N form in peat or vermiculite (Table 5). K content in roots of NO_3-treated plants was slightly higher than in NH_4-treated plants for all media. Roots of plants growing in peat had a lower K content compared to vermiculite, sand, or solution culture for both N forms.

Ca content. Ca contents in roots and in shoots of NH_4-treated plants grown in vermiculite, sand, and solution culture were about half that for NO_3-treated plants (Table 5). However, Ca content in tissue of plants grown in peat was less affected by N form than in the other media.

Mg content. The Mg content of the shoot and root tissue was reduced from 20% to 40% with NH_4-N nutrition (Table 5). Mg composition of the tissue was highest in vermiculite and lowest in peat. The Mg composition of the roots was about 50% that of the shoot tissue.

Total nutrient uptake. The total N and P uptake were decreased with NH_4-N compared to NO_3-N nutrition for plants growing in vermiculite, sand, and solution culture, reflecting the decreased dry matter yield (Table 6). The plants grown in peat medium had higher N and P uptake with NH_4-nutrition. K, Ca, and Mg uptake by plants grown in peat was not affected greatly by N source, whereas NH_4-N nutrition markedly reduced the uptake of K, Ca, and Mg by plants grown in solution, sand, and vermiculite media.

Root uptake efficiency. Uptake of P per unit area of root surface increased slightly with NH_4-N nutrition in all media (Table 7). Ca uptake was reduced by about 70% in sand and solution culture while in peat it was reduced only about 30% and just over 50% in vermiculite. Mg uptake per unit area of root was reduced 40% and 60% in solution and sand culture, respectively, while reduction was 20% and 30% in vermiculite and peat for plants on NH_4 nutrition.

Discussion

Different plant responses to N forms have been reported that could be attributed to different media on which the plants were grown. A preliminary experiment prior to this study showed that tomato plants grown in peat-vermiculite medium were much less sensitive to NH_4-N than plants grown in sand. The incorporation of $CaCO_3$ in sand culture to maintain solution near pH 6.0 decreased the detrimental effect of NH_4, agreeing with previously published data (4, 6, 15, 23, 24). However, the total dry weight was 47% less than for NH_4-treated plants grown in peat-vermiculite with low pH. Apparent contradictory results as reported by Morris and Giddens (16) and Bennet et al. (2) for the

Table 6. Total nutrient uptake by tomato plants as influenced by N form and growing media.

Element	Nutrient uptake (mg/plant)								LSD[z] 5%
	Solution		Sand		Vermiculite		Peat		
	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	
N	81.20	22.99	56.20	16.68	39.95	29.91	61.43	68.81	6.69
P	16.67	6.80	10.55	4.65	8.03	8.08	10.27	14.62	1.38
K	99.60	23.08	68.16	15.91	48.90	32.51	65.53	66.12	11.20
Ca	54.00	6.16	34.57	4.13	18.62	6.09	34.35	25.71	3.92
Mg	12.25	2.44	8.23	1.51	8.37	4.77	6.68	4.77	0.87

[z]All interactions significant.

Table 7. Nutrient uptake efficiency as influenced by N form and growing media.

Element	Nutrient uptake per root surface area								LSD[z]
	Solution		Sand		Vermiculite		Peat		
	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	NO_3	NH_4	5%
	Microgram/cm² root								
P	45.30	55.73	48.96	50.12	65.03	89.81	51.83	68.07	9.33
Ca	146.70	50.49	160.40	45.50	151.50	67.70	173.20	119.7	25.70
Mg	33.26	20.00	38.20	16.32	67.79	53.04	33.78	22.12	8.14

[z]All interactions significant.

same plant species could be explained based on different methodology. The former used fumigated clay loam soil, and corn grew equally well with NH_4-N and NO_3-N; the latter used solution culture, and NH_4-N was detrimental to growth of corn plants.

NH_4-N nutrition suppressed growth in solution and sand culture, in agreement with previous reports (6, 7, 12, 18). However, growth of NH_4-treated plants in pure peat was slightly better than that recorded for the NO_3-N treatment. Root diameter of NH_4-treated plants was greater in sand than in solution culture, consistent with results reported by Peterson and Barber (17), with the smallest root diameter in peat media.

Higher free amino acid accumulation in NH_4-treated plants, compared to NO_3-N nutrition, has been reported previously as being associated with NH_4 toxicity (1, 8, 10, 13, 14, 22). This effect was observed in this experiment for plants grown in sand, vermiculite, and solution. However, the NH_4-treated plants grown in peat contained almost twice as much free amino acids as plants grown in sand, vermiculite, or solution culture, but did not show any visible symptoms of NH_4 toxicity. In contrast, the content of uncomplexed NH_4 in shoot and root of NH_4-treated plants grown in peat was reduced markedly compared to that of plants grown in the other media. The total amino acids:free NH_4 ratio was from 0.6 to 1.7 for NH_4-fed plants exhibiting NH_4 toxicity symptoms when grown in sand, vermiculite, or solution culture. However, the ratio for NH_4-treated plants was 5.6 when grown in peat. This ratio was similar to that of the NO_3-treated plants, suggesting it to be a good indicator of NH_4 toxicity. Asparagine alone accounted for 23% of the total amino acids in NH_4-treated plants grown in peat. Asparagine and glutamine in NH_4-treated plants grown in peat were 3.5 and 11.3 times higher than with NO_3-N, indicating high efficiency in detoxifying NH_4 through incorporation into these amino acids (8, 14).

In agreement with results reported for several species (3, 7, 9, 11, 12, 18), NH_4-N suppressed K, Ca, and Mg content in tissue. However, K and Ca contents in tissue of plants grown in peat were not affected greatly by N form. NH_4-treated plants grown in peat contained almost twice as much Ca as in any other medium. Thus, the medium on which a plant is grown can have a marked influence on the plant response to N form.

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Evaluation of Combining Ability, Heterosis, and Genetic Variance for Fruit Quality Characteristics in Bush Muskmelon

Thomas J. Kalb II[1] and D.W. Davis[2]
Department of Horticultural Science and Landscape Architecture, University of Minnesota, St. Paul, MN 55108

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Abstract. **A 6-parent diallel was established in 1981 at Excelsior, Minn. and at Santa Paula, Calif. to analyze combining ability and heterosis for fruit quality of traits in bush muskmelon (*Cucumis melo* L.). GCA variance exceeded SCA variance for all traits. Minnesota breeding lines were superior in GCA for most interior quality traits, but inferior to Florida and California lines in exterior quality. Correlations between the performance of parents and the average of their hybrids were consistently positive, and often significant. Favorable heterosis over the midparent was shown for soluble solids, net density, and net rope, and, to a lesser extent, for flesh amount, rind thickness, cavity amount, and cavity dryness. A 3 × 10 design II at Excelsior showed estimates of additive variance exceeding those of dominance variance for all traits except fruit weight, shape index, and vein tract. The large estimates of additive variance provided for moderately high (40–70%) estimates of heritability for most traits.**

The development of bush or short internode cultivars is a new advance in the genetic improvement of muskmelon. The compact plant habit will allow home gardeners to culture melons in limited space. For commercial growers, the bush types may be used to increase plant populations and to concentrate the setting of fruit near the crown of the plant, both desirable qualities where once-over and (perhaps in the future) mechanical harvesting is practiced (21).

The bush character in muskmelon is reported to be controlled by a major recessive gene, and at least 2 modifier genes (8). Bush-type breeding lines have recently been developed at land-grant universities in California, Florida, and Minnesota (6, 12, 25, 26). Each program, however, has used different selection criteria and different germplasm under different environmental stresses, all leading to the development of breeding lines with much diversity among them. This genetic diversity may be utilized in a hybrid breeding program. The improvement of fruit quality in muskmelon through hybridization has been well-documented (3, 9, 17, 20).

These diverse lines grouped together also represent a reference population from which genetic variance components are estimated. The significance of additive and dominance gene action within a breeding population may be estimated through the variances of general and specific combining ability. Studies of muskmelon with the dominant, normal plant habit have revealed that general combining ability (GCA) is significant for all fruit quality characteristics evaluated (2, 17), indicating the importance of additive effects. The specific combining ability (SCA) variance in these studies was consistently of less magnitude than the GCA, but nonetheless, was also significant for many characteristics.

Besides the nature of the genetic variance, the degree to which genetic effects are expressed in the phenotype may influence selection methods. Heritability estimates for fruit quality characteristics have been reported as moderately high for normal-vined muskmelon (7, 16). Whether these estimates are representative of heritability in bush muskmelon may depend in part upon the linkage and pleiotropic effects of the genes responsible for the bush habit. Such effects have been reported for these genes (19, 21).

The first objective of this study was to analyze the effects of hybridization in bush muskmelon. This analysis involved the estimation of the combining ability for 6 breeding lines, and the computation of heterosis. Our other objectives were to evaluate the genetic variance of bush muskmelon, and to determine the degree to which genetic effects are expressed in the phenotype.

Materials and Methods

Six breeding lines, 2 from each of the university breeding programs of Minnesota, Florida, and California, were selected for use in a complete diallel. These lines were Minnesota 101

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[1]Graduate Student.
[2]Professor.