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The Influence of Medium Heterogeneity and Three Rootstocks on Growth and Nutrient Levels of Greenhouse-grown 'Valencia' Orange Trees[1]

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***Abstract*. One-year-old 'Valencia' orange [*Citrus sinensis* (L.) Osbeck] trees on rough lemon (*C. limon* Burm. f.), Carrizo citrange [*Poncirus trifoliata* (L.) Raf. X *C. sinensis*], and sour orange [*C. aurantium* (L.)] rootstocks were transplanted into 4 soil media and grown in the greenhouse for 2 years. Treatments were 1) the entire pot filled with 2 sand: 1 sphagnum peatmoss: 1 perlite (v/v/v); 2) the entire pot filled with 3 red clay: 1 sand (v/v); 3) the lower half of the pot filled with sand: sphagnum peatmoss: perlite and the upper half with clay: sand; 4) the lower half of the pot filled with clay: sand and the upper half with sand: sphagnum peatmoss: perlite. The trees were grown from February to October 1979 when the tops were cut off. A single shoot was allowed to regrow and the trees were harvested again in October 1980. The largest trees were on rough lemon rootstock; trees on Carrizo were slightly smaller, those on sour orange distinctly smaller. Trees on sour orange grew very poorly in treatments 1 and 4 when the whole medium or the upper layer was sand: sphagnum peatmoss: perlite. Trees on all rootstocks grew best in clay-sand over sand-sphagnum peatmoss-perlite. Rootstocks induced significant differences in 12 elements, the media in 10 of 14 elements determined in the leaves. They also affected K, Mg, Zn and water-soluble phenolics in wood and bark. There were rootstocks × medium interactions for growth, 13 elements in the leaves, and the 3 elements and phenolics in the wood and bark.**

Tree decline problems have been especially serious in the citrus-growing areas of southeastern and southwestern Florida. Citrus is commonly grown there on beds dredged out of marshes or swamps. The water table usually remains 1 – 1.5 m below the surface, which gives trees adequate rooting space. The dredging process, however, often mixes or layers different soil types to create a profile with strata of sharply varying properties (10). Susceptibility to declines, especially citrus blight, varies with rootstock. Accumulation of Zn and K in the young wood is one of the diagnostic criteria used to identify blight (6, 13, 15, 16, 17). This report shows how young 'Valencia' trees on 3 rootstocks grew when their rooting zone consisted of layers of 2 distinctly different soil media and how rootstocks and medium heterogeneity affected growth and nutrient uptake.

Materials and Methods

Virus-free trees of 'Valencia' orange on rough lemon, Carrizo citrange, and sour orange rootstock were grown in a 2 subsoil sand-1 sphagnum peatmoss-1 perlite medium (v/v/v), with dolomite added to raise the pH from 5.4 to 6.5, in pots (15 cm wide, 16 cm deep) in a greenhouse until they were 1 year old. Then they were removed from the pots and the soil was washed off their root systems with a stream of water before they were repotted in larger containers (29 cm wide, 27 cm deep). Five replications of trees on each rootstock were planted in 4 media.

Two types of steam-sterilized potting mix were used in making up the treatments: a) the same sand-sphagnum peatmoss-perlite mixture in which the trees had grown for a year; b) a 3:1 v/v mixture of red subsoil clay (an argillic horizon from a grossarenic paleudult), commonly found under citrus groves in central Florida, and subsoil sand. The clay, from a commercial clay pit, was of the nonshrinking, kaolinitic type. The mixture was water permeable, but it had a bricklike consistency, without cracks, when dry. Analyses of these soil mixes (pH, C.E.C., bulk density, and 1 N ammonium acetate and water extractable ions) are listed in Table 1.

The entire pot was filled with sand-sphagnum peatmoss-perlite mix in treatment 1 ("sand"). The pots were filled with clay-sand mix in treatment 2 ("clay"). Treatment 3 ("clay/sand") consisted of the lower half of the pot filled with sand-sphagnum peatmoss-perlite, and the upper half with clay-sand mix. Treatment 4 ("sand/clay") was the reverse of treatment 3, with sand-sphagnum peatmoss-perlite over clay-sand. In repotting, the root systems of the trees in treatments 3 and 4 were set so that half of the root system would be in one, half in the other soil medium.

All terminals were tagged so linear growth after the start of treatment could be measured. Five leaves were collected from each tree and pooled into a composite sample for each rootstock and each treatment. The leaves were analyzed for 13 elements by standard methods (2, 8, 17) and the results are summarized in Table 1.

The trees were grown on a greenhouse bench from February 1979 to October 1980 arranged in randomized, complete blocks, under 45% shade. They were watered and sprayed with insecticides as needed. A solution prepared with commercial fertilizers, containing 200 ppm N (22% NH_4, 78% NO_3), 37 ppm P, 120 ppm K, 60 ppm Ca, and 109 ppm Mg, with minor elements as described by Smith (12), was applied every 2 weeks.

The trees were fertilized only every 30 days between November 1979 and March 1980, when a 14-day regime was resumed. In October 1979, linear growth since the start of the ex-

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Table 1. Soil and leaf analyses at the beginning of the experiment.

Variable	pH	CEC (m.e./100g)	Bulk density (g/cc)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	Fe (ppm)	Cl (ppm)	SO_4 (ppm)
				Soil analyses							
Media											
Sand-sphagnum peatmoss-perlite (2:1:1)	6.5	4.60	0.74	86[z]	10	818	124	19	4		
					4[y]	31	32	29		34	262
Clay-sand (3:1)	4.8	2.47	1.39	52	16	24	22	3	19		
					6	9	6	6		22	87

Leaf analyses[x]

Rootstock	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Na (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	Cl (ppm)	B (ppm)	Mo (ppm)
Valencia/ Rough lemon	2.96a	.203ab	1.63c	3.03a	.525b	699b	78a	9c	21a	6a	926b	119a	3.2a
Valencia/ Carrizo citrange	3.20a	.222a	2.28a	2.46a	.535b	402c	79a	13b	15b	6a	965b	108a	1.2c
Valencia/ Sour orange	3.11a	.190b	2.00b	3.01a	.647a	984a	64b	22a	16b	4b	1523a	127a	2.2b

[z]Extraction with 1 N ammonium acetate, pH 7.
[y]1:1 water extract, shaken for 1 hr.
[x]Means of 4 samples; mean separation within column by Duncan's multiple range test, 5% level.

periment was measured, the shoots were cut off 4 cm above the budunion and weighed, 30-leaf samples were collected from each tree, the lowest 15 cm from each shoot was removed, and the bark was washed and separated from the wood. The washed leaf samples and the bark and wood samples were dried at 65°C, ground to 20 mesh, and ashed overnight at 450°. Calcium, Mg, Fe, Mn, Zn, Cu, and Mo were determined by atomic absorption, K and Na by flame emission; P (2) and B (8) were determined colorimetrically, S turbidimetrically (11), and Cl with a chloridometer. The wood and bark were analyzed only for Zn, K, and Mg, the 1-year-old wood also for water-soluble phenolics (15).

The regrowth was trained to a single shoot until it was about 1 m tall. New growth was measured in October 1980, and the shoots were cut off and weighed again. Leaf, wood, and bark samples were collected and processed as in 1979. The root systems were removed from the pots, washed clean, and weighed. The stumps of 2-year-old wood between the budunion and the 1980 growth were cut off, the bark removed, and the wood analyzed after drying.

Data for 1979 and 1980 were subjected separately to statistical analysis. There were few differences between years, therefore another analysis, containing both years where possible, was done and these data are shown in this report. The 1980 data were also analyzed by a stepwise regression procedure to evaluate the correlation of growth (shoot fresh weight) with subsets of factors measured that year.

Results and Discussion

The largest trees were on rough lemon (Table 2), the smallest trees on sour orange rootstock. There was no significant difference in weight in the sour orange and Carrizo citrange root systems, but the tops of trees on Carrizo were much larger than of those on sour orange. The trees growing in 2-layered media had 2-tiered root systems, about equally divided between the 2 layers, with a break between the roots growing in the upper and the lower layer. All trees grew best in the clay/sand medium; the smallest trees grew in sand medium. The sand medium, when filling the whole pot or when making up the upper layer (treatments 1 and 4), had an especially strong stunting effect on trees on sour orange (Table 2).

Table 2. Effects of rootstocks and media on growth.

Variable	Linear shoot growth (cm)	Fresh wt (g) Shoot	Fresh wt (g) Root	Shoot/ root ratio
Rootstock effects				
Rough lemon	298 a[z]	280 a	256 a	1.42 ab
Carrizo citrange	239 b	223 b	160 b	1.68 a
Sour orange	126 c	131 c	132 b	1.19 b
Medium effects				
Sand	179 c	171 c	147 b	1.48 a
Clay	225 ab	212 b	178 b	1.57 a
Clay/sand	263 a	257 a	243 a	1.39 a
Sand/clay	211 bc	199 bc	155 b	1.27 a
Rootstock x medium interactions				
Rough lemon				
Sand	221 b	193 b	168 a	1.48 a
Clay	333 a	306 a	253 a	1.57 ab
Clay/sand	342 a	325 a	338 a	1.39 b
Sand/clay	286 ab	288 a	248 a	1.27 ab
Carrizo citrange				
Sand	260 a	251 a	199 a	1.62 a
Clay	186 b	174 b	138 a	1.71 a
Clay/sand	263 a	242 a	167 a	1.70 a
Sand/clay	252 a	226 a	144 a	1.68 a
Sour orange				
Sand	69 b	78 b	89 b	0.95 a
Clay	156 ab	157 ab	141 b	1.66 a
Clay/sand	185 a	204 a	222 a	1.27 a
Sand/clay	94 b	84 b	74 b	0.88 a

[z]Mean separation by Duncan's multiple range test, 5% level.

Rootstocks affected the levels of N, P, K, Mg, S, Na, Fe, Mn, Zn, Cl, B, and Mo in the leaves; leaf Ca and Cu were unaffected (Table 3). There was little difference in the rootstock effects before and after treatment (Tables 1 and 3). The acid clay medium favored accumulation of Mn, Zn, and Cu. Leaf P was unaffected by the different media, regardless of rootstock. Trees on Carrizo citrange showed their well-known tendency to accumulate chlorides (7). The uptake of other elements varied with rootstock and treatment. The media had no effect on the leaf K levels of trees on Carrizo and sour orange; trees on rough lemon had a higher leaf K concentration in sand and sand/clay than in clay. Trees on Carrizo citrange accumulated more Mg and Zn in clay than in the other treatments; trees on sour orange and rough lemon were unaffected. Only the trees on sour orange varied in Cl uptake with medium (Table 3).

Magnesium in the 1-year-old wood and bark was higher in trees on sour orange than in trees on the other two rootstocks (Table 4). Wood Zn was little affected by rootstock, but there was a wide range in the Zn content of the bark, where trees on rough lemon had a much higher Zn concentration than those on sour orange. The media had no effect on the K concentration in 2-year-old wood. The clay medium, as in the case of the leaves, produced a higher Zn concentration in the older wood and the bark, but this was not the case in 1-year-old wood (Table 4).

Rootstock × medium interaction effects on mineral element levels in the wood and bark were largely confined to trees on sour orange (Table 4), the trees which had the strongest growth response to the media. The stunted trees on sour orange in sand had the highest K, Mg, Zn, and phenolic levels in the 1-year-old wood.

Stepwise regression analysis of the 1980 data, using the SAS computer package program, a technique for selecting a subset of variables as predictors of a dependent variable, chose the 3 variables of linear growth, root weight, and Zn in the 1-year-old wood for predicting shoot weight (Table 5).

Superimposing layers of light and heavy soil media with sharply different characteristics affected growth and mineral uptake of trees with roots in both layers. The clay-sand treatment showed that layering soil media with different textures can have a beneficial effect on growth; trees on all 3 rootstocks grew better in the combination of acid clay over sand-peatmoss with a pH considered ideal for citrus orchards. Roots grew well in both layers under these conditions and in most cases filled all the space available. The constant supply of nutrients and water and aeration through the drainage holes in the bottom of the pots make it doubtful, however, that similar results could be obtained in the field.

Rough lemon and Carrizo citrange were less affected by the different soil media than was sour orange. The "sand" treatment reduced tree size on rough lemon, the "clay" treatment on Carrizo citrange. The strongest medium effect on growth was on trees on sour orange where the sand-peatmoss mix ("sand") sharply reduced growth, but only when it filled the whole pot or made up the upper layer.

The size of the root system reflected the growth response of sour orange to the media. The root system of trees on sour orange in clay/sand was 2 to 3 times as large as in the other media. The average size of the root system of trees on sour orange was the same as that of trees on Carrizo citrange, but the tops of the trees on Carrizo were much larger, as reflected in the higher shoot/root ratio (Table 2).

The mineral uptake characteristics of trees on the 3 rootstocks used were only occasionally modified by the 4 media. The array of leaf nutrient levels on the 3 rootstocks before and after the experiment was very similar (Tables 1 and 3). Many, but not all, the

Table 3. Effects of rootstocks and media on leaf nutrient levels.

Variable	Leaf nutrients N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Na (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	Cu (ppm)	Cl (ppm)	B (ppm)	Mo (ppm)
Rootstock effects														
Rough lemon	2.66 c[z]	0.134 a	2.10 b	2.84 a	0.516 a	0.347 b	447 b	89 a	12 b	20 a	5 a	560 c	83 a	1.9 a
Carrizo citrange	2.85 b	0.140 a	2.28 a	2.72 a	0.458 b	0.419 a	365 b	72 b	11 b	16 b	5 a	1483 a	64 b	1.5 b
Sour orange	3.04 a	0.125 b	2.10 b	2.76 a	0.546 a	0.406 a	547 a	76 b	17 a	15 c	5 a	1023 b	79 a	1.6 b
Medium effects														
Sand	2.98 a	0.137 a	2.33 a	3.18 a	0.521 a	0.380 a	629 a	78 a	10 bc	15 b	4 b	1224 a	76 a	2.2 a
Clay	2.84 a	0.132 a	2.01 b	2.13 c	0.520 a	0.409 a	380 b	77 a	22 a	20 a	6 a	974 ab	81 a	1.3 c
Clay/sand	2.66 a	0.129 a	2.05 b	2.96 ab	0.511 ab	0.401 a	391 b	79 a	12 b	16 b	5 ab	1059 ab	67 b	1.4 c
Sand/clay	2.94 a	0.133 a	2.26 a	2.87 b	0.475 b	0.371 a	430 b	82 a	9 c	17 b	5 ab	902 b	76 a	1.7 b
Rootstock x medium interactions														
Rough lemon														
Sand	3.02 a	0.138 a	2.53 a	2.78 ab	0.542 a	.320 b	482 a	101 a	8 c	18 a	5 a	578 a	71 b	2.6 a
Clay	2.57 bc	0.133 a	1.80 c	2.56 b	0.511 a	.330 ab	388 a	79 a	18 a	22 a	6 a	679 a	93 a	1.6 b
Clay/sand	2.34 c	0.131 a	1.95 bc	3.12 a	0.525 a	.366 ab	465 a	87 a	13 b	21 a	5 a	616 a	77 b	1.5 b
Sand/clay	2.74 ab	0.133 a	2.17 b	2.89 ab	0.488 a	.370 a	456 a	92 a	8 c	19 a	5 a	525 a	90 a	2.2 a
Carrizo citrange														
Sand	2.86 ab	0.136 a	2.35 a	3.18 a	0.420 b	.413 ab	395 a	56 b	7 b	14 c	4 b	1545 a	64 ab	1.9 a
Clay	2.91 ab	0.138 a	2.16 a	1.90 b	0.525 a	.489 a	404 a	88 a	22 a	21 a	6 a	1610 a	71 a	1.1 b
Clay/sand	2.70 b	0.142 a	2.19 a	2.95 a	0.436 b	.388 b	350 ab	75 ab	9 b	14 c	6 a	1499 a	59 b	1.5 b
Sand/clay	2.95 a	0.144 a	2.43 a	2.91 a	0.420 b	.320 b	314 b	67 b	7 b	17 b	5 a	1287 a	62 ab	1.3 b
Sour orange														
Sand	3.05 a	0.138 a	2.13 a	3.59 a	0.603 a	.410 ab	1011 a	76 ab	15 b	13 a	3 b	1551 a	92 a	2.0 a
Clay	3.03 a	0.126 a	2.08 a	1.92 c	0.524 a	.410 ab	348 b	64 b	27 a	17 a	6 a	633 b	80 ab	1.1 b
Clay/sand	2.94 a	0.115 a	2.02 a	2.81 b	0.545 a	.449 a	357 b	75 ab	14 b	15 a	6 a	1063 ab	65 b	1.4 ab
Sand/clay	3.12 a	0.123 a	2.18 a	2.82 b	0.518 a	.356 b	521 b	89 a	11 b	14 a	4 ab	896 b	78 ab	1.8 a

[z]Means of 2 years and 5 replications; mean separation within columns by Duncan's multiple range test, 5% level.

Table 4. Effects of rootstocks and media on K, Mg, Zn, and water soluble phenolics in the wood and the bark.

	1-year-old scion wood				2-year-old scion wood		1-year-old scion bark		
Variable	K (%)	Mg ppm	Zn ppm	Water soluble phenolics (mg/g)	K (%)	Zn ppm	K (%)	Mg (%)	Zn ppm
Rootstock effects									
Rough lemon	0.324 b[z]	242 b	4 ab	2.9 b	0.483 ab	7 a	1.89 a	0.198 b	59 a
Carrizo citrange	0.406 a	235 b	3 b	2.5 b	0.530 a	6 a	1.96 a	0.154 b	45 b
Sour orange	0.426 a	436 a	5 a	3.4 a	0.461 b	6 a	1.91 a	0.323 a	35 c
Medium effects									
Sand	0.459 a	452 a	5 a	3.3 a	0.467 a	5 b	1.93 ab	0.340 a	41 c
Clay	0.340 c	258 b	3 b	2.9 ab	0.476 a	9 a	1.83 b	0.178 b	51 a
Clay/sand	0.345 c	234 b	3 b	2.7 b	0.493 a	5 b	1.90 ab	0.173 b	43 bc
Sand/clay	0.404 b	286 b	4 ab	2.9 ab	0.526 a	5 b	2.04 a	0.221 b	48 ab
Rootstock x medium interactions									
Rough lemon									
Sand	0.413 a	273 a	4 a	2.8 a	0.460 a	5 b	1.98 a	0.193 a	57 a
Clay	0.272 bc	256 a	4 a	3.0 a	0.458 a	10 a	1.79 a	0.223 a	56 a
Clay/sand	0.290 c	211 a	4 a	2.9 a	0.474 a	5 b	1.87 a	0.189 a	54 a
Sand/clay	0.329 b	234 a	3 a	2.8 a	0.530 a	6 b	1.94 a	0.184 a	67 a
Carrizo citrange									
Sand	0.418 a	221 b	3 a	2.3 b	0.570 a	5 b	2.08 a	0.205 a	35 c
Clay	0.431 a	267 a	3 a	2.8 a	0.506 a	9 a	1.98 a	0.142 a	54 a
Clay/sand	0.365 a	230 ab	3 a	2.7 ab	0.466 a	5 b	1.89 a	0.140 a	43 bc
Sand/clay	0.411 a	219 b	3 a	2.4 b	0.578 a	6 ab	1.90 a	0.129 a	46 ab
Sour orange									
Sand	0.537 a	822 a	6 a	4.7 a	0.368 b	5 b	1.73 b	0.593 a	31 b
Clay	0.318 b	252 b	3 b	2.8 b	0.464 ab	9 a	1.71 b	0.168 b	43 a
Clay/sand	0.379 b	261 b	4 ab	2.6 b	0.540 a	4 b	1.95 ab	0.189 b	33 b
Sand/clay	0.471 a	404 b	6 a	3.5 ab	0.470 ab	6 b	2.25 a	0.342 ab	31 b

[z]Mean separation within columns and groups by Duncan's multiple range test, 5% level.

observed mineral uptake effects of rootstocks generally agree with the large amount of information available (9, 18). Nitrogen, S, Na, and B showed "growth dilution" (3), i.e. the fastest-growing trees had the lowest levels. The amounts of extractable Ca and Na in the media were reflected in their concentration in the leaves, high with "sand", low with "clay", intermediate when the 2 media were combined. Differences in rootstock × medium interaction were mostly small, but there were distinctly higher K levels in the leaves of trees on rough lemon and higher Cl levels on sour orange in sand.

Accumulation of Zn, K, Mg and water-soluble phenolics in the young wood is characteristic of blight, and the elevated Zn levels are thought to be specific for the disorder (6, 13, 15, 16). These same components accumulated in the wood of the slow-growing trees in the present experiment. Rootstock also influenced wood Zn; trees on sour orange had the highest Zn levels in 1-year-old wood in sand and sand/clay, the same treatments where growth was minimal. Trees on sour orange rarely get blight in the field in Florida (6, 14), but in Belize and Cuba a blightlike decline which also causes zinc accumulation in the wood is widespread (Reynold Gabourel and Alexis de Bernard, personal communication).

Table 5. Stepwise regression of shoot weight on subsets of other measurements.

Variable	r^2
Linear growth	.754
Linear growth, Zn in 1-year-old wood	.795
Linear growth, root weight, Zn in 1-year-old wood	.838

The high negative correlation of Zn in the 1-year-old but not in the 2-year-old wood (Tables 4, 5) with growth agrees with the zinc accumulation pattern in these tissues with blight (13). Analysis of the bark for Zn has been suggested as a diagnostic test for blight (1). The bark Zn levels in this experiment (Table 4) followed the same pattern as leaf Zn, i.e. they correlated with soil pH rather than growth retardation. The parallels with blight are not clear enough to draw definite conclusions, but the experiment shows that soil factors can cause similar growth responses and changes in mineral element concentration.

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The Influence of Irrigation and Row Spacing on the Quality of Processed Snap Beans[1]

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Abstract. **Irrigation method and row spacing had a significant influence on the quality of fresh, canned, and frozen snap beans (*Phaseolus vulgaris* L.). Sprinkle irrigated fresh and canned snap beans contained more ascorbic acid than rill irrigated snap beans. Rill irrigated snap beans had more intense color, lower shear values, less turbid brine, and less drained weight loss. Canned snap beans grown in narrow rows had less drained weight loss than snap beans from wide rows. Frozen snap beans from narrow rows had more drip loss, less moisture, increased soluble solids, and increased ascorbic acid content than those from wide rows. Under the conditions of this study, rill irrigated snap beans and snap beans grown in narrow rows did have quality advantages over sprinkle irrigated snap beans and snap beans grown in wide rows.**

During recent years snap bean production has undergone many changes. Cultural practices have changed from small areas, dependent on seasonal conditions, to large areas where seasonal conditions are controlled to some degree with irrigation. To increase yields, changes in cultural practices have included increased plant populations. These increased plant populations have been obtained by more plants/row, and closer spacing of rows. What quality changes, in snap beans, can be expected from these changes in cultural practices?

Studies have shown (4, 7, 11, 12, 16, 17) that weather conditions and water stress have marked effects on pod yield, percent seed, sieve size distribution, color, firmness, and sloughing. Row spacing (12) affected yield and color; snap beans grown in narrow rows (22.9 cm) had less color intensity and uniformity resulting in reduced sensory quality.

Processed snap bean quality has been the subject of many studies (2, 3, 5, 7, 9, 10, 14, 15, 16, 17), particularly the influence of blanching conditions on quality. Low temperature blanching of snap beans (82.2°C or less) resulted in excess vitamin losses (16), as a result of enhanced enzyme activity, and was not recommended unless necessary to avoid other quality losses. As blanching temperature increased, sloughing increased, and firmness decreased. When snap beans were blanched at temperatures less than 82.2°, increased blanching time led to less sloughing (6).

Above 82.2° increased blanch time led to greater sloughing (8, 10, 15). One study (17) indicated that a short-time high temperature (90.6° to 93.3°) blanch resulted in less loss in color for frozen snap beans. Longer blanch times resulted in less color and a softer product. Pectic substances were found to be responsible for firmness in processed snap beans (6, 10, 14) and were influenced by blanching conditions. Blanching conditions also influence water retention (8) by plant material, which may have a relationship with drained weight and turbidity of the brine. Sloughing was influenced by transit from processor to consumer (3).

This study was conducted to determine what influence irrigation, row spacing, blanching temperature, and blanching time have on the quality of processed snap beans.

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