SOME EFFECTS OF NITROGEN, PHOSPHORUS AND POTASSIUM FERTILIZATION ON THE CONSTITUENTS OF PERSIAN LIME FRUITS

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Frozen limeade became a factor in utilizing the Persian lime crop of south Florida in 1951 when 15 to 20% of the total production was put into cans. By the following year 25 to 30% of the crop was frozen. This year, 1953, 50% or more of the total production of this fruit has been frozen. Such a rapid change in the utilization of the crop has not given the grower time to change his thinking on fertilizer practices. Neither has it provided the processor time nor information to set up standards by which to evaluate the fresh fruit as it comes to the plant. The great majority of the fruit which is picked easily passes the standards established for fresh fruit in regards percentage of juice, i.e. 42% juice by volume. Much of this fruit is 45 to 50% juice because the fruit is often picked at a more advanced stage of maturity for processing.

Fruit for processing is usually field run with the medium sized first grade removed for fresh fruit sales when the price of fresh fruit is high. As the price of fresh fruit drops, it often reaches the point when all the field run fruit is sent to the processing plant. A paradox occurred during 1953 when, for several weeks during the summer harvesting season, the first grade fresh fruit returned about $4.00 per bushel to the grower but the second and third grade fruit which was frozen returned $5.00 per bushel. However, during most of the heavy picking season the two prices were very close. All of this fruit that found its way to the processors was bought or consigned on the basis of a 55 pound bushel or 90 pound field crate with a minimum juice content of 42% by volume (2¾ to 3 gals. of juice per bushel). The processor has paid no attention to *soluble solids*, acids or premium volume of juice when obtaining fruit.

Processors who buy oranges for frozen concentrate formerly used the basis of gallons of juice per box but now this criteria is used along with percent soluble solids calculated as sugars and the available acid as citric acid. In fact, the price paid for oranges is based on the pounds of solids per box. This has encouraged the grower to plan his cultural methods, especially fertilizing, in such a way as to give the greatest yield of sugars and acid per dollar of production cost. As the production of Persian limes increases, and in turn the greater total volume of fruit being utilized by the processors increases, it seems logical to expect that more emphasis in the fruit production will be placed on the percentage juice and the composition of this juice in addition to total box yield. The factors receiving greatest consideration will most likely be acids and volume of juice since solids at the present time do not play as vital a role in producing "limeade concentrate" as they do with "citrus concentrate". There is no concentration necessary with the lime product as there is in other citrus and only if the acids are low will the product be too inferior. However it stands to reason that a bushel of Persian limes giving 3 to 3½ gallons of juice is of greater monetary value than one giving 2¾ to 3 gallons of juice.

There has been some excellent work carried out by Sites and Deszych (6), Sites (5), Reuther and Smith (3) and Reuther et al. (4) in Florida, as well as Chapman & Royner (1) and Jones and Parker (2) in California, on the effects of certain major plant foods upon the internal quality of citrus fruit as well as on crop yield. All the above workers were in general agreement on the overall effects of nitrogen, phosphorus or potassium on fruit quality where their work dealt with these elements. Heavy nitrogen fertilizers had a slight tendency to decrease fruit weight (3) while heavy potassium fertilizers had a strong tendency to increase fruit weight. Juice content of oranges was increased moderately with heavy nitrogen fertilization, while heavy potash fertilization reduced it slightly (3). Apparently differences in phosphate fertilization had little or no direct effect on the juice content of oranges (4). However, when phosphate was deficient in the fertilizer (1), there was less juice due in part to coarser and thicker rinds and more pulp or rag within the fruit. Heavy nitrogen fertilization has in general a slight tendency to depress total soluble solids in the juice of oranges (3), whereas heavy potassium fertilization has a strong depressive effect on the soluble solids in orange juice (3, 6). There was little effect from phosphorus fertilization on the soluble solids content of orange juice (2, 1). There was a slight (2) to significant (4, 1) lowering of the total acid content of the orange juice where phosphorus was applied but most significant at the highest levels of phosphorus. Fruit from trees receiving the higher percentages of potassium in the fertilizer were found to contain a slightly higher acid content (6) in one experiment. In another experiment (3) there was a fairly consistent tendency for the intermediate level of potassium fertilization to produce a slightly greater total acid content of the juice than either the low or high levels. In a third experiment (2) there was observed a tendency of the potassium alone or with phosphorus to increase the acid content. In this last experiment (2) nitrogen alone also resulted in an increase of acid over the check treatment. Probably this could be related to decreased phosphorus content of the fertilizer. It was found by others (3) that heavy nitrogen fertilization tended to depress slightly the total acid content of oranges. With grapefruit (5) it was found that variations in the rate of potassium applications, between 3 and 10%, in most cases caused no significant difference in the soluble solids of the juice. In the same experiment the percentage of titratable acid is consistently and very sharply reduced where potassium is limited, but is increased significantly with higher concentrations of potassium, up to 10 percent, in the fertilizer mixtures. It has been found (6, 5, 3, 1) that fruit from low potassium fertilized trees generally reach legal maturity two or three weeks earlier than fruit from high potassium fertilized trees regardless of high nitrogen treatment.

The ratio of total soluble solids in the juice to total acid is one of the major factors on which the maturity laws of citrus are based. However, this solids-acid ratio would mean very little in lime juice other than being a reflection of the raising or lowering of titratable acid.

There has been no comprehensive literature available for studying the effects of major elements on the internal quality of limes, but it is felt that this review of some of the effects of the major elements on oranges and the interrelation between them would make a good starting point for a discussion of the work with Persian limes.

Experimental Methods

The data contained in this report are some preliminary analyses taken from an overall fertilizer experiment on Persian and Idemore limes budded on rough lemon rootstocks. These trees were set in scarified and ditched sandy phase Rockdale series soil in May 1950. Three-tree plots, completely buffered, were used with two randomized replications per variety. The first full crop was produced in 1953. The treatments were started on the plots in December 1950. They consist of 18 variations of N, P, and K. The nitrogen levels are 2, 4 and 6%, with 30% derived from natural organic sources and the remainder from half nitrate and half ammonia salts. The phosphate levels are 0, 3, 6, 9% P_2O_5, derived from super phosphate. The potassium levels are 0, 3, 6, 9% K_2O, derived from muriate of potash. The fertilizer treatments are applied every 60 days in quantities similar to regular grove practices. At three years of age the average application per tree was about 5 pounds. These trees were all adequately irrigated and the minor elements were supplied uniformly by maintenance sprays.

Table 1 shows the list of variations selected for these data. From the heavy surge of the June-July crop of limes a sample was taken from July 1st-17th, and a second sampling was taken from the August-September surge of limes, August 17-August 20th, 1953. Four fruit of salable maturity (130 to 150 days of age) were taken from each tree in a plot thus giving 12 fruit per plot as a sample. Where loss of a tree or replacement had been made, increased fruit were taken from the remainder of the trees in the plot to make up 12 fruit. Fruit were selected from all quarters of the tree. The average weight of fruit mentioned in Table 1 was the average of all fruit picked from January through August from the particular plots.

The juice was extracted with a Hamilton Beach No. 32 hand press extractor which is the same as used by the State Inspection Service. Total soluble solids were measured with a Brix hydrometer and readings corrected to a temperature of 20° C. Total titratable acidity, expressed as anhydrous citric acid, was determined by the titration of a 10 ml. aliquot of juice against standardized sodium hydroxide solution. Total nitrogen was determined on 25 ml. aliquots of juice using the Kjeldahl procedure. Phosphate, potassium and calcium were determined from a 10 ml. aliquot of juice which had been wet-ashed by the perchloric acid method (7). Phosphorus, expressed as p.p.m., was determined on an adaptation of Sterges, Hardin and MacIntire method (7) using a Fisher Electro-photometer. Potassium and calcium, both expressed as p.p.m. were determined on the Perkin Elmer *Model 52A flame* photometer.

Experimental Results

Weight of Fruit: (The data in Table 1 represent too few samplings to analyze statistically but they do indicate a few general trends.) Moderate applications of nitrogen produced as heavy or heavier fruit than did either the heavy nitrogen application or the light nitrogen application. There appeared to be little differences in the weights of the fruit between heavy, moderate or light applications of either phosphorus or potassium.

Percent of Juice in Fruit: There is a trend for percent juice to increase as the nitrogen increases in the fertilizer. This effect of nitrogen seemed to be more dominant than either the effect of phosphorus or potassium on percent juice in the fruit. The latter two had very little effect on juice content. On the plots receiving low nitrogen, much of the fruit was of a rough thick-skinned type which may have played a part in the lower juice content.

Soluble Solids: There appeared to be very little influence of phosphorus and potassium on the soluble solids at a particular level of nitrogen but the general trend was for soluble solids to be at a slightly higher level at the moderate nitrogen level or where the nitrogen, phosphorus and potassium were about equal quantities.

Titratable Acid, Solids-Acids Ratio: Nitrogen apparently has a very slight effect on the

TABLE 1.
EFFECTS OF FERTILIZER TREATMENTS ON SOME CONSTITUENTS OF PERSIAN LIME FRUIT.
(Each value in table is an average of 2 separate samplings from 2 three-tree replications).

Treatment N P K	Ave. Wt. of Fruit	% Juice by Wt.	Composition of Juice: Soluble Solids	Titratable Acid	Solids/Acid	Nitrogen	Phosphorus	Potassium	Calcium
	(gms.)		%	%	Ratio	p.p.m.	p.p.m.	p.p.m.	p.p.m.
2 0 6	78.0	46.3	9.16	5.52	1.66	418	101	912	81
2 6 9	63.5	45.3	9.13	5.59	1.65	389	116	867	102
2 3 9	65.3	46.8	9.38	5.50	1.72	448	118	1161	79
2 6 6	71.3	40.8	9.11	5.61	1.63	419	120	1043	96
2 9 3	68.1	44.0	9.11	5.38	1.70	411	108	948	115
2 9 9	68.5	43.2	9.22	5.54	1.67	433	125	1071	96
4 0 9	67.4	50.8	10.05	5.71	1.77	567	103	899	94
4 9 0	70.6	48.4	9.38	5.21	1.80	472	101	649	84
4 3 9	65.3	48.8	9.72	5.90	1.65	523	119	1055	68
4 9 3	70.3	44.8	9.52	5.49	1.74	473	115	904	92
4 9 9	76.9	50.4	9.72	5.75	1.69	559	112	1008	84
4 6 6	76.7	49.9	9.57	5.71	1.68	491	114	935	89
6 0 6	71.7	52.1	8.90	5.81	1.65	566	97	862	93
6 3 0	62.2	48.7	8.97	4.73	2.01	432	107	669	119
6 6 0	69.9	49.5	9.38	4.58	2.07	433	107	564	102
6 3 9	68.5	50.6	9.70	5.78	1.68	506	117	914	81
6 6 6	74.0	49.6	9.84	5.95	1.67	562	108	978	103
6 9 3	71.4	50.5	9.19	5.71	1.60	510	110	768	88

titratable acid in that the greater the amount of nitrogen the more acid is developed. Potassium, however, apparently has a very strong effect on the formation of acid in that at any one level of nitrogen the acid is directly increased as the potassium in the fertilizer is increased. It is this same effect that is so apparent in the solids-acids ratio where low potassium fertilizers tend to give higher solids-acids ratios than moderate and heavy potassium fertilizers. It is almost entirely brought about by the differences in increased acid due to increased potassium. The variations in phosphate fertilizing in this experiment indicated no effect on either acid formation or solids-acids ratio.

Nitrogen in the Juice: The amount of nitrogen in the juice was lowest at the lowest nitrogen level and tended to increase as nitrogen was increased in the fertilizer mixture regardless of the phosphorus or potassium level. The increase seemed to be greatest between the low and moderate levels. As the potassium was increased in the fertilizer at a particular nitrogen level, the nitrogen in the juice tended to be increased. The influence of the potassium seemed to be less than that of nitrogen.

Phosphorus in Juice: Phosphorus in the juice remained fairly constant for all variations of the nitrogen, phosphorus and potassium levels except where phosphorus was left out entirely from the fertilizer mix, in which plots there was a slight depression of the phosphorus within the juice. With the addition of 3 to 9% phosphate, regardless of the nitrogen treatment, the phosphate levels were relatively consistent in the juice. At the highest potassium levels with the phosphates varying from 3 to 9%, there appeared to be a trend towards slightly higher phosphate in the juice.

Potassium in the Juice: The potassium in the juice tends to decrease as the nitrogen in the fertilizer mix increases and conversely when the nitrogen is kept constant, the potassium increases in the juice as the potassium in the fertilizer is increased. Phosphate itself appears to have little influence on the potassium in the juice in this experiment.

Calcium in the Juice: There appears to be little effect of increased nitrogen on the calcium content of the juice. Neither does there appear to be any effect of phosphorus and potassium on the calcium content of the juice.

Discussion

The results obtained to date in this experiment as typified by Table 1 are quite inconclusive but they do indicate some trends which are very similar to those obtained on oranges and grapefruit in the above mentioned literature. They further show a trend for the nitrogen to increase somewhat in the juice as higher percentages are used in the fertilizer mixes. Also there is a definite trend for potassium to decrease in the juice as nitrogen fertilization is increased. At the same time as potassium fertilizer is increased, regardless of the nitrogen level, potassium itself increases in the juice. Potassium also tends to cause an increase of phosphorus in the juice. In a general way, it would appear that phosphorus has the least direct effect on any of the constituents here discussed with potassium probably having the greatest effect.

The lowest level of nitrogen has considerable effect on tree growth and yield as well as on the general external quality of the fruit. Generally speaking, from field observations, it appears that the 1-½-1 or 1-1-1 ratio of nitrogen, phosphorus and potassium where the nitrogen is kept at 4% or higher would give as good a result as any of the formulas tested.

Summary

This paper, giving a very small portion of a larger overall study on the effect of nitrogen, phosphorus and potassium on the yield, growth and constituents of Persian and Idemore lime fruits, indicates to date that there are very slight modifications made in the juice by varying the major plant food elements.

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