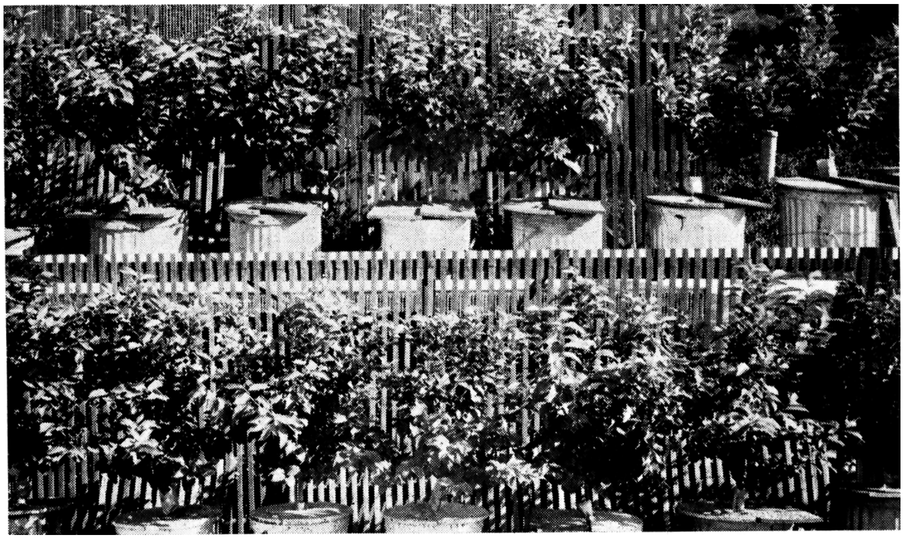
Nitrate in Lemon Soil Cultures

nutrient experiments show increased nitrate concentrations improved tree growth and yield but with a loss in fruit size

A. R. C. Haas and Joseph N. Brusca

Nitrogenous fertilizers — in some form—are applied to most lemon orchards and in the majority of cases constitute the only fertilizers used. The growing of legume or other cover crops for the most part has been abandoned.

To reduce costs and losses of unabsorbed nitrogen, efforts are continually being made to lower the amounts of nitrogen applied to the soil. Such efforts raise the questions as to whether lemon tree growth and fruit yields can be improved by the use of high nitrate levels —nitrate divided by 4.426 equals nitrogen—and whether, without properly balancing the increased nitrate, the fruit sizes can be maintained.



Comparative growth—after one year—of Eureka lemon trees on sour orange rootstocks planted bareroot in large out-of-door cultures supplied with large volumes of nutrient solution containing nitrate in various concentrations. Upper row, right to left: 25, 50, 75, 100, 125, and 150; lower row, right to left: 250, 350, 450, 550, and 600 ppm nitrate.

Tests were conducted at various nitrate levels with Eureka lemon trees on sour orange rootstocks planted bareroot in out-of-door cultures in Hanford sandy loam in 29-gallon-capacity containers. Tap water was used at all times. For more than three years the soil cultures daily received up to five gallons of nutrient accompanied by a more or less continuous soil drainage.

The nutrient solutions consisted of tap water to which were added—parts per million—potassium 21, phosphate 52.5, as potassium dihydrogen phosphate; potassium 21, sulfate 24, as potassium sulfate; magnesium 54, sulfate 216, as magnesium sulfate; iron 0.5, as ferric tartrate; nitrate at various levels: 25, 50, 75, 100, 125, 150, 250, 350, 450, 550, and 600 as calcium nitrate, and calcium sulfate to equalize the calcium.

The photograph shows the appearance of the trees less than a year after being planted. The subsequent excellent growth can be visualized from the data in the accompanying table. It is almost impossible to decide at which of the nitrate levels the growth was at its best, for the total fresh weight of the tree and the circumference increase —in 1/16″—were greatest at the 600 ppm nitrate level. The increase in dry matter in the fresh weight of the leaves from 31% to a high of over 43%—as shown in the table on this page—also is indicative of the increased vigor and manufacture of organic matter in the leaves as the nitrate level in the nutrient solution was increased.

As the concentration of nitrate increased, the ash in the dry matter of the lemon leaves gradually increased from 13.06% to nearly 19%. The ash constituents water soluble in the dry matter and expressed as percentages of the total ash were: 50.8, 55.7, 60.0, 64.5, 68.2, 68.6, 74.3, 75.4, 75.7, 77.5, and 78.7.

The table below shows the increased calcium content in the leaves as the nitrate level of the nutrient was increased

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Growth of Eureka Lemon Trees on Sour Orange Rootstock in Soil Cultures That Received a Nutrient Solution Containing Various Part per Million of Nitrate in the Form of Calcium Nitrate. The Weights of the Various Portions of the Trees and the Fruit-Picking Data Are Those Obtained at the Time the Test Was Concluded.

Nitrate in nutrient solution; p.p.m.	Leaves, fresh weight; lbs.	Lemon trunk and shoots, fresh wt.; lbs.	Rootlets; main root excluded; fresh wt.; lbs.	All of rootstock below bud union; fresh wt.; lbs.	Total fresh weight of tree without fruit; lbs.	Fresh wt. tree-ripe, or silver fruit; lbs.	Circumference increase, above bud union; 1/16 inches	No. of tree-ripe or silver fruit	Fresh wt. per fruit, tree-ripe or silver; grams	No. of green fruit	Fresh wt. of green fruit; lbs.
25	1 1/8	3 3/8	2 1/8	3 1/8	7 5/8	2 2/8	28	8	127.6	0	0
50	1 3/8	4 3/8	2	3	8 6/8	5 3/8	29	20	121.9	0	0
75	2	8	5	6 6/8	16 6/8	15 6/8	46	65	109.9	9	1
100	3 7/8	11 4/8	4 6/8	6 6/8	22 1/8	20 4/8	53	78	119.2	24	3 2/8
125	4 2/8	10 4/8	5	7	21 6/8	25 7/8	56	100	117.3	23	2 7/8
150	5 3/8	14	5 2/8	6 7/8	26 2/8	36	56	150	108.8	9	1 2/8
250	7 2/8	15 4/8	7 4/8	9 5/8	32 3/8	45	54	202	101.0	9	1 4/8
350	4 7/8	10 7/8	5	6 5/8	22 3/8	39 2/8	45	240	74.2	7	1
450	7 1/8	13 7/8	6 4/8	8 3/8	29 3/8	30 4/8	52	143	96.7	8	1 2/8
550	8 4/8	15 1/8	9	11 2/8	34 7/8	43	51	198	98.5	19	2 2/8
600	8 3/8	16 3/8	11 4/8	13 4/8	38 2/8	37 4/8	63	174	97.8	9	1 2/8

NITRATE

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by means of calcium nitrate. The water-soluble calcium in the dry matter increased gradually from 12.89% to 18.55%. Because of the large content of calcium in the dry matter of the leaves, the potassium percentages were greatly reduced as the addition of calcium nitrate was increased. The leaves were all dark green in color and healthy in appearance with no symptoms of a copper deficiency becoming apparent. In the dry matter of the leaves the total phosphorus increased when the nitrate content of the nutrient was low. The percentages of potassium in the dry matter of the rootlets tended to increase, whereas those of total phosphorus were decreased as the nitrate level was increased. In the dry matter of the peel and pulp of the fruit, the percentages of calcium, potassium, and total phosphorus decreased as the nitrate levels increased.

Effect of Nitrate

The maximum yield in pounds was produced at the 250 nitrate level—roughly at the 56 ppm nitrogen level—with the second highest yield in pounds at the 550 nitrate level—roughly 124 ppm nitrogen. The pounds of fruit produced when multiplied by 454—one pound equals roughly 454 grams—and divided by the number of fruit gives the grams weight per fruit. These results in the table on page 9 clearly show the effects of the nitrate level in increasing the pounds of fruit produced—yield—while at the same time decreasing the size of the lemon.

The tabulated data on this page would indicate that such increased, or possibly overproduction of lemon fruit as the trees increase in age, gradually would use up the food reserves in the trees so nearly to completion that the onset of tree decline might become apparent. The severe pruning of such trees temporarily reduces the crop and increases the vegetative growth, thereby permitting the accumulation of food reserves which are once more reduced to injurious levels when the fruit production again is increased.

The use of nitrogen as the sole fertilizer—under certain conditions—can result in a more or less cyclical production of lemon fruit of desirable size.

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The above progress report is based on Research Project No. 1086.

Composition in January of Leaves and Rootlets and of Peel and Pulp of Fruit from Eureka Lemon Trees on Sour Orange Rootstock Grown in Large Out-of-Door Soil Cultures with a Nutrient Solution Containing Various Concentrations of Nitrate

Parts per million nitrate in nutrient	25	50	75	100	125	150	250	350	450	550	600
Leaves:											
Calcium (Per cent in dry matter)	2.84	3.98	4.82	4.56	4.63	5.53	6.52	6.16	5.97	7.13	6.85
Magnesium (Per cent in dry matter)	.29	.30	.15	.17	.16	.20	.23	.16	.18	.21	.21
Potassium (Per cent in dry matter)	2.49	2.45	2.78	2.00	1.78	1.56	.75	.53	.71	.47	.49
Total phosphorus (Per cent in dry matter)	.24	.20	.13	.11	.11	.11	.12	.13	.12	.11	.11
Dry matter as per cent in fresh weight	32.95	31.15	34.96	36.34	36.24	37.78	41.04	41.32	41.06	42.59	43.46
Rootlets:											
Calcium (Per cent in dry matter)	1.09	3.01	1.02	2.64	2.24	2.55	2.30	1.82	2.03	.98	1.96
Magnesium (Per cent in dry matter)	.41	.35	.37	.39	.40	.47	.42	.40	.31	.21	.28
Potassium (Per cent in dry matter)	.95	1.27	.92	1.11	1.20	1.14	1.15	1.43	1.34	1.56	1.52
Total phosphorus (Per cent in dry matter)	.15	.15	.12	.10	.10	.10	.09	.10	.09	.08	.09
Peel:											
Calcium (Per cent in dry matter)	1.20	1.33	1.49	1.12	1.19	.93	.85	.93	.85	.97	.89
Magnesium (Per cent in dry matter)	.08	.10	.09	.09	.11	.10	.10	.09	.10	.09	.09
Potassium (Per cent in dry matter)	1.48	1.09	1.13	1.02	.85	.91	.83	1.01	.94	.86	.81
Total phosphorus (Per cent in dry matter)	.13	.09	.10	.07	.07	.07	.07	.08	.08	.08	.07
Dry matter as per cent in fresh weight	17.99	18.85	18.89	19.12	19.47	18.46	19.33	19.44	18.31	17.80	18.32
Fresh weight as per cent of whole fruit weight	31.91	29.44	33.11	40.56	33.93	37.68	36.41	30.22	34.06	35.62	34.22
Pulp:											
Calcium (Per cent in dry matter)	.41	.32	.37	.32	.32	.27	.27	.28	.30	.32	.29
Magnesium (Per cent in dry matter)	.11	.12	.11	.11	.12	.11	.10	.10	.11	.11	.11
Potassium (Per cent in dry matter)	2.30	2.22	2.23	1.92	2.02	1.76	1.77	1.70	1.91	1.87	1.75
Total phosphorus (Per cent in dry matter)	.29	.24	.19	.21	.20	.18	.18	.18	.19	.18	.17

LEMON

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curred. With the growth in frozen concentrated lemonade and canned single-strength lemon juice, the products outlet is now made up of a larger proportion of high-value products. It is due to these higher valued products that grower returns from processed lemons attained the relatively favorable levels in some of the recent years. At the same time, there was generated a degree of consumption competition between the fresh lemon and juice products markets. As a result, there arose a different type of problem with respect to allocation of the crop among the fresh and products outlets. Previously, the two outlets were substantially independent in consumption demand; but now the two outlets have become significantly if not completely interdependent in consumption demand.

*Consumption competition may be il*lustrated by the demand for fresh lemons for homemade lemonade and that for frozen concentrated lemonade. From the view of the household consumer and in terms of current retail prices, lemonade made from fresh lemons and lemonade made from frozen concentrate cost about the same on an equivalent quart of lemonade basis. Further, for many consumers the frozen concentrated lemonade provides use conveniences sought by contemporary home managers. The same applies to canned single-strength lemon juice, because the household cost is currently extremely favorable in terms of cents per ounce of lemon juice compared with fresh home-squeezed juice.

Products Marketing Order

The federal marketing order for fresh lemon shipments was utilized to regulate *the flow of fresh lemons from the* California-Arizona producing areas to the receiving markets. Similarly, the California state marketing order for lemon products was introduced with the regulation of the manufacture and flow of juice products into trade and consumption channels as one of its major objectives. However, it also directly affects prices and returns from processed lemons. In the majority of the years since 1950—with important exceptions—the available supply of California lemons for processing, was more than adequate to provide product packs which would be absorbed by the market without substantially depressing the price for juice products.

The products order was intended to equalize the burden of surplus lemons for products or to cushion price breaks in lemon-juice products. The order was framed with the implication that—since the dominant source of supply was from

California lemons—the order could provide a mechanism for controlling the supply pressure of juice products. Significant leakages from supply sources outside of California apparently were not fully envisaged. The importation of lemon stock for the domestic manufacture of juice products has tended to increase and—because of the increased value of processing lemons—areas in the United States that had not produced lemons previously became potential suppliers.

As the state marketing order has been operating in most years, a price floor has been established for California lemons processed into juice products. In addition, the order has indirectly afforded price protection to such competing areas as Italy, Florida, and Arizona, where growers enjoy lower lemon-producing cost structures than do most growers in California.

Interlocking Markets

These developments not only bear upon the lemon-juice products market but also on the fresh lemon market because of the consumption competition between the two markets. Further, as juice supplies originating outside California assume increasing volume, there develops a relatively restricted market outlet of value for California lemons for juice products.

The current situation in which the California lemon industry operates—in conjunction with potential developments —emphasizes the importance of considering the fresh and processed markets and their respective marketing orders as closely interrelated dimensions of an essentially single economic market.

The California lemon industry faces the problem of developing an integrated system of operating that is oriented toward the dynamic economic setting in which the industry finds itself.

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This series of five articles will be available as a reprint early in 1957, and may be obtained without cost by addressing a request to The Giannini Foundation of Agricultural Economics, 207 Giannini Hall, University of California, Berkeley 4.

ISOTOPES

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made in the center of Australia, as far from the sea as possible and where the situation was not complicated by coal burning industrial operations. There, in cloudless clear weather, the highest activities in these experiments were recorded.

The air was generally calm at night so the sampling program was changed to separate the catches made in daytime from those at night. The fraction of lead^{212} accumulated during 10 hours or more proved to be in the neighborhood of half of the total activity. The data point to the conclusion that calm weather in inland areas tends to produce high burdens of atmospheric radioactivity. Yet the high proportion of lead^{212} could not be attributed to industrial activities, so it was postulated that its parent isotope—thoron—was delivered continuously from the soils to the atmosphere. To test this assumption, a plot of soil 18″ × 40″ was dug over and covered by a galvanized iron lid leaving one end open and placing the filter at the other end. The rate of air flow was arranged so the air traveled over the 40″ path of loosened soil in a period of two minutes before passing through the filter. If thoron were to escape from the soil, its half life of 54.5 seconds should allow a considerable proportion of it to be converted to polonium^{216}—0.14 second half life—and thence to lead^{212}. Even though it is assumed that radon also diffused from the soil its half life of 3.8 days would require that most of the gas should pass on through the filter without disintegrating to lead^{214}. For comparison a parallel filter was run filtering the same quantity of air from the open atmosphere. It was demonstrated that air in close contact with loosened soil accumulated considerably more activity and the higher proportion of this activity was due to the presence of lead^{212} derived from thorium decay.

Samples of 120 different soils representative of the great soil types of the world were examined and radon was found to be an important component of all of the soil atmospheres.

In the absence of any direct information on health hazard features from natural radioactivity in the atmosphere, a test was conducted with a sheep. On the 20th and 21st of April 1955, two record high counts of radioactive lead^{212}—444 and 417 counts per minute—were measured. On the second day of high activity a sheep which had been penned for two weeks close to the site of measurement was slaughtered and its respiratory organs examined.

From the lead isotopes recovered from the sheep's lungs it was concluded that approximately 18% of the lead^{212} inhaled by the sheep during the preceding 24 hours was retained in the respiratory system. Unfortunately this experiment could not show where the balance of the activity had gone. It may have been returned to the atmosphere, or it may have been distributed throughout the body.

The steady intake of lead^{214}, which decays to lead^{210} with a 22 year half life, may be retained by the body. Lead^{210} would accumulate and reach half its maximal value in 22 years, 75% in 44 years, and 87½% in 66 years.

The principal findings of this series of investigations are that radioactivity is always present in the atmosphere in the form of decay products of uranium and thorium and that the short-lived thoron—54.5 second half life—and its daughter products assume equal importance with those of radon.

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METABOLITES

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soak period, storage, and growth in soil after treatment are currently under study. The multiple effects of the gibberellins on dormancy, growth, flowering, and fruiting suggest a critical study of their effects on dormancy of pome fruit seeds as well as on dormancy, growth, fruit set and development of pomological crops.

Although the results of these studies are highly suggestive, the practical significance of the gibberellins as agricultural chemicals requires extensive evaluation.

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C. A. West, B. O. Phinney and Anton Lang of the University of California, Los Angeles, and S. H. Wittwer and M. J. Bukovac of Michigan State University conducted the additional research on gibberellins referred to in the above article.

Dr. F. D. Stodola, Northern Utilization Research Branch, USDA, Peoria, Illinois, supplied the gibberellins used in these studies.

The above progress report is based on Project 1175 D.

CLOVER

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Plants receiving 300 pounds of superphosphate produced twelve times as much clover and contained 0.157% phosphorus. They were clearly deficient since more applied phosphorus gave a large additional yield increase.

Clover from the 600-pound treatment produced 94% of the maximum yield and contained 0.190% total phosphorus. Further application of fertilizer in the 1,200-pound treatment caused no significant increase in yield, though phosphorus content did increase.

At the control and at the low rates of application the phosphorus content curve follows the yield increase. The yield approached maximum with the 600-pound

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