Response of Young Lemon Trees 
to Potassium and Zinc Application — 
Yield and Fruit Quality

W. W. Jones², T. W. Embleton², J. H. Foott³ and R. G. Platt⁴,⁵

University of California, Riverside

Abstract. Yield of young lemon trees increased with either soil application of K₂SO₄ or foliar application of KNO₃ in an orchard where leaf K was low. Leaf Zn was low but one annual foliage spray of ZnSO₄ (control in this study) supplied adequate Zn and there was no response to additional Zn sprays. Peel thickness decreased, and percent juice and percent acid in the juice increased with added K.

Response of young lemon trees, planted on soils virgin to citrus, to added nutrients has not been reported. Leaf level ranges of the various nutrients associated with yields of mature orange trees have been developed (13). Embleton, Jones, and Page (5) showed improvement in trees and fruit condition from K applications and described K-deficiency symptoms for lemons. Embleton and Jones (2, 3) observed that an increase in K in the lemon, reduced peel thickness and increased juice content of the fruit. In oranges, an increase in K resulted in an increase in peel thickness and a reduction in juice content of the fruit (9).

In California, massive soil applications of K fertilizers are necessary, in some orchards, to obtain an increase in K in trees (8, 9, 14). In some cases, high application rates have been detrimental to tree condition because of associated salinity effects (7). To overcome such effects, efforts were made to supply K by KNO₃ foliage sprays (6).

Lemon trees may be low enough in Zn to restrict yields and yet show no Zn-deficiency symptoms in leaves, but one foliage spray may not correct the deficiency (11). Thus leaf analysis serves as an indicator of Zn need in lemons.

In the present study, preliminary leaf analysis indicated that both K and Zn were low. This paper considers the influence of soil applied K₂SO₄, foliar applied KNO₃, and foliar applied ZnSO₄ on yield and fruit quality of young lemons.

Materials and Methods

The trees were ‘Frost Nucellar Lisbon’ lemon, Citrus limon (L.) on ‘Troyer’ citrange, Poncirus trifoliata (L.) x Citrus sinensis (L.) Osbeck, rootstock. They were planted in the field in 1964 near Nipomo, San Luis Obispo County, California. The experiment started in 1967 and ended in 1972. The trees were not pruned during this study. The soil was Oakley silt loam and was dry-farmed to beans and barley with little or no fertilizer for a number of years before lemons were planted.

The experiment consisted of a 3 x 3, K x Zn, factorial replicated 10 times with single-tree plots with no guard trees. The K treatments were: K₀ — no K; Ksp — 3 sprays each year with 40 lb. KNO₃ per 100 gal applied in the April-May, August-October, and November-January periods; K₃₀ — 5 lb. K per tree from K₂SO₄ applied to the soil in May, 1967 and again in April, 1968. The Zn treatments were foliar applications of 1 lb. ZnSO₄ (36% Zn) per 100 gal applied each year in the following periods: Zn₁ — May-July; Zn₂ — May-July and October-November; Zn₃ — May-July, July-September, and October-November.

Yield records, in kg per tree, were obtained for 1968, 1969, 1970, and 1971. There were 3 to 4 harvests each year. In October or November, from each year, 20 5- to 7-month-old, spring-cycle leaves from nonfruiting terminals, were obtained. Lemon leaves sampled for diagnosis of K status should be at least 5 months old or a deficiency may go undetected (10). Samples of 16 fruit per tree at the “silver” (1) stage of maturity, were obtained at varying intervals during the study.

Preparation and analysis of leaf and fruit samples were by reported methods (4, 16) except K and Zn were determined with a Perkin-Elmer 303 Atomic Absorption spectrophotometer.

Results and Discussion

The Zn treatments produced no significant differences in yield or fruit quality. Leaf analyses indicated that 1 Zn foliage spray per year supplied sufficient Zn. Since there were no interactions between Zn and K, only the main effects of K treatments are presented.

Yields and leaf analysis. Treatments were first applied in May 1967. There was a rapid response to K (Fig. 1-A). A large part of the yield recorded for 1968 was set in the later part of 1967. The Ksp was more effective than K₃₀ except for the last year recorded. After the first year, leaf K was about equal for the 2 treatments (Fig. 1-B), however, leaf N (Fig. 1-C) was slightly higher for the Ksp than for K₃₀ and might account for the slightly higher yield in Ksp. Leaf N appeared to be slightly limiting (15). For the last year, however, there was no difference in leaf N. All of the yield increase of both Ksp and K₃₀ over K₀ could be attributed to K.

The increase in yield from year to year was due to increasing age and tree size. Continued increases in yield of these 8-year-old trees is expected. For mature lemon trees — 12 to 15 year — yields are about 390 Kg/tree/yr (15). The yield increase of K over no K for the first 4 years of production for these young trees averaged 38%. In order to avoid such loss in production for young trees planted on soils virgin to citrus, leaf analysis should be early and, where indicated, corrective measures taken.

In the no K trees, there was a gradual increase in leaf K from 0.42% in 1967 to 0.59% in 1971 (Fig. 1-B). No K trees adjacent to trees receiving soil applied K contained, in the 1971 leaf sample, 0.51% K while those trees not adjacent to trees with soil

1Received for publication March 5, 1973.
2Professors of Horticulture, Department of Plant Sciences.
3Farm Advisor, University of California, San Luis Obispo Co.
4Extension Subtropical Horticulturist, University of California, Riverside.
5We express our appreciation to R. Woods, and others, of the Suey Ranch, Santa Maria, California and to C. B. Cree, M. Matsumura, and B. Salter, Staff Research Associates in the Department of Plant Sciences, University of California, Riverside. We also acknowledge financial assistance provided by the Soil Improvement Committee of the California Fertilizer Association, the Potash Institute of North America, and the Kerr-McGee Chemical Corporation.

K contained 0.62% K. Apparently there was no cross-feeding and continuing extension of the root system probably accounted for the increase in leaf K. If the increase in leaf K continues at the same rate until 1974, the leaf K would be up to 0.7% and these trees would probably no longer respond to applied K. However, the authors observed that in certain young


Fig. 1. Influence of soil and foliar applied K on: A) yield, B) leaf K, C) leaf N, and D) acid in the juice of the fruit of young lemon trees.

Fig. 2. Influence of soil and foliar applied K on: A) peel thickness, B) percent juice, C) ascorbic acid in juice, and D) K in juice of lemon fruit.

‘Valencia’ orange orchards leaf K decreased with age and eventually resulted in K deficiency.

Fruit quality. The factors related to fruit quality are presented in Fig. 1-D and 2-A, -B, -C, -D. An increase in K resulted in an increase in acid in the juice of oranges (9).
likewise occurred for lemons in this study (Fig. 1-D). For each sample date, acid was low for the K₀ treatment. Both Kₚ and K₀ were equally effective in increasing acid content of the juice. Unlike oranges (9), and in accord with previous work on lemons (3), an increase in K in lemons reduced peel thickness and increased the percent juice in the fruit (Fig. 2-A, -B). The amount of ascorbic acid in the juice was increased by added K, although not always significantly (Fig. 2-C). The amount of K in the juice was increased by added K (Fig. 2-D). We have no explanation for the variation in juice concentration between sampling dates. But temp preceding sampling appears to be the most likely cause. Acid in the juice was highest in the August sample and lowest in the March and April samples. However, Hilgeman (12) reports an increase of acid in the juice of grapefruit during the cold part of the year.

Abstract. Onset of rest, anthocyanin development, and leaf senescence and abscission were delayed in Euonymus alatus Sieb. 'Compactus' grown under intermittent mist. Leaf and bud tissues of misted plants contained less extractable abscisic acid (ABA) than did leaves and buds of non-misted plants. Mist leached endogenous and applied ABA from Euonymus leaves. Application of synthetic racemic ABA to growing Euonymus plants hastened onset of rest and increased anthocyanin development. This suggests that the observed responses of Euonymus to intermittent mist may be due to leaching of endogenous ABA.

Abscisic acid has been implicated in the control of rest in many species, both through correlation of high endogenous ABA concn with periods of rest (3) and induction of rest by exogenously applied ABA (4, 5, 9). Applied ABA has occasionally promoted development of fall color in foliage of a limited range of species (7, 11) and has caused increased anthocyanin levels in Cymbidium floral parts (1). High concn of applied ABA also promoted senescence and abscission of intact leaves (2, 5, 6, 7).

In Euonymus alatus 'Compactus', a woody ornamental prized for its intensely red autumn foliage, the onset of rest, anthocyanin development, and leaf senescence and abscission were delayed or prevented by intermittent mist. Normal endogenous levels of many leaf constituents such as total sugars, soluble N, protein N, K, starch, and flavans were altered in plants grown under mist (8). Several substances involved in anthocyanin synthesis, including sugars, K, and flavanoid compounds were leached from Euonymus by mist, as were auxin-like and growth inhibitory substances (8). This suggests that the effects of mist on rest and anthocyanin development in Euonymus might be partially attributable to leaching of substances, particularly inhibitors such as ABA, as the following experiments demonstrate.

Materials and Methods

In July 1971, 200 2-year old uniform rooted cuttings of Euonymus alatus 'Compactus', growing in sphagnum peat:perlite:sandy-loam (1:1:1 v/v) in 6-in plastic pots, were placed in a Cornell Walk-In-Type plant growth chamber. The light source consisted of 84% input wattage of warm white fluorescent lamps and 16% input wattage of 40 watt incandescent lamps with a plexiglass barrier between lamps and plants. Light intensity at soil level in the center of the chamber...