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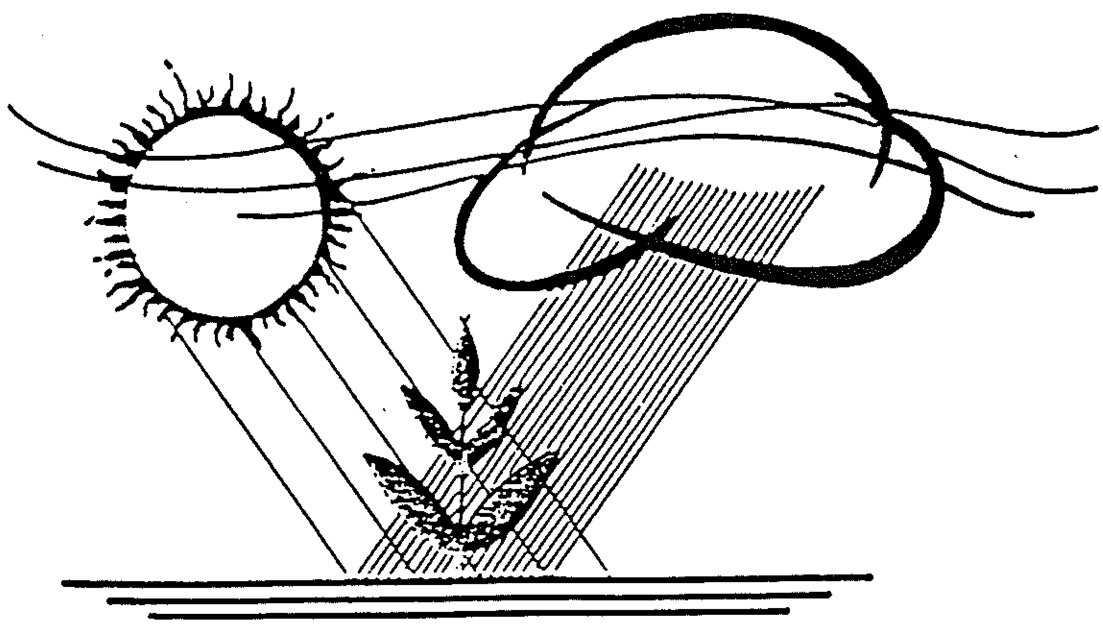

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AN EFFICACY STUDY TO EVALUATE THE USE OF FOLIAR-APPLIED UREA NITROGEN FERTILIZER AS A NON-PESTICIDE AGENT TO CONTROL CITRUS THRIPS (*Scirtothrips citri* (Moulton)).

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California citrus growers are a proactive group. In response to the accusation that the citrus industry has contributed to nitrate contamination of groundwater in California, the citrus industry as a whole has decreased the amount of nitrogen applied to the soil and increased the use of foliar-applied nitrogen fertilizer. However, with current and pending legislation, the citrus industry may have to further reduce the amount of soil-applied nitrogen.

The results of Embleton *et al.* (1986) demonstrated that even if growers used soil applications of nitrogen at the minimal levél required for optimal citrus production (225 kg NO_3^-/ha/yr), nitrate pollution of the groundwater would result. Most citrus growers fertilize with significantly higher rates of nitrogen. Worse still, $Ca(NO_3)_2$ applied to the soil at rates as low as 100 to 300 kg/ha/yr increased soil salinity from 0.93 to 1.56 dS/m (Embleton *et al.*, 1986). Thus, the continued use of soil-applied nitrogen in citrus production is a real and significant threat to both water and soil quality in California. Despite the fact that Embleton and Jones (1974) demonstrated that maximum nutritionally-attainable orange yields were associated with annual nitrogen rates from 0.45 to 0.65 kg/tree regardless of the method of application (soil-applied or foliar-applied), the expense of low-biuret urea and inconvenience of spraying have thwarted greater adoption of foliar nitrogen fertilization. Citrus growers need an economic incentive to abandon the use of soil-applied nitrogen in favor of foliar-applied urea. Our research addresses this issue by demonstrating that citrus growers can actually increase yield without a reduction in fruit size or quality by manipulating the timing of foliar urea application. In light of the fact that there are 258,430 acres (104,627 ha) of bearing citrus in California, reducing the amount of nitrogen applied to the soil by the citrus industry would make a major contribution to California's statewide program to improve water and soil quality.

The potential exists that the citrus industry is also contributing to the degradation of water and soil quality in California through the use of chemical pesticides to control citrus thrips (*Scirtothrips citri* (Moulton). Since the early 1900s, 1 to 4 chemical sprays have been applied during the pre-bloom and post-petal fall period to control this pest in much of California's citrus, especially in the San Joaquin Valley and southern California desert regions, where citrus thrips is a major concern in most years (Horton, 1981; Morse and

Brawner, 1986). Over the past 10 to 20 years, citrus thrips has also become a major problem in other citrus-growing regions of California, especially in the coastal regions of Ventura County. According to the CDFA, over the years 1983-1986, pesticide use for control of citrus thrips in California was 174.6, 190.5, 271.6, and 387.3 (thousand) lbs. active ingredient per year, respectively (Atkins *et al.*, 1989). Thus, 1986 pesticide use for citrus thrips control averaged 1.53 lbs. active ingredient on each of California's 253,681 acres of bearing citrus (Atkins *et al.*, 1989). Although the increase (221.8%) over this 4-year period may be partially due to more accurate reporting, much of the reported increase in pesticide use is real and results from an alarming increase in resistance of citrus thrips to the chemicals which are presently available for its control (Morse and Brawner, 1986; Morse *et al.*, 1986, 1988; Immaraju *et al.*, 1989). Citrus growers need an effective "non-pesticide" approach to control citrus thrips.

A non-pesticide strategy to control citrus thrips would make it possible to convert San Joaquin Valley citrus acreage to biological control (Luck *et al.*, 1986). Growers in the San Joaquin Valley, which comprises a majority (54%) of the state's citrus acreage, have historically used chemicals to control citrus thrips. Broad-spectrum materials such as dimethoate and formetanate, the two main pesticides used over the last 15 years to control citrus thrips, are devastating to biological control agents such as *Aphytis melinus* DeBach (Morse and Bellows, 1986), which can be used to successfully control red scale in citrus. The current use of chemicals to control citrus thrips precludes the use of biological control for other insect pests.

This project is a direct outgrowth of the basic research of Dr. Carol Lovatt, Department of Botany and Plant Sciences, on the role of ammonia and its metabolites in flowering, fruit set, fruit development, and yield of citrus and the applied research of Dr. Joseph Morse, Department of Entomology, in controlling citrus thrips populations and **reducing the economic loss to growers due to fruit scarring by thrips.**

Flower formation in *Citrus* species is promoted by drought or low temperature followed by restoration of climatic conditions favorable for growth (Lovatt *et al.*, 1988a; Monselise, 1985; Monselise and Goren, 1969; Monselise and Halevy, 1964; Southwick and Davenport, 1986). Lovatt *et al.* (1988a, 1988b) have quantified changes in leaf concentrations of several carbon and nitrogen compounds that occur during the low-temperature or water-deficit stress induction period and during the 4 weeks after removal of stress, which culminates in full bloom. For both 5-yr-old rooted cuttings of the 'Washington' navel orange induced to flower by low-temperature stress and a commercial orchard of 16-yr-old 'Frost Lisbon' lemon trees induced to flower by water-deficit stress, the increase in leaf NH_3-NH_4^+ content paralled the duration and severity of the stress.

Flower number was significantly correlated with leaf NH_3-NH_4^+ content: $p \leq 0.0001$ for low-temperature-induced flowering in the 'Washington' navel orange and $p \leq 0.05$ for water-deficit stress-induced flowering in the field-grown 'Frost Lisbon' lemon. No changes occurred in leaf concentrations of total nitrogen, nitrate, glucose, or starch either during or after the induction treatments.

A cause and effect relationship between tree NH_3-NH_4^+ status and floral intensity was established by subjecting trees to minimal stress and artificially raising the NH_3-NH_4^+ content of the tree by foliar application of low-biuret urea at the end of the minimal stress treatments. Increasing the leaf NH_3-NH_4^+ content by foliar applications of urea significantly increased the number of floral shoots and number of flowers per shoot but did not influence the number of vegetative shoots produced (Lovatt *et al.,* 1988b).

Leaf NH_3-NH_4^+ content ranged from 389 to 2,636 μg per g dry wt for more than 100 trees used in the experiments, including trees receiving foliar applications of low-biuret urea. The corresponding number of flowers per tree was from 4 to 3065 (Lovatt *et al.,* 1988b).

Of additional interest to us was the question of whether a winter foliar application of urea prior to or during the normal period of floral initiation preceding spring bloom of *Citrus* in California would increase floral intensity and result in increased fruit set and yield. For two consecutive years, a winter application of foliar urea in January or February increased the yield of 30-yr-old 'Washington' navel orange trees on Troyer citrange rootstock under commercial production at the Agricultural Experiment Station of the University of California, Riverside, in terms of both total fruit weight per tree and number of fruit per tree (without reducing fruit size) compared to control trees receiving only soil-applied urea. (All trees were determined to have optimal levels of nitrogen by leaf analysis).

A January or February foliar application of urea increased yield by just over one carton per tree in 1989-90 and just under one carton per tree in 1990-91 compared to trees receiving only soil-applied urea.

In addition, the increase in yield resulting from the winter foliar application of urea had no negative effect on fruit size in either year of the study. For each year, the treatment having the greatest number of fruit per tree had the greatest number of fruit with diameters from 7.0 to 8.0 cm (carton sizes 88 and 72: an additional carton per tree in 1989-90 and an additional half-carton per tree in 1990-91).

In addition, the results of our research provided evidence that flower ammonia (NH_3-NH_4^+) content and putrescine synthesis via arginine are metabolically linked during early development of the ovary (fruit) through the period of fruit set in navel oranges (Fig. 1) (Sagee and Lovatt, 1991).

FIGURE 1. *<u>DE NOVO</u>* <u>ARGININE BIOSYNTHESIS</u> <u>POLYAMINES</u>

NH_3-NH_4^+ + ATP + CO_2 → → → → ARGININE → PUTRESCINE → SPERMIDINE → SPERMINE

The conclusion to be drawn from these results is that the synthesis of putrescine and polyamines can be increased by increasing the NH_3-NH_4^+ content of developing flowers and fruit by foliar application of low-biuret urea (Lovatt *et al.*, 1988a, b).

Research is rapidly establishing the importance of polyamines as factors regulating fruit development and fruit set in plants. High polyamine biosynthetic activities and polyamine accumulation were previously reported to be associated with early stages of citrus fruit development characterized by cell division (Nathan *et al.*, 1984). Experimental use of exogenous applications of putrescine (10^{-4} M) to apple flowers increased fruit set and yield per tree (Costa *et al.*, 1986).

If these nitrogen compounds are important to fruit development and fruit set in citrus, we should be able to increase fruit set and yield with foliar applications of low-biuret urea during the period of early ovary (fruit) development prior to fruit set, i.e., sometime during the period from March 1 to May 1. This is the hypothesis we have proposed to test. Please note that the use of putrescine itself has little potential as a commercial practice because it is expensive and can cause serious eye and skin irritation.

The future of chemical control of citrus thrips is in question (Morse *et al.*, 1988). Resistance is rapidly developing in most areas of California to dimethoate (Cygon) and formetanate (Carzol) the two main pesticides used over the last 15 years (Immaraju *et al.*, 1989). Pyrethroids have not been registered on bearing citrus as yet but the California Citrus Quality Council has received an Emergency Exemption Permit (Section 18) for the use of cyfluthrin (Baythroid) against citrus thrips in 1991. Pyrethroid use is viewed with some concern because of the potential for scale insect and mite flare-ups in citrus as reported on various deciduous tree crops. It is also possible that abamectin (Agri-mek or Avid) may be registered sometime in 1993 or 1994.

A predaceous mite, *Euseius tularensis* (*hibisci*) Congdon and McMurtry, appears to provide some biological control of citrus thrips, especially where pressure from citrus thrips and fruit scarring is lighter in most years (Tanigoshi and Griffiths, 1982; Tanigoshi *et al.*, 1984, 1985). In general, however, and especially in situations where pressure from citrus thrips is high (e.g., San Joaquin Valley navel oranges = 90,979 acres), a selective chemical is needed to reduce citrus thrips to levels below economic threshold levels. *E. tularensis* is a polyphagous natural enemy of thrips. During warm periods after petal-fall, citrus thrips levels can rapidly increase to levels that the predaceous mite can not control. A selective material that could reduce the level of first generation citrus thrips before this time would be helpful. We believe that foliar urea will prove to be a selective material that is effective in reducing first generation citrus thrips levels. The only other selective materials presently available for citrus thrips control are sabadilla (Veratran D) and ryania (Ryan 50), both marginally effective botanical baits (mixed with sugar), which are in short supply. If as expected with increased interest in citrus integrated pest management including *Aphytis* releases for California red scale control, a moderate number of growers started to use one or both of these materials, supply could not meet demand.

We believe that the use of urea sprays may provide some control of citrus thrips during the critical pre-bloom to petal-fall period while being innocuous to important citrus natural enemies, e.g. *E. tularensis*. In California, bee-toxic pesticides cannot be sprayed from the time the citrus trees reach 10% anthesis in the southwest tree quadrant through 75% petal fall in the northeast tree quadrant as determined each spring by the Agricultural Commissioner in each county. It is of significant advantage to the grower that urea could be used during this period. The level of control afforded by urea sprays might not be very high. However, foliar urea (i) can be used during bloom when most chemical insecticides can not be used, (ii) would supplement biological control of citrus thrips by *E. tularensis*, and (iii) would supplement the use of botanical sprays without an additional expense to the grower since nitrogen fertilization must be accomplished regardless.

In glasshouse studies investigating the effect of phosphorus deficiency (-P) on the nitrogen metabolism of several citrus species, we observed that the leaves of the -P plants, which accumulate high levels of ammonia (Rabe and Lovatt, 1986a, b), had very low levels of polyphagous insects relative to the +P controls. Dr. J. G. Morse, Associate Professor of Entomology at UCR, quantified the survival of young, first instar citrus thrips (less than 24 h post-hatch) on -P and +P leaves. In two separate experiments, only 12 and 3% survived to the prepupa stage on -P leaves, compared to an 88 and 86% survival rate on +P leaves. To confirm that the death of the thrips was due to the high concentration of NH_3-NH_4^+ (1,215 μg/g dry wt) in the -P leaves, the petioles of +P leaves were immersed in 50 mM NH_4Cl for 48 h or in distilled water for 48 h. Results are summarized in Table 1. It is clear that high levels of NH_4^+ (> 1,600 μg per gram fresh weight leaf tissue) cause significant citrus thrips mortality (> 80%).

Results from South Africa confirm that foliar-applied urea can be used to reduce scarring from citrus thrips. The experiments also established that the time of urea foliar application is important. A foliar urea 1% w/v spray applied during bloom significantly

($p \leq 0.05$) reduced citrus scarring caused by *Scirtothrips aurantii* (a species very similar to California citrus thrips). However, a later application made at 100% petal fall had no toxic or antifeedant effect (Grout and Richards, 1988). Grout and Richards (1988) concluded that once absorbed, the urea either must have had an antifeedant or toxic effect for several weeks, or else dramatically reduced the thrips generation that occurred during bloom, to cause such a significant reduction in scarring by citrus thrips (Table 2).

Table 1. Effect of Leaf Ammonia Content on Citrus Thrips Survival

Treatment	NH_3-NH_4^+ (μg/g FW)	Number of thrips	% Reaching prepupa	Days to prepupa	% Reaching adult	Days to adult
Control 1	50	60	98	10	93	14
Control 2	174	60	98	8	97	13
NH_4^+ (48 h)	1,972	60	8	14	8	18
NH_4^+ (48 h)	1,619	60	38	11	18	15

Table 2. Effect of Foliar-Applied Urea on Citrus Thrips Scarring

Treatment	Application date, 1986	Mean percent fruit scarred 10 Nov. 1987
Untreated	---	22.2 a
Urea 1% w/v	Sept. 16 - bloom	8.9 b
Urea 1% w/v	Nov. 13 - petal fall	24.2 a

(Grout and Richards, 1988)

Thus, urea sprays applied during the pre-bloom to petal-fall period from March 1 to May 1 may be optimal for citrus thrips control and also for maximizing the growth regulator-like properties of urea to improve fruit set and yield. If our hypothesis is correct, the results of our field research employing 17-yr-old 'Washington' navel orange trees on Troyer citrange rootstock under commercial production in the Southern San Joaquin Valley will provide evidence that foliar-applied low-biuret can do triple duty: (*i*) as a "non-pesticide" to control citrus thrips and reduce fruit scarring; (*ii*) as a plant "growth regulator" to increase fruit set and yield without a reduction in fruit size or quality; and (*iii*) as a source of nitrogen fertilizer so that less nitrogen is applied to the soil. This will provide citrus growers with an environmentally sound alternative that imposes no economic hardship to citrus growers should the current use of toxic pesticides be restricted and an economic incentive to switch, at least in part, from soil-applied nitrogen in favor of foliar-applied urea to increase yield, thus reducing the potential for pesticide and nitrate pollution of groundwater.

LITERATURE CITED

Atkins, D. R., C. W. Coggins, Jr., D. J. Gumpf, J. D. Hare, W. M. Harrell, L. S. Jordan, R. F. Luck, J. A. Menge, J. G. Morse, J. E. Pehrson, Jr., J. D. Radewald, A. A. Rhodes, M. L. Roose, and G. P. Walker. 1989. Alternatives to preharvest chemical inputs in California citrus. *In* H. O. Carter and C. F. Nuckton (eds.), Agricultural chemicals in California plant production: are there alternatives? Univ. Calif. Agric. Issues Center, Davis, CA, pp. 100-147.

Bellows, T. S., Jr., Jr. G. Morse, and C. J. Lovatt. 1989. Modelling flower developing in *Citrus*. In: C. Wright (ed.), Manipulation of Fruiting. Butterworths, pp. 115-129.

Costa, G., R. Biasi, and N. Bagni. 1986. Effect of putrescine on fruiting performances of apple (cv Hi Early). Acta Hort. 179:335-361.

Embleton, T. W. and W. W. Jones. 1974. Foliar-applied nitrogen for citrus production. J. Environ. Quality 3:388-391.

Embleton, T. W., M. Matsumura, L. H. Stolzy, D. A. Devitt, W. W. Jones, R. El-Motaium, and L. L. Summers. 1986. Applied Agricultural Research, Vol. 1, No. 1, pp. 57-64.

Grout, T. G., J. G. Morse, N. V. O'Connell, D. L. Flaherty, P. B. Goodell, M. W. Freeman, and R. L. Coviello. 1986. Citrus thrips (Thysanoptera: Thripidae) phenology and sampling in the San Joaquin Valley. J. Econ. Entomol. 79:1516-1523.

Grout, T. G. and G. I. Richards. 1988. Annual report on research for the period August 1987 to July 1988. Entomology Section, Citrus Exchange, Port Elizabeth, South Africa.

Horton, J. R. 1981. The citrus thrips. U.S. Dept. Agric. Bull. 616.

Immaraju, J. A., J. G. Morse, and D. J. Kersten. 1989. Citrus thrips (Thysanoptera: Thripidae) pesticide resistance in the Coachella and San Joaquin Valleys of California. J. Econ. Entomol. 82:374-380.

Lovatt, C. J., Y. Zheng, and K. D. Hake. 1988a. A new look at the Kraus-Kraybill Hypothesis and flowering in citrus. Proc. of the Sixth Int. Citrus Congress, pp. 475-484.

Lovatt, C. J., Y. Zheng, and K. D. Hake. 1988b. Demonstration of a change in nitrogen metabolism influencing flower initiation in Citrus. Israel J. Bot. 37:181-188.

Luck, R. F., J. G. Morse, and D. S. Moreno. 1986. Current status of integrated pest management in California citrus groves. *In* R. Cavalloro and E. D. Martino (eds.), Integrated Pest Control in Citrus-Groves, Proc. Experts' Meet./Acireale/26-29 March 1985. A. A. Bal Kema, Boston, pp. 533-543.

Monselise, S. P. 1985. Citrus and related genera. In: A. H. Halevy (ed.) CRC Handbook of Flowering, pp. 257-294, vol. 2. CRC Press, Boca Raton, Florida.

Monselise, S. P. and R. Goren. 1969. Flowering and fruiting-interactions of exogenous and internal factors. Proc. 1st Intl. Citrus Symp. 3:1105-1112.

Monselise, S. P. and A. H. Halevy. 1964. Chemical inhibition and promotion of citrus flower bud induction. Proc. Amer. Soc. Hort. Sci. 84:141-146.

Morse, J. G. and T. S. Bellows. 1986. Toxicity of major citrus pesticides to *Aphytis melinus* (Hymenoptera: Aphenlinidae) and *Cryptolaemus montrouzieri* (Coleoptera: Coccinellidae). J. Econ. Entomol. 79:311-314.

Morse, J. G. and O. L. Brawner. 1986. Toxicity of pesticides to *Scirtothrips citri* (Thysanoptera: Thripidae) and implications to resistance management. J. Econ. Entomol. 79:565-570.

Morse, J. G., H. S. Elmer, and O. L. Brawner. 1986. Resistance thrips: the 1986 control recommendations for California. Citrograph 71(6):118-120.

Morse, J. G., J. A. Immaraju, and O. L. Brawner. 1988. Citrus thrips: looking to the future. Citrograph 73(6):112-115.

Nathan, R., A. Altman, and S. P. Monselise. 1984. Changes in activity of polyamine biosynthetic enzymes and in polyamine contents in developing fruit tissues of `Murcott' mandarin. Sci. Hort. 22:359-364.

Rabe, E. and C. J. Lovatt. 1986a. Phosphorus deficiency results in a state of ammonia toxicity. Plant Physiol. 81:774-779.

Rabe, E. and C. J. Lovatt. 1986b. Relative phosphorus dependency of citrus rootstock cultivars is reflected in their nitrogen metabolism. J. Amer. Soc. Hort. Sci. 111:922-926.

Sagee, O. and C. J. Lovatt. 1991. Putrescine content parallels ammonia and arginine metabolism in developing flowers of the `Washington' navel orange. J. Amer. Soc. Hort. Sci. 116:280-285.

Southwick, S. M. and T. L. Davenport. 1986. Characterization of water stress and low temperature effects on flower induction in citrus. Plant Physiol. 81:26-29.

Tanigoshi, L. K. and J. Griffiths. 1982. A new look at biological control of citrus thrips. Citrograph 67:157-158.

Tanigoshi, L. K., J. Fargerlund, J. Y. Nishio-Wong, and H. J. Griffiths. 1985. Biological control of citrus thrips, *Scirtothrips citri* (Thysanoptera: Thripidae), in southern California citrus groves. Environ. Entomol. 14:733-741.

Tanigoshi, L. K., J. Y. Nishio-Wong, and J. Fargerlund. 1984. *Euseius hibisci*: its control of citrus thrips in southern California citrus orchards. *In* D. A. Griffiths and C. E. Brown (eds.), Acarology VI, Vol. 2. Ellis Horwood, Chichester, England, pp. 717-724.