PROBLEMS WITH UREA-N FOLIAR FERTILIZATION OF AVOCADO

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Summary

Based upon total leaf N concentration, Embleton and Jones in California in the early 1950's found no response to urea leaf sprays on mature 'Fuerte' avocado trees in the field. Up to three sprays a year were applied.

In Egypt, urea sprays resulted in an increase in 'Fuerte' fruit yield, size, and weight (no leaf analysis reported).

In field experiments conducted at the University of California, Riverside, no significant effect of concentrations of urea sprays on the total N in 'Hass' avocado leaves could be demonstrated.

Using detached leaves of 'Fuerte' avocado, researchers in Israel reported substantial uptake of foliar urea-N when applied with surfactants. They subsequently reported the translocation of ^{15}N from foliar-applied urea to vegetative and reproductive sinks of both 'Fuerte' and 'Hass' avocado.

Recent research at the University of California, Riverside, provided evidence that the leaf NH_3-NH_4^+ content of 'Hass' avocado on clonal 'Duke 7' rootstock 2 years from budding was not increased by foliar application of urea at the same concentration that increased citrus leaf NH_3-NH_4^+ content two-fold. Maximum uptake of ^{14}C-urea by 'Hass' avocado leaves was physiologically insignificant (2.1% of the total urea applied) at the end of 2 days. Over 96% of the ^{14}C-urea applied was recovered from the leaf surface even after 5 days. Maximum uptake of ^{14}C-urea by leaves of 'Gwen' and 'Fuerte' was less than 7% and did not increase significantly after the first 4 h over a 24-h period. 'Hass', 'Gwen' and 'Fuerte' leaves exhibited an active urease in the presence of 2 mM urea. Urease activity was linear after an initial 1 h incubation up to 6 h at 30°C.

This report will be directed to practical application of available information. Factors considered in present discrepant results are: geographical, environmental, concentration, surfactant, leaf age and source, and experimental design.

1. Introduction

Discrepant results exist among research findings on effectiveness of urea-N foliar fertilization of avocado. From 1950 to the present, three studies in California (USA) indicated that such sprays were not an effective means of supplying N to the trees. Conclusions from one study in Egypt and two in Israel indicate that such sprays are effective.

The reasons for the discrepancy are not apparent. This report summarizes findings, to date, and suggests the avocado world be cautious in use of urea foliar fertilization until reasons for the discrepancy are known.

2. Results and discussion

2.1. Previous research

In the early 1950's T. W. Embleton and W. W. Jones (unpublished), in a well-replicated experiment on mature 'Fuerte' avocados near Corona, California, USA, sprayed a 1.0% w/w solution on trees three times a year. Using total N in leaves as a measure of effectiveness, they concluded that such sprays were not effective. Such a report was given verbally to California growers many times over the years.

A report from Egypt on 'Fuerte' by Abou Aziz *et al.* (1975) showed an increase in fruit yield, size, and weight from such sprays. They reported yields during a 2-year period varying from 15 to 40 g of fruit per tree. This is obviously incorrect. They probably meant kg per tree. There were five treatments replicated three times with single-tree plots. Calcium nitrate was applied to the soil at rates of 250 and 500 g N per tree annually. Drenching sprays of a 1.0% w/w urea solution were applied to the foliage in March, April, May, and June to supply 250 and 500 g of N per tree annually. Both soil and spray applications increased yields varying from 12 to 122%. Drenching sprays would probably result in a considerable amount of spray solution reaching the soil. However, for the 500 g spray treatment, 125 g of urea would have to be applied in each of the 4 months. That would be 12.5 liters per spray, which would not be a drenching spray on mature trees.

Galindo-Tovar (1983) was able to increase N leaf concentrations in 'Hass' avocado seedlings grown in a greenhouse and lathhouse with low concentrations of urea sprays (0.6% w/w). Surfactants and humectants also showed some significant influences. Toxic effects of higher concentrations (1.2 and 1.8% w/w) of urea occurred. However, similar treatments on 3-year-old 'Hass' avocados in the field applied in March, April, and May did not increase the concentration of leaf N in mature leaves sampled 1 week after each application. There were no toxic effects from the sprays.

Galindo-Tovar cited evidence for crops other than avocado suggesting that urea can penetrate leaf surfaces when grown in a greenhouse, but when grown in the field under full sun, leaf surface characteristics are different and resist movement of urea into the leaf.

For detached 'Fuerte' avocado leaves from mature trees dipped momentarily in urea solutions, Klein and Zilkah (1986) found that the

percentage of N increased from 2.28 to 3.26% within 12 days, following three foliar applications of 3% urea. This represented 65-85% of the applied urea. Leaf age, leaf surface, and surfactant had no significant effect on kinetics of urea uptake. Phytotoxicity 4 days after dipping was observed with 4, 8, and 16% urea solutions. Young leaves were damaged by repeated applications of 2% and flowers by concentrations above 0.5 to 1% urea.

Increasing concentrations of ^{15}N-enriched urea applied to old 'Fuerte' avocado leaves on shoots having inflorescences resulted in significantly increased N concentrations in both terminal and lateral inflorescences. Obviously, the N from the urea was absorbed by the leaves and translocated (Zikah *et al.*, 1987). These authors show other sinks for the ^{15}N absorbed by the leaves.

Young, fully expanded leaves of 'Hass' avocado on clonal 'Duke 7' rootstock, 2 years from budding, were used to assess changes in leaf NH_3-NH_4^+ content. Foliar application of 1.5 g low biuret urea per tree failed to increase the leaf NH_3-NH_4^+ content: compare 23.6 $\pm$ 5.8 versus 20.1 $\pm$ 5.7 μg NH_3-NH_4^+ per g fr. wt. leaf tissue (x $\pm$ STD. DEV., N = 3 trees per treatment) from trees treated with and without urea, respectively (Nevin and Lovatt, 1989). Foliar application of 1.5 g of low biuret urea per tree to 5-year-old rooted cuttings of the 'Washington' navel orange of comparable size increased the leaf NH_3-NH_4^+ content of the trees subjected to 4, 6, or 8 weeks of low temperature 1.7-, 2.2-, and 1.2-fold, respectively (Lovatt *et al.*, 1988) (Table 1).

To further test the capacity of 'Hass' avocado leaves to take up foliarly applied urea, areas of a leaf (1 cm x 1 cm) were painted with a single application of ^{14}C-urea (12 x 10^3 dpm/nmol, 0.2 μM final concentration). These areas were collected with a cork borer after 1 h, 2 h, 4 h, 6 h, 12 h, 24 h, 48 h, and 5 days. Sample areas were swabbed with distilled water until no radioactivity remained on the leaf surface. The leaf sample was placed in 80% methanol and bleached. The content of radioactivity was determined using a Beckman LS100 liquid scintillation counter.

Table 1 - Effect of foliar application of 1.5 g low biuret urea per tree on the leaf NH_3-NH_4^+ content of 'Hass' avocado and 'Washington' navel orange 1 week after application.

	Leaf NH_3-NH_4^+ content (μg/g dry wt.)		
Plant	without urea	with urea	net increase
'Hass' avocado[z]	35	40	5
'Washington' navel orange	559[y]	928	369
	583[x]	1253	670
	672[w]	901	229

[z] Leaf NH_3-NH_4^+ was determined using fresh leaf tissue and the average value of the final results (Nevin and Lovatt, 1989) converted to μg/g dry wt. for comparison.

[y-w] 'Washington' navel orange trees were subjected to 4, 6, and 8 weeks of low temperature [8-h day (500 $\mu\Sigma/m^2$·sec) at 15-18°C/16-h night at 10-13°C], respectively. Urea was applied at the end of the low temperature treatment and transfer of the trees to the warm temperature [12-h day (500 $\mu\Sigma/m^2$·sec) at 24°C/12-h night at 19°C] (Lovatt *et al.*, 1988).

Movement of ^{14}C-urea applied to the upper surface of 'Hass' avocado leaves into the leaf was minimal. The amount of ^{14}C-urea recovered in the leaf increased with exposure. Maximum uptake occurred after 2 days and was not improved by an additional 3 day of exposure to the ^{14}C-urea (Table 2). Maximum uptake represented only 2.1% of the urea applied to the leaf surface, which is physiologically insignificant. At such levels of urea, urease activity of intact cells of 'Hass' avocado leaves was also insignificant (Table 3) (Nevin and Lovatt, 1989).

Table 2 - Uptake of foliar-applied ^{14}C-urea by 'Hass' avocado.[z]

Time after application	Uptake as a percent of the total ^{14}C-urea applied to the leaf[y]
2 h	0.3
4 h	0.4
6 h	1.0
12 h	1.2
24 h	1.6
2 days	2.1
5 days	2.0

[z] Nevin and Lovatt (1989).

[y] For each treatment, greater than 95% of the applied ^{14}C-urea was recovered in the H_2O used to wash the surface of the leaf before tissue uptake was determined.

Table 3 - Urease activity of 'Hass' avocado leaves incubated with 0.2 μM urea.[z]

Source of leaves	Relative age	nmol ^{14}C released by urease per g fr. wt. leaf tissue · 3 h
Greenhouse	young, fully expanded	0.044
	mature	0.038
Field	young, fully expanded	0.043
	mature	0.049

[z] Nevin and Lovatt (1989).

2.2. Current research

To determine if there were cultivar differences, the ^{14}C-urea uptake experiments were repeated with 'Gwen' on seedling 'G6' rootstock, 7 months from budding, and with 'Fuerte' on seedling 'Duke 7' rootstock, 1-1/2 years from budding. Five-year-old rooted cuttings of 'Washington' navel orange served as the experimental control.

Uptake of ^{14}C-urea applied to the upper surface of 'Gwen' and 'Fuerte' avocado leaves was more rapid and greater than uptake by 'Hass' avocado leaves. However, the uptake of foliar-applied urea by all three avocado cultivars was significantly lower than that of 5-year-old rooted cuttings of the 'Washington' navel orange (Tables 4, 5 and 6).

Table 4 - Uptake of foliar-applied ^{14}C-urea by 'Gwen' avocado.[z]

Time after application	Uptake as a percent of the total ^{14}C-urea applied to the leaf	Percent recovery of ^{14}C-urea from the leaf surface
2 h	1.1 a	93 a
4 h	3.8 b	86 b
7 h	3.6 b	84 b
24 h[y]	5.2 b	68 c

[z] Data within a column followed by a different letter are significantly different at $P < 0.05$.
[y] After 24 h, less than 0.04% of the ^{14}C-urea applied to the leaf was translocated to the base of the leaf.

Table 5 - Uptake of foliar-applied ^{14}C-urea by 'Fuerte' avocado.[z]

Time after application	Uptake as a percent of the total ^{14}C-urea applied to the leaf	Percent recovery of ^{14}C-urea from the leaf surface
2 h	1.7 a	90 a
4 h	5.3 b	87 a
7 h	6.1 b	79 b
24 h[y]	6.7 b	48 c

[z] Data within a column followed by a different letter are significantly different at $P < 0.05$.
[y] After 24 h, less than 0.02% of the ^{14}C-urea applied to the leaf was translocated to the base of the leaf.

Table 6 - Uptake of foliar-applied ^{14}C-urea by 'Washington' navel orange.[z]

Time after application	Uptake as a percent of the total ^{14}C-urea applied to the leaf	Percent recovery of ^{14}C-urea from the leaf surface
2 h	21 a	85 a
4 h	26 a	74 b
7 h	27 a	55 c
24 h	5 b	20 d

[z] Data within a column followed by different letters are significantly different at $P < 0.05$.

Avocado leaf discs incubated in the presence of levels of urea greater than physiological (2 mM) exhibited significant urease activity. After an initial 1 h incubation period at 30°C, urease activity was linear up to 6 h for all three avocado cultivars and for the 'Washington' navel orange (Table 7).

Table 7 - Urease activity of leaves incubated with 2 mM urea.

	nmol $^{14}CO_2$ released by urease per g fr. wt. leaf tissue			
Source of leaves[z]	1/4 h	1 h	3 h	6 h
'Hass'	68	735	2641	5329
'Gwen'	82	889	3120	5644
'Fuerte'	150	1011	3049	6109
'Washington' navel orange	126	1363	4890	10241

[z] Trees were maintained in the glasshouse ('Hass', 'Washington' navel orange, 'Gwen') or lathhouse ('Fuerte'); young, fully expanded leaves were used in each case.

3. Conclusion

The practical aspects of using urea sprays as an N source for avocado is not clear. Only one study reported positive results in terms of fruit yield. Even though the experiment had only three single-tree plot replications, the magnitude of the response to soil and foliar application of N was so great that statistically significant differences were obtained.

Other experiments addressed leaf age, humectants, surfactants, leaf cuticle characteristics, etc. None of these factors gave a good explanation of present discrepancies.

It appears that studies in Egypt and Israel are in agreement that such sprays are of practical value. California studies are negative on this issue. Is there something in the "environment" around the Mediterranean area that is different from that in California? Are sinks for N masking something that makes total leaf N an inappropriate guide for effectiveness? If so, studies on other crops where urea sprays are effective would not support this.

Effective foliar urea sprays on avocado would be highly desirable for production as well as for protection of the environment by reducing nitrate pollution of ground water. However, before recommending this procedure, well-replicated field experiments are needed to demonstrate that urea sprays are an effective means of N fertilization of the avocado.

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