

Foliar applied urea improves freezing protection to avocado and peach¹

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Abstract

The effect of foliar applied urea on freeze hardiness was evaluated under orchard and laboratory conditions. Freezing injury and senescence of avocado (*Persea americana* Mill.) cv. 'Hass' leaves in the orchard was inversely correlated to N content. Three foliar applications of 2% low-biuret urea caused a 26% nitrogen enrichment of leaves. Consequently, leaf freezing hardiness was increased and senescence retarded. Urea-treated leaves were 2.5 times more tolerant to freezing than untreated leaves, at the same level of senescence. The freeze protection effect of foliar-applied urea was confirmed using potted plants of the cultivar 'Fuerte' under controlled conditions. Potted avocado plants treated with 2% low-biuret urea, gradually cooled, and exposed to -2°C for 4 h, were significantly more hardy than control plants. Foliar application of 10% low-biuret urea to peach (*Prunus persica* L.) cv. 'Maravilha' shoots before flowering, 3 days before frost occurrence, increased the freezing hardiness and survival of the reproductive organs. The protective effect of foliar-applied urea on peach flower buds in spring decreased gradually as bud development progressed.

Keywords: Avocado; Freezing injury; Peach; Urea

1. Introduction

Avocado and peach are economically important crops, liable occasionally to severe cold injury. Three races of avocado, the Mexican, the Guatemalan and the West Indian,

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have been classified (Berg, 1975). The races and their respective cultivars vary in their frost susceptibility (Knight, 1974; McKellar and Buchanan, 1992). 'Hass' and 'Fuerte' (Mexican × Guatemalan hybrids) are prevalent avocado cultivars which show an intermediate susceptibility to frost (Barak and Israeli, 1990).

A positive relationship between nitrogen fertilization and freeze hardiness has been observed in orchards of several fruit crops such as citrus (Smith and Rasmussen, 1958), avocado (Lahav et al., 1985) and peach (Proebsting, 1961). However, the tolerance of some species to freezing was not influenced by N levels (Pellet and Carter, 1981).

Field investigations have been carried out to find growing conditions or treatments that could enhance the resistance of trees to cold. For some fruit tree species, plant growth regulators such as ethephon (Proebsting and Mills, 1976), abscisic acid (Holubowicz and Boe, 1969), gibberellic acid (Holubowicz and Boe, 1969; Modlibowska, 1965), maleic hydrazide (Hendershott, 1962) and (2-chloroethyl) trimethylammonium chloride (Modlibowska, 1965) have been tried for protection against frost, but none has been adopted in practice. Some of the treatments, i.e. ethephon application, were aimed to postpone the flowering time, in order to evade the early spring frosts, or simply to escape from low (not freezing) temperatures (Galán Saúco et al., 1993).

Urea is widely used as a nitrogen fertilizer, mostly applied through soil but also to the plant canopy (Swietlik and Faust, 1984). Leaf N content can be increased rapidly by the foliar application of urea (Klein and Zilkah, 1986; Zilkah et al., 1987).

The objective of the present study was to evaluate the potential use of foliar urea application for frost protection under controlled and field conditions.

2. Materials and methods

2.1. Field studies

The avocado experiment was conducted on 10-year-old *Persea americana* Mill. cv. 'Hass' trees growing on a fine clay soil with 10% calcium carbonate, near Hadera, on the coastal plain of Israel. Tree spacing was 6 m × 6 m. Soil nitrogen (590 g per tree) was applied by fertigation (30 m³ per tree year⁻¹), from the beginning of May to the end of November.

Avocado trees were sprayed, using a blower sprayer, with 2% (w/v) low-biuret urea (Deshanim, Haifa, Israel) in 0.05% Triton X-100 solution (20 l per tree), on three occasions: 2, 12 and 18 February 1988. Two rows (25 trees) were sprayed adjacent to three control rows (31 trees).

Ten viable leaves per tree were sampled for N analysis at intervals throughout the season from the same five randomly selected replicates of urea-treated and control trees. Nitrogen was determined prior to and after each application. During January 1989, the trees were exposed to freezing temperatures for 16 nights. On 30 January 1989, leaves from an additional five trees from both urea-treated and control trees were sampled.

On 3 February 1989, freezing injury symptoms (dark brown water-soaked spots) and degree of senescence (symptoms of discolored and scorched leaves) were visually rated by three independent observers.

The sampled leaves were dried at 60°C for 48 h and ground. Leaf nitrogen was colorimetrically determined with an auto analyzer after micro-Kjeldahl digestion.

Experiments with urea spray were conducted on 10-year-old peach (*Prunus persica* L. cv. 'Maravilha') trees growing at Talmei Yehiel, in the southern coastal region of Israel. Flowers developing on 1-year-old shoots, 50–70 cm in length, were selectively thinned, leaving only one type of flower bud per shoot, at the following stages of development: green tip, pink bud, open flower and petal-fall flower. Ten shoots of each type were sprayed with 10% (w/v) low-biuret urea in 0.05% Triton X-100 solution, until run-off, by the use of a hand sprayer. Ten control shoots with each type of flower bud were sprayed with Triton X-100 solution. Treatment layout was a paired comparison. Pairs were replicated on different trees. Treatments were applied on 1 February 1989, 3 days before the first freeze. The trees were exposed for 4 nights at freezing temperatures. The reproductive organs were counted immediately before and 27 days after urea application.

2.2. Controlled conditions study

The effect of foliar-applied urea on freeze protection was studied using potted plants in temperature controlled chest freezers. Four 8-month-old avocado plants (containing about four main shoots) cv. 'Fuerte' were sprayed until run-off with 2% (w/v) low-biuret urea in 0.05% Triton X-100 solution, using a hand sprayer. Four control plants were sprayed with the surfactant only. After being sprayed with urea, the plants were immediately exposed to 8°C for 8 h, then cooled to -2°C at a rate of 2°C h⁻¹, followed by a 4 h holding period at -2°C. Following the exposure to the freezing temperature, the plants were thawed gradually to 5°C at a rate of 2°C h⁻¹ and transferred to a greenhouse. Freeze injury damage was rated during the following 2 weeks. The percentages of injured leaves and stems (degenerating symptoms of desiccation), were determined relative to the initial numbers of leaves and stems. The experiment was repeated three times.

3. Results

3.1. Field study—avocado

Three consecutive applications of 2% urea significantly increased the N content of leaves (Fig. 1). The N content of the sampled trees ($n = 5$) showed a 26% increase 1 week after the third foliar spray. Subsequently it declined but remained 11% higher than in control plants during the growing season of 1988. Nitrogen content after freezing was higher ($n = 10$, $P \leq 0.05$) in the urea-treated trees (1.97%) than in the untreated controls (1.81%). Leaf freeze injury symptoms were significantly ($P \leq 0.01$) and inversely correlated with the leaf N content (Fig. 2(a)). The same correlation was also significant ($P \leq 0.05$), when only the control trees were used. The correlation between these two parameters in the urea-treated trees was not statistically significant, owing to limited variation in their N content, and consequently the low rate of freeze injury. Similar

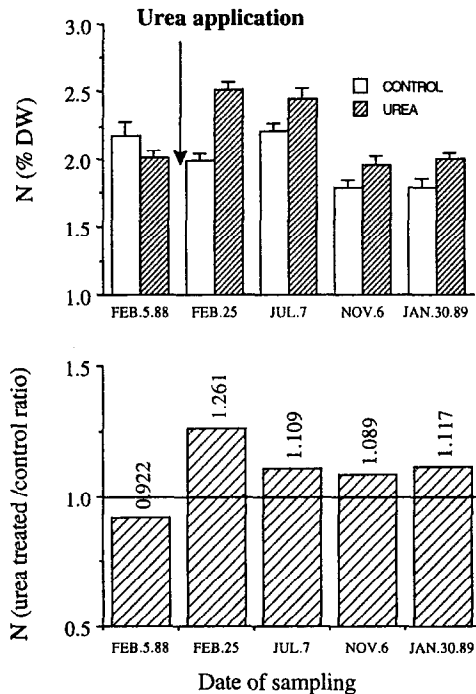


Fig. 1. The effect of foliar-applied urea on nitrogen content (\pm SE) of 'Hass' avocado leaves. Three applications of 2% urea were performed during February 1988.

inverse correlation was found between N content and leaf senescence (Fig. 2(b)). The urea-treated trees had a significantly ($P \leq 0.05$) lower degree of leaf senescence than control trees. The average degree of leaf senescence in the urea-treated trees was 1.4 ± 0.12 compared with 1.9 ± 0.19 in the controls. Despite the significance (which indicated with high probability that the true correlation coefficient is not zero), the actual value of r^2 explained only 36% (Fig. 2(a)) or 22% (Fig. 2(b)) of the total variability. This was also evident from the large dispersion around the regression lines.

Avocado leaf senescence was already underway when freezing occurred. Freezing injury was correlated with the degree of leaf senescence (Fig. 3). The correlation was calculated separately for urea-treated and untreated trees. The linear correlation coefficient in both cases was highly significant. The slope of the control line was 2.5 times steeper than that of the urea treatment (1.5 and 0.6, respectively). The difference between the two regression lines was significant ($P \leq 0.05$, F test). Freezing protection resulting from the urea treatment was more evident in more senescent leaves.

3.2. Effect of foliar applied urea on cold injury of avocado plants under controlled conditions

'Fuerte' avocado plants exposed to controlled freezing for 4 h were severely injured (Table 1). A 2% foliar application of urea reduced freezing injury. The percent symptom

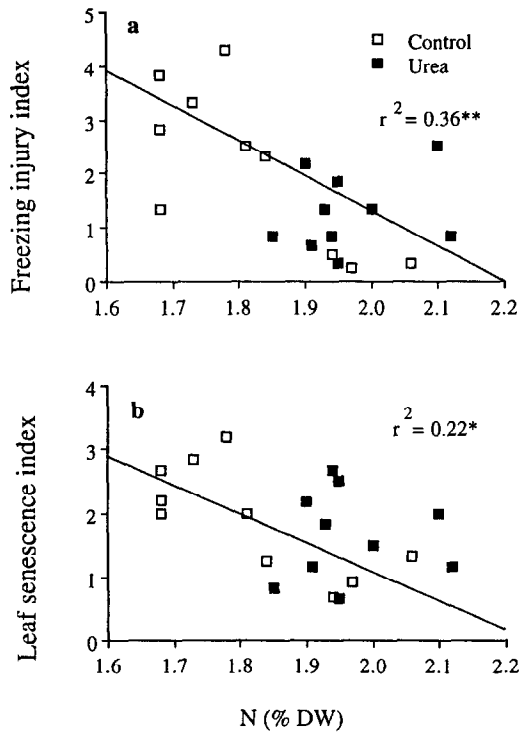


Fig. 2. Correlation between N content of leaves with freeze injury (a) and leaf senescence (b) in urea-treated and untreated avocado trees. Senescence and freeze injury were rated from 0 to 5, with higher values representing a greater degree of injury and senescence. Asterisks denote significance of the r correlation coefficient: * $P \leq 0.05$; ** $P \leq 0.01$.

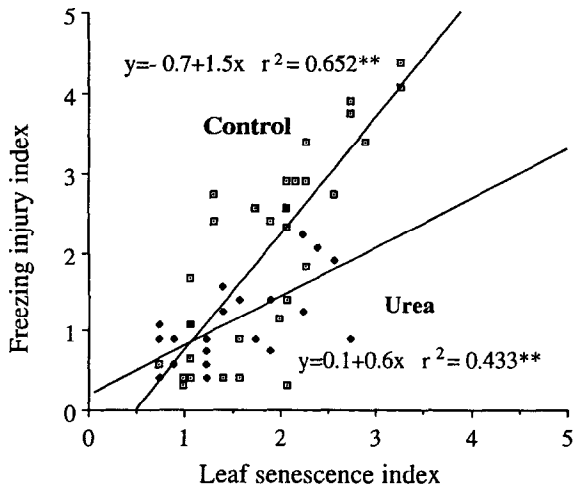


Fig. 3. Correlation between freeze injury and leaf senescence of urea-treated and untreated leaves of avocado. The r correlation coefficients are significant ($P \leq 0.01$). The two regression lines are significantly different ($P \leq 0.05$).

Table 1
Effect of foliar-applied urea on freeze injury of 'Fuerte' leaves and stems on potted plants 1 and 10 days after freeze treatment

Treatment	Damaged leaves (%)		Damaged stems (%)	
	1 day	10 days	1 day	10 days
Control	76a	90a	81a	88a
2% urea	31b	47b	38b	44b

Mean separation in columns by *t*-test, $P \leq 0.05$.

Table 2
Effect of urea application on mean (\pm SE) percent survival of 'Maravilha' peach flower buds at various stages of development, following exposure to freezing temperatures. Reproductive organs had been selectively thinned, leaving only one type of flower bud per shoot. Ten percent urea was applied about 3 days before freeze occurrence

Developmental stage	Survival (%)	
	Control	Urea treatment
Green tip	20 \pm 4	73 \pm 11
Pink bud	0	30 \pm 7
Open flower	0	19 \pm 5
Petal-fall flower	0	9 \pm 5

expression in injured leaves and stems of the urea-treated plants was significantly reduced 1 and 10 days after their transfer to the greenhouse.

3.3. Peach study

Freezing at the experimental site of the peach orchard caused severe damage to 'Maravilha' flower buds (Table 2). Only $28.3 \pm 5.2\%$ ($n = 10$) of the reproductive organs set fruit. Without urea treatment all reproductive organs at the pink bud, open flower and petal-fall stage were aborted and only some of the green-tip buds survived. Urea spray significantly increased the flower bud retention. The effect on survival rate decreased at progressively advanced stages of flower development.

4. Discussion

Foliar application of urea was selected to enrich rapidly the nitrogen content of avocado trees. Nitrogen enrichment through the canopy may be preferable to soil application during the winter and the early spring, when uptake and mobilization through the roots are still limited due to water saturation and low soil temperature. It has been shown that the N content of avocado leaves (Klein and Zilkah, 1986) and flowers (Zilkah et al., 1987) could be rapidly and quantitatively enriched following foliar application of urea to individual leaves on shoots. In the present investigation it was

shown that the N reserves of large avocado trees could be enriched readily by foliar application of urea under field conditions. The 26% enrichment of leaf nitrogen was short lived (Fig. 1), since it was timed to precede the early spring reproductive and vegetative sink activity. However, the N content remained at a higher level (11%) for the rest of the season.

Conflicting results have been reported on the correlation between nitrogen content and freezing tolerance. Similar to our results (Fig. 2), data collected in the field and the laboratory showed a positive relationship between leaf N and tolerance to freezing following nitrogen fertilization (Smith and Rasmussen, 1958; Lahav et al., 1985; Proebsting, 1961). Other reports showed decreased or no change in bud hardiness following nitrogen fertilization (Edgerton and Harris, 1950). The exact relationship of leaf nitrogen with hardiness may strongly depend on tree and environmental factors which could explain the discrepancy between these results (Proebsting, 1961).

To what extent the protective effect of the urea could be attributed to a non-specific retardation effect on leaf senescence or to a direct effect on leaf disposition against freeze damage is an open question. The finding that the freezing damage of avocado leaves treated with urea increased at a significantly (2.5-fold) slower rate than control leaves, with increasing senescence (Fig. 3), suggested that urea or its derived N-status could independently delay senescence and increase hardiness.

Similar to the higher cold-susceptibility that has been observed for the more developed 'Maravilha' buds (Table 2), it was earlier reported that peach buds lost their ability to undergo super cooling and to enhance their frost tolerance, when they reached full bloom (Proebsting and Andrews, 1982).

The protective effect of urea seems to be quite rapid. It was applied to peach trees in the field 3 days before freezing (Table 2) and to potted avocado plants immediately before exposure to the low temperatures (Table 1).

The present finding that foliar-applied urea has the potential to enhance plant tolerance to freezing temperatures has important implications for the fruit industry.

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