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Yield benefits associated with pre-blossom low-biuret urea sprays on *Citrus* spp.

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SUMMARY

This study evaluated the potential yield benefits of pre-blossom urea sprays on various *Citrus* spp. and to ascertain whether these yield benefits are as a result of altering the blossom composition or of supplying readily utilizable N during the critical flowering/fruit set period. Pre-blossom low-biuret urea sprays, 6–8 weeks before anthesis, at 1% concentration, one or two sprays 10–14 d apart, have resulted in significant ($P<0.05$) yield benefits in certain orchards. Experiments were conducted over a period of 2–4 years. Cultivars evaluated included 'Shamouti' oranges, 'Ellendale' tangor and 'Minneola' tangelo. In orchards where the leaf N level was below optimum the results were most significant while only slight or no yield responses were obtained in orchards where N levels approximated or exceeded 2.6%. Endogenous leaf ammonia levels were significantly increased for 14–30 d after the spray. This indicated a beneficial N level during the critical flowering and fruit set period. Because of large field variation no consistent trend with respect to the effect of the urea spray on changing the blossom composition (leafless vs. leafy inflorescences) could be demonstrated. Despite the increased ammonia levels recorded, no longer term increases in reserve leaf N levels were obtained.

FRUIT set and yield in citrus is usually positively correlated with flower density (Moss, 1971; Guardiola *et al.*, 1984). Fruit set and yield in *Citrus* spp. is also enhanced by high endogenous nitrogen levels (Du Plessis and Koen, 1988; Embleton *et al.*, 1973), girdling treatments (Cohen, 1981; Krezdorn and Brown, 1970) and gibberellic acid foliar sprays (De Lange *et al.*, 1982; Krezdorn, 1969; Krezdorn and Brown, 1970) during and soon after flowering. Inflorescence composition also markedly influences fruit set: 'leafy' inflorescences (new leaves associated with flowers) have a higher set potential than 'leafless' inflorescences (flowers only) (Delgado *et al.*, 1986; Lenz, 1966; Moss *et al.*, 1972). Flower formation and density in *Citrus* spp. are enhanced by stressful conditions followed by restoration of climatic conditions favourable to growth: water stress and low temperature (Lovatt *et al.*, 1988; Monselise, 1978, 1985; Monselise and Goren, 1969; Monselise and Halevy, 1964; Southwick and Davenport, 1986), graft incompatibilities (Mosse, 1962), restriction of root volume (Furr *et al.*, 1947) root pruning (Monselise, 1985; Monselise and Halevy, 1964), pathological stress (pers. obs.) and girdling (Cohen, 1981; Monselise, 1985).

Endogenous ammonia levels are correlated with stress (Rabe and Lovatt, 1986; Lovatt *et al.*, 1988). The water stress requirement for flowering could be substituted with a pre-blossom urea spray under greenhouse conditions (Lovatt *et al.*, 1988). Maranto and Hake (1985) demonstrated the commercial use of water deficit stress and urea sprays at the resumption of irrigation in the production of summer lemons.

The usual N fertilization practice in southern Africa is to apply soil N during late winter or early spring at the first signs of budbreak. It was demonstrated by Kato (1986) and Mooney and Richardson (1992) that as much as 80% of the N utilized during the spring growth flush and fruit set period is derived from storage (reserve) N. The timing of the normal soil application is such that it probably does not contribute significantly to the N requirement for the emerging flowering and vegetative flush. Low-biuret foliar urea is used only under conditions of severe N deficiency and not generally as an annual component of the fertilization programme.

Embleton *et al.* (1986) and Ali and Lovatt (1992) demonstrated the feasibility of satisfying a major requirement for nitrogen by citrus trees via leaf N applications. Heavy soil applications and subsequent leaching due to rainfall and irrigation can pollute ground water and river systems. Foliar N applications are thus environmentally desirable (Embleton *et al.*, 1986).

This study was undertaken to evaluate the potential yield benefits of pre-blossom urea sprays on various *Citrus* spp. and to determine whether the yield benefits derived from the urea sprays are as a result of altering the blossom composition or via supplying readily utilizable N during the critical flowering/fruit set period. Therefore, in addition to foliar urea applications, paclobutrazol applications was done to alter flowering intensity (Delgado *et al.*, 1986) as well as girdling (Cohen, 1981) and gibberellic acid foliar applications (Krezdorn and Brown, 1970) to increase fruit set.

MATERIALS AND METHODS

Low-biuret foliar urea sprays were applied at 1% concentrations. One or two applications were normally done, usually 10–14 d apart, with the first spray within 7–10 d after the resumption of the full irrigation regime, which is from 8–10 weeks before anthesis. Treatments were applied to 'Shamouti' sweet oranges (*C. sinensis* L. Osbeck), 'Minneola' tangelo (*C. reticulata* Blanco × *C. paradisi* Macf.) and 'Ellendale' tangor (*C. reticulata* Blanco), all under non-cross-pollinated conditions and thus induced to set parthenocarpically. The orchards were under commerical grove management with respect to all cultural practices. Normal soil N applications continued unaltered (600 g to 1000 g of limestone ammonium nitrate (LAN) per tree per annum; 2 or 3 split applications during late winter to early summer). Urea (low biuret) was applied as a full-cover foliar spray, i.e. until run-off. Application rates differed depending on tree size but varied between seven and 18 l per tree, about 2000 to 5000 l per hectare. For comparative purposes girdling, paclobutrazol (β-[4-chlorophenyl)methyl]α (1,1-dimethylethyl)-1H-1,2,4-triazole-1-methanol) or gibberellic acid treatments were included as treatments in certain trials. Girdling was done with a budding knife by making an incision in the bark onto the xylem without the removal of any bark segments. Paclobutrazol was soil-applied in a 30 cm band around the trunk of individual trees as a water mixture containing a specific amount of active ingredient per tree. Gibberellic acid treatments, applied as a full cover spray were done during the flowering period. Agral 90, at a rate of 25 ml per 100 l, was added as a wetting agent.

Leaf ammonium levels were measured on the 'Minneola' tangelos prior to and at different times after urea application. Thirty to 50 youngest fully expanded leaves (YFE) were sampled randomly in late winter/early spring at shoulder height for 5–10 trees per treatment. The same number of leaves were sampled in March (late summer) from fruiting terminals for the determination of total leaf N levels. Samples were cold-stored (4°C) for a maximum of 24 h before being washed in detergent, frozen in liquid nitrogen, freeze-dried and subsequently

TABLE I
A summary of the data recorded for each trial[1]

Cultivar	Root-stock	Tree age	No. of treatments	No. of replicates	No. trees per rep.	Trial duration (years)	Data recorded: Total yield	Fruit size	Total leaf N	Leaf NH4+	Blossom composition
Shamouti	RL[2]	6	5	10	1	2	Yes	Yes	Yes	–	–
Ellendale	RL	5	3	4	10	2	Yes	–	–	–	–
Minneola (A)	TC[3]	7	3	8	3	4	Yes	–	Yes	Yes	Yes
Minneola (B)	TC	4	3	6	5	4	Yes	–	Yes	–	Yes
Minneola (C)	RL	6	4	5	4	2	Yes	–	Yes	–	–

[1]All trials were laid out as randomized complete blocks.
[2]RL = Rough lemon.
[3]TC = Troyer citrange.
[4]Tree age at start of trials.

TABLE II

Effect of pre-blossom urea sprays, paclobutrazol and girdling treatments on 'Shamouti' orange yield and fruit size. Figure in brackets denotes mean cumulative yield (kg/tree) for untreated controls

Treatment	Two-year cumulative yield (% of control)[4]	Mean fruit size (mm)
Control	100 (415)	71.0
Paclobutrazol, 8 g a.i./tree[1]	95	64.1*
Urea, 2 sprays at 1%[2]	118*	69.1
Girdling FB[3]	85	70.9
Girdling, 2 weeks AFB[3]	102	71.3
LSD (P = 0.05)	17	1.9

[1]Paclobutrazol application: year 1—19 July 1989; year 2—July 1990.
[2]Urea sprays: year 1—19 July 1989 and 17 August 1989: year 2—9 July 1989 and 4 August 1990.
[3]Girdling: fullbloom (FB) on 12 September 1989 and 19 September 1990; 2 weeks after FB (AFB) on 27 September 1989 and 8 October 1990.
[4]Harvest dates: 5 June 1989 and 30 May 1990.
*Denotes a significant (P<0.05) difference from the control.

ground to a fine powder. Analysis was done by a modified procedure of the salicylic acid method of Nelson (1983) on a 50 mg sample in 25 ml of 1 M KCl without the use of EDTA in the analysis procedure. Total leaf N levels were determined by the conventional micro-Kjeldahl method.

Blossom quality was assessed on six randomly selected shoots (three on each side of the tree row). Sprouting nodes were categorized into either 'leafless' inflorescences (flowers only) or 'leafy' inflorescences (flowers and leaves) or as purely vegetative shoots. Total yield was determined by weighing individual tree yields. Fruit size was determined on a random subsample of fruit (5 to 10%) from each replicate by measurement of the fruit diameter with a caliper.

TABLE III

Effect of pre-blossom urea and blossom gibberellic acid (GA) sprays on cumulative yield (two years) in 'Ellendale' tangors. Figure in brackets denotes mean cumulative yield (kg/tree) for untreated controls (10 trees)

Treatment	Yield as % of control
Control	100 (1,104)
GA—10 mg/l[1]	120
Urea (2 × 1%) +GA – 10 mg/l[2]	133
LSD (P = 0.05)	46

[1]GA spray (60% to 100% petal drop stage). year 1—25 September; year 2–23 September.
[2]Urea sprays (full bloom around 10 September): year 1—30 July and 6 August; year 2—7 July and 2 August.

The trials were all laid out as randomized complete blocks with 4–10 replicates per treatment and 1–10 trees per replicate. Treatment means were separated by the LSD procedure of the Statgraphics 2.0 programme. The trials were done over periods of 2–4 years, viz. 'Shamoutis' (two seasons), 'Minneola' tangelos (two to four seasons), 'Ellendale' tangor (two seasons). A summary of the data recorded for each trial is provided in Table I.

RESULTS

Yield response

A significant (P<0.05) increase in yield over two seasons was obtained with 'Shamouti' oranges with pre-blossom urea sprays without a concurrent decrease in fruit size (Table II). Neither the paclobutrazol nor the girdling treatments yielded positive results in this trial. A tendency, though not significantly different (P>0.05), for higher yields was noted in the 'Ellendale' tangors; a 20% increase over the control resulted from a gibberellic acid (GA) spray which further increased to 33% when in combination with pre-blossom urea sprays (Table III). Trials with 'Minneola' tangelos, gave varying results (Table IV). In Trial A the urea/GA combination resulted in a significant (P<0.05) yield response while GA alone did not increase yield. Trial B showed no response to the urea sprays. In trial C, the urea sprays increased yields by nearly 50% over the two seasons while the urea/GA combination significantly (P<0.05) increased yield by 72%. By contrast, in this trial, GA on its own resulted in no yield benefit.

TABLE IV

Urea and gibberellic acid (GA) sprays on 'Minneola' tangelo yield response

Treatment	Yield—% of control[3]		
	Trial A	Trial B	Trial C
Control	100	100	100
Urea[1] (once)	–	106	148
Urea[2] (twice)	–	109	–
Urea[1] (once) +GA[2]	124*	–	172*
GA[2]	115	–	96
LSD (P = 0.05)	18	39	65

[1]All urea sprays at 1% concentration, 8–10 weeks pre-blossom.
[2]GA sprays during full-bloom at 10 mg l^{-1}.
[3]Based on cumulative yield for number of seasons as indicated in Table I.
*Significantly different (P<0.05) from the control.

TABLE V
Leaf nitrogen levels for 'Shamouti' oranges and 'Minneola' tangelos

Trial/cultivar	Leaf type	Sampling month	% N ± SE Control	% N ± SE + Urea	n[3]
Shamouti	YFE[1]	August	1.85 ± 0.10	2.06 ± 0.06	5
	LF[2]	March	1.93 ± 0.03	1.93 ± 0.06	5
	YFE[1]	March	2.03 ± 0.04	2.10 ± 0.08	5
Minneola (Trial A)	LF[2]	March	2.50 ± 0.07	–	8
Minneola (Trial B)	LF[2]	March	2.34 ± 0.06	–	6
Minneola (Trial C)	LF[2]	March	1.96 ± 0.06	2.08 ± 0.06	5
	YFE[1]	March	1.98 ± 0.06	2.07 ± 0.06	5

[1]YFE leaves: youngest fully expanded leaves from previous flush.
[2]LF leaves: leaves from fruiting terminals; normal sampling procedure.
[3]n: no.of replicate samples.

TABLE VI
Endogenous leaf ammonium levels in 'Minneola' tangelos as affected by leaf urea sprays

Treatment	NH_4+, % of control[1]				
	7 August	14 August	19 August	26 August	9 September
Urea once (7 August)	100	139	108	114	100
Urea twice (7 August and 14 August)	100	137	125	135	100

[1]Each value represents the mean of five replicate determinations, each comprising leaves from three trees; youngest fully expanded leaves sampled.

Leaf N levels and endogenous ammonium levels

The leaf nitrogen levels of both 'Shamouti' orchards were low, i.e. less than 2.1% (Table V). N levels for Trials A and B on 'Minneola' were high (approximately 2.5%) while that of Trial C was low at around 2.0% (Table V). The pre-blossom urea sprays markedly increased leaf ammonium levels for a short period (14–30 d) in 'Minneola' (Table VI). The same trends were obtained in a non-statistical trial on navels where leaf ammonium levels were still 21% above the controls 25 d after a double urea spray, after a high value 45% above the controls 7 d after the spray (unpublished data). The increased ammonia levels were quite transient and the urea sprays did not lead to a general marked increase in the leaf N status of the trees (Table V).

TABLE VII
Effect of pre-blossom urea sprays on flower quality in 'Minneola' tangelos

Treatment	% Active meristems/category		
	Leafless	Leafy	Vegetative
Orchard A			
Control	29	58	13
Paclobutrazol soil[1]	52*	44*	4*
Urea[2]	36	46	17
LSD (P = 0.05)	11	14	7
Orchard B			
Control	30	55	15
Paclobutrazol soil[1]	60*	34*	6*
Paclobutrazol foliar[1]	47*	43*	10
Paclobutrazol foliar[1] + urea[2]	34	50	16
LSD (P = 0.05)	10	7	6

[1]Paclobutrazol soil application in April at 2 g a.i./tree, foliar application in June at 1000 mg l^{-1}; full-bloom around 10 September.
[2]Urea sprays (1%) 6 to 8 weeks before full-bloom (mid to end July); full-bloom around 10 September.
*Significantly different to the control at P<0.05.

Urea spray effect on blossom composition

In the 'Minneola' trials (Table VII) Orchard A, a slight, but nonsignificant, shift towards 'leafless' inflorescences occurred with the urea spray. By contrast, the urea spray negated the significant shift caused by the paclobutrazol application towards 'leafless' inflorescences (Orchard B). No effect of the urea spray on the blossom composition of a navel orchard could be demonstrated (unpublished data).

DISCUSSION

A substantial, and generally significant (P<0.05) yield increase, was obtained with pre-blossom urea sprays. In orchards where no or only marginal yield increases were obtained, the leaf N status of the trees was adequate (2.5% and higher). It seems that the pre-blossom urea sprays serves only to increase N levels for a short time, as seen with the endogenous leaf ammonia levels being increased for about three weeks (Table VI), and thereby increasing yield. This short-term increase in the N level during the critical flowering and fruit set period, however, benefits fruit set, especially where the reserve N levels are low. Kato (1986), substantiated by Mooney and Richardson (1992), indicated that 80% and more of the N incorporated into new spring growth is derived from reserve N. The general commercial practice of applying N to the soil during the middle to late winter is thus of limited immediate benefit to the tree, especially since root activity starts only after soil temperature rises above about 14°C (Monselise, 1947) and is limited even up to 22°C (Bevington and Castle, 1985). Therefore, in low N situations, the pre-blossom urea spray augments the reserve N pool since it is readily accessible and metabolizable.

Despite the short-term increase in leaf ammonia levels, no long-term increase in the overall N status of the tree has been observed (Table V), in agreement with the field data of Ali and Lovatt (1992). With the general application of between 10 and 20 l of spray solution per tree, two 1% urea spray applications would translate into 92 to 184 g of N per tree (low-biuret urea, 46% N) or an equivalent of 328 to 656 g of limestone ammonium nitrate (LAN, 28% N) per tree. This would amount to 30 to 50% of additional N per tree per annum. Since the normal soil N regime was also followed, one would have expected a reasonable increase in the reserve N level, which did not occur. Despite the above results, producers are still cautioned not to apply too much N, either via soil or foliar applications and thereby cause supra-optimal N levels. The pre-blossom urea spray should be used as a tool to stimulate the tree when, and if, required.

The general lack of a significant field response of the pre-blossom urea spray on blossom composition may be explained by the tremendous variation in flowering response observed in the field between and within trees. Only a slight, non-significant shift in blossom quality towards a 'leafless' situation (Table VII) was obtained in this study. However, in general the results obtained in these trials do not confirm the data of Lovatt *et al.* (1988) in greenhouse studies where blossom intensity was increased and a shift towards 'leafless' flowers was obtained with a pre-blossom urea spray. Consequently, the beneficial yield effects recorded in most orchards in this study with pre-blossom urea sprays seem to be mainly due to the urea effect on N levels during the flowering/fruit set period and not due to a shift in the blossom composition.

REFERENCES

ALI, A. G. and LOVATT, C. J. (1992). Winter application of foliar urea. *Citrograph*, **78,** 7–9.

BEVINGTON, K. B. and CASTLE, W. S. (1985). Annual root growth pattern of young citrus trees in relation to shoot growth, soil temperature and soil water content. *Journal of the American Society for Horticultural Science*, **110,** 840–5.

COHEN, A. (1981). Recent developments in girdling of citrus trees. *Proceedings of the International Society for Citriculture*, **1,** 196–9.

DE LANGE, J. H., DU PLESSIS, S. F., VINCENT, A. P., DU PREEZ, M. B., HOLMDEN, E. A. and RABE, E. (1982). Studies on 'Clementine' yield, fruit size and mineral composition of leaves. *Subtropica*, **3**(2), 7–16.

DELGADO, R., CASAMAYOR, R., RODRIQUEZ, J. L., CRUZ, P. and FAJARDO, R. (1986). Paclobutrazol effects on oranges under subtropical conditions. *Acta Horticulturae*, **179,** 537–44.

DU PLESSIS, S. F. and KOEN, T. J. (1988). The effect of N and K fertilization on yield and fruit size of Valencia. *Proceedings of the Sixth International Citrus Congress*, 663–71.

EMBLETON, T. W., JONES, W. W., LABANAUSKAS, C. K. and REUTHER, W. (1973). Leaf analysis as a diagnostic tool and guide to fertilization. In: *The citrus industry*, Vol. 3 (Reuther, W., Ed.). University of California, Berkeley, California, USA, 183–210.

EMBLETON, T. W., MATSUMURA, M., STOLZY, L. H., DEVITT, D. A., JONES, W. W., EL-MOTAIUM, RAWIA AND SUMMERS, L. L. (1986). Citrus nitrogen fertilizer management, groundwater pollution, soil salinity and nitrogen balance. *Applied Agricultural Research*, **1,** 57–64.

FURR, J. R., COOPER, W. C. and REECE, P. C. (1947). An investigation of flower formation in adult and juvenile citrus trees. *American Journal of Botany*, **34,** 1–8.

GUARDIOLA, J. L., GARCIA-MARI, F. and AGUSTI, M. (1984). Competition and fruit set in Washington navel orange. *Plant Physiology*, **55,** 136–42.

KATO, T. (1986). Nitrogen metabolism and utilization in *Citrus*. *Horticultural Reviews*, **8,** 181–216.

KREZDORN, A. H. (1969). The use of growth regulators to improve fruit set in citrus. *Proceedings of the First International Citrus Symposium*, **3,** 113–9.

KREZDORN, A.H. and BROWN, H. D. (1970). Increasing yields of 'Minneola', 'Robinson' and 'Osceola' varieties with gibberellic acid sprays and girdling. *Proceedings of the Florida State Horticultural Society*, **83,** 29–34.

LENZ, F. (1966). Flower and fruit development in 'Valencia Late' orange, as affected by type of inflorescence and nutritional status. *Horticultural Research*, **6,** 65–78.

LOVATT, CAROL J., ZHENG, Y. and HAKE, K. D. (1988). Demonstration of a change in nitrogen metabolism influencing flower initiation in *Citrus*. *Israel Journal of Botany*, **37,** 181–8.

MARANTO, J. and HAKE, K. D. (1985). Verdelli summer lemons: a new option for California growers. *Californian Agriculture*, **39,** (5 & 6), 4.

MONSELISE, S. P. (1947). The growth of citrus roots and shoots under different cultural conditions. *Palestinian Journal of Botany*, **6,** 43–4.

MONSELISE , S. P. (1978). Understanding of plant processes as a basis for successful growth regulation. *Proceedings of the International Society for Citriculture*, **1,** 250–5.

MONSELISE, S. P. (1985). Citrus and related genera. In: *Handbook offlowering*. (Halevy, A. H., Ed.). Vol. 2, CRC Press, Boca Raton, Florida, USA, 257–94.

MONSELISE, S. P. and GOREN, R. (1969). Flowering and fruiting—interactions of exogenous and internal factors. *Proceedings of the First International Citrus Symposium*, **3,** 105–12.

MONSELISE, S. P. and HALEVY, A. H. (1964). Chemical inhibition and promotion of citrus flower bud induction. *Proceedings of the American Society for Horticultural Science*, **84,** 141–6.

MOONEY, P. A. and RICHARDSON, A. C. (1992). Seasonal trends in the uptake and distribution of nitrogen in Satsuma mandarins. *Proceedings of the Seventh International Citrus Congress*, **2,** 37–9.

MOSS, G. I. (1971). Effect of fruit on flowering in relation to biennial bearing in sweet orange (*Citrus sinensis*). *Journal of Horticultural Science*, **46,** 177–84.

MOSS, G. I., STEER, B. T. and KRIEDEMANN, P. E. (1972). The regulatory role of inflorescence leaves in fruit setting by sweet orange (*Citrus sinensis*). *Physiologia Plantarum*, **27,** 432–8.

MOSSE, B. (1962). Graft-incompatibility in fruit trees. *Technical Communication*, No 28. Commonwealth Agriculture Bureau, Farnham Royal, Bucks, UK.

NELSON, D. W. (1983). Determination of ammonium in KCl extracts of soils by the salicylic acid method. *Communication of Soil Science and Plant Analysis*, **14,** 1051–62.

RABE, E. and LOVATT, C. J. (1986). Relative phosphorus dependency of *Citrus* rootstocks is reflected in leaf nitrogen metabolism. *Journal of the American Society for Horticultural Science*, **111,** 922–6.

SOUTHWICK, S. M. and DAVENPORT, T. L. (1986). Characterization of water stress and low temperature effects on flower induction in *Citrus*. *Plant Physiology*, **81,** 26–9.

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