Improved plant nutrition in Citrus production

Stephen Burdette
AgriExchange Pty Ltd

Project Number: CT09048

CT09048

This report is published by Horticulture Australia Ltd to pass on information concerning horticultural research and development undertaken for the citrus industry.

The research contained in this report was funded by Horticulture Australia Ltd with the financial support of AgriExchange Pty Ltd.

ISBN 0 7341 2501 1

Published and distributed by:
Horticulture Australia Ltd
Level 7
179 Elizabeth Street
Sydney NSW 2000
Telephone: (02) 8295 2300
Fax: (02) 8295 2399

HAL

Know-how for Horticulture™

Improved plant nutrition in Citrus production – 19th August 2010 – 3rd September 2010

Visit by Professor Dr Rafael Martinez Valero

Project Code: CT09048

Voluntary Contributor (VC) Organization name: AgriExchange Pty Ltd

VC ABN: 13 050 165 921

Project Leader: Arthur Edwards

Project Expert: Professor Rafael Martinez

Administrator: Steve Burdette

Professor Rafael Martinez and Arthur Edwards

TABLE OF CONTENTS Page

1. Media Summary

Agriculture in general and tree fruit production in particular are heading down a very dangerous path that urgently needs to change. As you all know, fruit production has an income every 12 months and in some cases due to adverse conditions every 24 months. This makes fruit production the "poor cousin" of economic activity as other industrial activities have healthier cash flows. In addition, industrial products can be diversified anywhere in the world, whilst fruit production markets are concentrated in USA, Europe and Far East. The produce on offer is concentrated in these centers and therefore prices achieved will reduce as supply increases.

Confronted with this situation, the production costs, quantity exported and yields are going to be the determining factor in the survival of fruit production. Costs are going to increase as materials, energy and labor increases. These will increase to a point that will make this activity collapse unless we change the production technology that we are applying today. This situation can be overcome as scientific research advances and applying this technology will allow the survival of fruit production.
Now here is where there is a tremendous and obvious gap between scientific research and applied technology and enterprises that cannot introduce these changes have to move to countries with lower production costs in order to survive.

2. Expected Outcomes and how they were achieved

The reasons for the gap between scientific research and applied technology in fruit production include:

(i) **Production factors**. Nutritional programs are still being drawn up on Units of Fertilizer per hectare (N, P, K, etc) in several applications as can been seen in publications from the 40's in last century. The great French masters published all this work as they new trees required N, P, K etc. Today we know that trees do not absorb nutrients the way we thought, they do it in the form of ions with their different charges and do it in an orderly and compensated way. The only things that have changed since the 40's is the irrigation systems, instead of flood we now use sprinkler or drip. Therefore, we have reached a production limit with the current growing philosophy; there is no consideration for the amount of nutrients absorbed by the tree or the degradation suffered by the fertilizers and no consideration for the irreversible damage done to the environment.

(ii) **Lack of applied technology**. Many of the great advances in agricultural technology made in the last 33 years of the twentieth century by Nobel Prize winners have been totally ignored. Cellular nutrition, P. Mitchell Nobel Prize 1978, photosynthesis J. Deisenhofer, R. Huber and H. Michel Nobel Prize 1988, as well as research by E. Epstein (1972), Schultz (1972), J. A. Raven (1986). The first mentioned scientist explains the methodology to determine the amount of nutrients absorbed by a plant per gram of dry matter per hour. The second one sets a parallel between photosynthesis and vapor deficit. The third one explains what happens to the nitrates and other ions when they metabolize and the electrochemical unbalance that happens at a cellular level with an enormous loss of productive potential. These advances together with other smaller discoveries make an enormous difference to the productive potential of a tree.

(iii) **Social problems**. This is more a problem that affects the Agricultural schools and Universities. A candidate to become a Professor, as is human nature, will try to fulfill his/her *curriculum vitae* with the largest amount of articles or papers published in the shortest time. Some Universities demand that they publish 2 or 3 papers per year in order to keep their jobs. This has taken candidates to work on annual crops where results are achieved in 3 to 6 months and never engage in work that will take 15 to 25 years to produce a result as would be required in fruit production. Therefore, these projects are not feasible for professors and are substituted for research that is more "commercial". Therefore, as long as all the Universities in the world keep evaluating their professors on the amount of scientific publications they produce and not on the amount of time they dedicated to study and research, this problem will persist.

Concluding from the above and once Prof. Martinez had secured his position in the University; he dedicated all his efforts working out how to apply all these advances in agriculture to the everyday farming activity in fruit production.

This is how after 25 years of research and work he has been able to implement a method that incorporates all these new advances in technology. This is called Martinez Open Hydroponics Technology (MOHT). Large companies around the world have trialed, tested and implemented this production method with outstanding results.

3. Results of Discussions

3.1 Scientific technology integrated in MOHT systems

There are two types of technology advances in MOHT systems:

- **A.** in the nutritional control
- **B.** in the physiological control
- **C.** in the control of the environmental impact

A. Nutritional control

1. Nutrient absorption through ions (P. Mitchell 1978 Nobel Prize)
2. Ion balance (J. A. Raven 1986)
3. Increased chlorofilic efficiency (J. Deisenhofer, R Huber and H. Michel. Chemistry Nobel Prize 1988).
4. Determining the amount of each nutrient ion absorbed per gram of dry matter per hour. (E. Epstein 1972)
5. The way to maximize photosynthesis when controlling the opening of stomata and the vapor deficit tension (Schultz, 1972).
6. Reduction of NADP (Nicotinamide Adenine Dinucleotide Phosphate) necessary for the dark phase of photosynthesis.
7. Nutrient absorption according to the Nernst and Goldman equation.

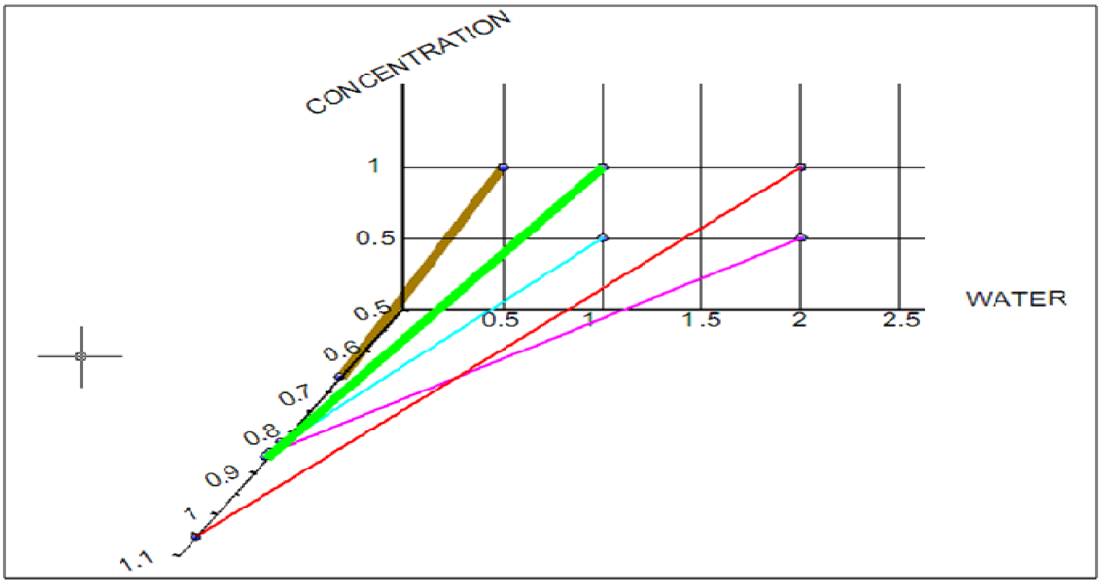
The following is a trial done over 3 years in Avocados with different nutritional concentrations and with different volumes of water (X, ½ X and 2 X) and

FIELD TRIALS	CONCENTRATION NUTRITION SOLUTION	VOLUME WATER	ABSORPTION uEqN/(gDM h)	gDM/tree (BIOMASA)
Ensayo 1	1	0.5	0.66	21161,17
Ensayo 2	0.5	1	0.83	33632,50
Ensayo 3	1	1	0.86	58552,17
Ensayo 4	0.5	2	0.85	46129,97
Ensayo 5	1	2	1.07	83423,67

determining the amount of Nitrogen absorbed expressed in grams of dry matter per hour as well as the amount of biomass obtained per tree.
From these results we can conclude that the largest biomass is obtained in trial 5 with a value of 83,423.67gDM/tree and the trial 3 of 58,552.17gDM/tree. We can also conclude that the absorption efficiency:

X = 58,552.17 gDM/tree x 1.07 uEqN/(gDM/hr) / 83,423.67 gDM/tree = **0.751 uEqN/(gDM/hr)**

STUDY OF FIELD TRIALS	CONCENTRATION NUTRITION SOLUTION	VOLUME WATER	PERCENTAGE ABSORBED	STATISTICAL SIGNIFICANCE
Ensayo 5 vs Ensayo 4	1 : 0,5	2 : 2	79,88	NS
Ensayo 3 vs Ensayo 2	1 : 0.5	1 : 1	96,26	SS*
Ensayo 5 vs Ensayo 3	1 : 1	2 : 1	80,72	NS
Ensayo 3 vs Ensayo 1	1 : 1	1 : 0,5	77,03	NS



This indicates that the 2 X irrigation is less efficient then the adjusted normal amount (X).
Therefore, the normal irrigation is the most efficient; it avoids the leaching of water and reduces the environmental impact.

This comparative study was done to determine the interaction: water-nutrients and nutrients-water with statistical significance in the percentage of absorption according to the Michaelis-Menter equation. Studying the interactions: same volume of water with different nutrient concentrations and same concentrations of nutrients with different volumes of water. This shows that trials 2 and 3 give a statistical significance of 96.26% whilst the other trials are not significant. Therefore, we can conclude that it is imperative to adjust the amount of water to the real needs of the plant without excess, with the correct nutrient balance and the correct nutrient concentration. These are determining factors in order to increase the percentage of nutrient absorption and reduce the environmental impact.

Another observation done over the three years was that the trial with double amounts of water were the ones that required more pruning and were more alternate bearing, whilst the normal water (X) were more productive and less alternate bearing in the accumulated yields over the three years.

B. Physiological control

In the MOHT system, the irrigation is adjusted daily or weekly in a statistically valid manner according to the “Helplines” (X; ½ X and 2 X). Trees are slowed down when needed, they are pushed when required and pushed when requiring fruit size. Therefore, if flower induction and differentiation is controlled at the correct time, with a production adjusted to its productive potential and in the correct harvesting time, there is no alternate bearing with minimal pruning.

Pruning in Avocados reduces the fruit size in time, shortens the productive life of a tree, and productive potential is lost as trees try to recover the lost foliage. Trees end up with wounds in their branches and it encourages late flower differentiation that causes small size fruit.

C. Control of the environmental impact

MOHT is the system with least quantitative environmental impact to date. The reasons for this are:

1. Water is only applied according to plant absorption. Moisture should not go beyond the 50 cm depth.
2. Wet surface is only 10 to 12 % of planted density.
3. Because it has, a water usage of less than 400 litres per kilo of Avocados exported per year and less than 100 litres per kilo of Oranges exported per year.
4. Because the fertilizer needs are less than 4.16 Kg of N per tonne of exported Avocados and less than 3.1 Kg of N per tonne of exported citrus.

3.2 Injection of nutritional solutions into pressurized pipes

When injecting liquids (in this case nutritional solution) into pressurized pipes these behave in the following way: the nutritional solution remains concentrated in “fillets” (laminar flow) and the speed of these fillets is 3 times faster in the centre than in the periphery due to friction (Navier and Bernoulli effect). The pressure required to mix these fillets would be very high.

Example: a 100 hectare Avocado property, irrigated in 4 sections of 25 hectares each, planting 6m x 4m, with 8 drippers per tree of 4 liters/hour. The pressure

required to create a turbulent mix injecting at 1 liter/m^3 and at 5 litres/m^3 would be:
25 x 416 x 8 x 4 = 332,800 litres/hour per section

The amount injected when injecting at 1 litre/hr would be 332.8 litres/hr and 332.8 x 5 when injecting at 5 litres/hour.

P x V = P' x V'   P = 2 bars x 332,800 / 332.8 = 2,000 bars

And;

P = 2 bars x 332,800 / 5 x 332.8 = 400 bars

As there is no pump that can inject at these pressures, the nutritional solution remains concentrated in the outer fillets of the pressurized pipe and will emerge in the first valve with all the problems that this can cause.

3.3 Nutritional solution injected with membrane and piston pumps

When injecting a nutritional solution into a pressurized pipe there is a degradation of the fertilizers due to the high concentration in the outer fillets.

$2NO_3K + \Sigma\ 4\ H^+ + 2SO_4^{2-} = 2SO_4HK + 2\ NO_2\ (1) + H_2O + ½\ O_2$

$(NO_3)_2Ca + \Sigma\ 4\ H^+ + SO_4^{2-} = SO_4Ca + 2\ NO_2\ (1) + 2\ H_2O$

$SO_4Zn.7\ H_2O + \Sigma\ 2H^+ = SO_4\ H_2 + Zn + 7\ H_2O$

$SO_4Cu.5\ H_2O + \Sigma\ 2H^+ = SO_4\ H_2 + Cu + 5\ H_2O$

EDDHA Fe + pH < 4 = degrades as the stable pH is between 4 and pH 9.

$NO_3\ NH_4 = N_2O\ (2) + 2\ H_2O$ reaction in hot due to injection of Sulphuric Acid into the pipe

(1) the 2 NO_2 is a toxic product.
(2) N_2O is an anaesthetic gas (laughing gas).

When using a booster pump, this will not mix the fillets, it will only further impulse the solution.

3.4 Injections using Venturies

1. Same fertilizer degradation as explained above
2. Injected amounts will vary according to:
    - tank full or empty it will inject more or less
    - solution density, will inject more or less
    - accumulation of products in the venturies, will inject less.

- injection is discontinuous, therefore leaving gaps with no nutrients injected

In conclusion: it is impossible to accurately inject a balanced nutritional solution utilizing the venture system. Not only is it very inaccurate it also will produce irreversible damage to the environment as well as require extra irrigation to minimize chemical damage to plants.

Manufacturers of venturies, Mazzei Injection Corporation indicate in their model 1078, that: real injection = Theoretical suction / specific weight
Therefore: 75 gallons per hour / 1.5 = 50 GPH real suction

Example: Citrus orchard in Marrakech injecting 1,000 litres per hour in theory, with a density of 1.113 the actual amount being injected is 898.47 litres per hour or 10.15% less than thought.
Therefore, when the tank is full the injection is 5.075% more than it should be, and when the tank is less than 50% full it will inject 5.075% less than it should. This would require adding this extra amount of nutritional solution into the tank in order to have a uniform solution absorbed by the plants. All the nutrients that are supplied to the plant out of the balance will accumulate on the outer side of the root balls, requiring extra irrigation of 15 to 20% to leach these salts.

As the injection is so variable, it is impossible to maintain a constant electro conductivity and pH.

Sensors (pH and EC) that take readings with large intervals are very inaccurate. Sensors that take many reading in a short space of time are more accurate.

4. Implications for Australian horticulture

After 25 years of studying all these problems and applying them out in the field, running trials comparing various systems, applying all known plant physiology, ensuring minimal environmental impact, it was concluded that there had to be a system that brought all these factors together.

1. That it complied with all the hydraulic laws of liquids in pressurized pipes.
2. That it avoided high concentration of nutrients and acidity in the balanced mixed solution to be injected. This would be done by a mixing tank at atmospheric pressure.
3. That it had a mixing disc in the main pipeline with small orifices allowing the injection at pressure in different levels and with different directions in order to achieve a homogeneous solution without the need for extreme pressures.
4. That it could inject solutions at stable and precise pH and EC.
5. That it could eliminate all the Bernoulli and Navier effects in pressurized pipes and that together with the mixing disc in the main pipe it would create the necessary turbulence to avoid the degradation of the nutrients.

6. The Department of Microbiology and plant production of the Polytechnic School of Orihuela (University Miguel Hernandez De Elche, Alicante, Spain) together with the Research and Development department of Hermisan S.A. (Alicante, Spain) developed what they called the “Project Nutricompact”. This machine remains to date as the only one capable of applying the MOHT system.

REFERENCES and BIBLIOGRAFY:

AYERS, R.S. and D.W. WESTCOTT. 1985. FAO.Water Quality for Agricultural Irrigation and Drainage. Paper 29. Rev. 1, Rome. Italy. 174 pp

CALVIN, M. 1962. In: Forty years of photosynthesis and related activities. CALVIN, M. 1989. Photosynthesis Research. 21: 3016.

DEISENHOFER J. & MICHEL, H. 1988. The photosynthetic Reaction Centre from the Purple Bacterium *“Rhodopseudomonas viridis”.* Nobel Lecture 1988: 526-565.

EPSTEIN, E. 1972. In: Mechanisms of ion transport through plant cell membranes. EPSTEIN, E., 1973. Intern. Rev. Cytol, 34: 123-168.

MARSHNER, H., 1986. Mineral Nutrition in Higher Plants. Academic Press. New York. 899 pp.

DEPARTMENT OF AGRICULTURE OF AUSTRALIA, 2005. IREC Prize. Ministry of Agriculture of Australia. Australian Citrus News. August/September 2005. 33: 14-15.

MITCHELL, P. 1978. Membrane transport and metabolism (Kleinzeller, A. and Kotyk, A., Eds) Mitchell, P., 1961(a) Academic Press., New York. 22-34 pp. In David Kielin’s Respiratory Chain Concept and its Chemiosmotic Consequences. Nobel Lecture, 1978. 296-328.

RAVEN, J.A. 1986. Biochemical disposal of excess H^+ in growing Plants. New Phytol. 104:175-206.

SCHULZE, E.D.; LANGE, O.L.; BUSCHBOM, U. *et al.* 1972. Stomatal response to changes in humidity in plants growing in the desert. Planta, Berlin, v. 108, n. 2, p. 259-270, Feb. 1972.

UNIVERSITY OF ARIZONA, 2008.
http://www.nernstgoldman.physiology.arizona.edu

5. Dissemination of Information

Professor Rafael Martinez and Arthur Edwards met regularly to discuss issues during the duration of the visit. Six grower presentations on this topic “Improved Plant Nutrition in Citrus Production” were done to citrus growers in:

(i) Gingin (Western Australia)
(ii) Carnarvon (Western Australia)
(iii) Renmark (South Australia)
(iv) Mildura (Victoria)
(v) Leeton (New South Wales)
(vi) Cobram (Victoria)

6. Itinerary

16/08/2010

Professor Dr. Rafael Martínez Valero visit to Australia - Aug/Sep 2010

				o/n
Aug				
	19	Thur	Prof. R. Martinez arrives in Perth - Travel to Gingin - **Grower presentation**	Perth
	20	Fri	Travel to Carnarvon - **Grower Presentation**	Carnarvon
	21	Sat	Orchard visits in Carnarvon	Carnarvon
	22	Sun	Travel by road to Wooramel. Inspect citrus at Wooramel. Travel by road to Geraldton	Geraldton
	23	Mon	Travel by road to Moora. Orchard inspections. Travel by road to Perth	Perth
	24	Tue	Travel to SA and by road to Renmark	Renmark
	25	Wed	Orchard inspections. Cittgroup Riverland - **Grower presentation** at Renmark Club	Renmark
	26	Thur	Orchard inspections in the Riverland	Renmark
	27	Fri	Orchard inspections in the Riverland - travel to Mildura	Mildura
	28	Sat	Orchard inspections in Wentworth, Curlwaa and Dareton	Mildura
	29	Sun	Free	Mildura
	30	Mon	Orchard inspections in Nangiloc - **Grower presentation** at MVCB Mildura	Mildura
	31	Tue	Travel to Hillston, Griffith and Leeton. Orchard inspections in the MIA	Leeton
Sep	1	Wed	Orchard inspections in MIA - **Grower presentation** in Leeton Soldiers Club	Leeton
	2	Thur	Travel to Berrigan/Cobram - **Grower presentation** in Cobram	Leeton
	3	Fri	Travel to Sydney via Narrandera and off to Spain	

7. Recommendations

- Applying new technology to citrus production
- Implementing a professional approach to plant nutrition
- Achieve physiological control of trees
- Control the environmental impact

8. Acknowledgements

Our sincere thanks and appreciation is conveyed to HAL and the citrus industry for making this visit possible and affording us the opportunity to gain very useful information. We would also like to thank the following for their valuable contribution:

- Helen Ramsey – Dep. Agriculture WA
- Tim Hyde – Northwest Agricultural Group
- Richard Nixon – Global Groundwater
- Kym Thiele – Citrus IDO Riverland
- Mary Cannard – Murray Valley Citrus Board
- Darren Gibbs – Riverina Citrus

9. Contact List

Prof. Dr. Rafael Martínez Valero; Phone: 0011 34 628 233 888; email rafaelmartinezvalero@gmail.com