a residue and is quick and easy to use.

- Fruit surface: a fruit disinfectant treatment should be one of the first steps when entering the packhouse. Chlorine (Calcium Hypochloride) is the most popular active for this step. Remember to strictly manage the chlorine concentration, pH and ORP. Alternatives such as liquid or powder PAA formulations can also be used. In the case of PAA there is no need to adjust the pH. However, the PAA concentration levels must be managed carefully, and fruit must be dried timeously (both to prevent rind injury).
- Floors and walls: wash weekly with a registered soap and disinfectant product. In these areas, a product that leaves a residue (such as a QAC product) can be used. Importantly, a dirty surface can't be sanitised. Rather use a registered soap before sanitation. The areas to clean include the packhouse, degreening rooms, and cold rooms.
- Degreening rooms and cold rooms: need to be washed and then – where possible – fumigated with a suitable product that can reach into crevices and folds. Never fumigate when there is fruit in the room, to avoid the risk of residue transfer.
- Orchard bins and picking bags: must be washed and sanitised before re-use.

Sources of inoculum (spores):

- **The orchard:** spores naturally occur in the orchards, so orchard sanitation is key, to reduce the inoculum load.
- **Post-degreening fruit:** degreening conditions are hugely favourable for disease development and unfortunately, some sporulating fruit are often tipped into the packhouse system.
- **Waste fruit:** have a process in place to remove this fruit without delay, and to keep the waste in sealed containers.
- **Juice fruit:** this fruit is often treated with fungicides and sits in the packhouse area until it's transported to the juicing plant. Therefore, any decay on such fruit holds a resistance risk.


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- **Small fruit:** this fruit, if not properly graded out, can fall between brushes or gaps between units and lie unseen on drip trays in the packhouse.
- **Retention samples:** shelf-life fruit has also been treated with fungicides and holds a similar resistance risk as juice fruit.

Recommendations that can reduce the risk of infection and/or resistance development:

- Treat all harvested fruit promptly (within 12–18 hours), as most fungicides cannot control infections older than a day.
- Don't let fruit stand from Friday afternoon to Monday morning without any fungicide protection. In this case it would be prudent to drench the fruit on Friday.
- Keep fruit degreening brief.
- Do not exceed the volume limit of your packline. This is to avoid accelerated agitation and movement of the fruit, which will result in bruising and injuries, and reduce the efficacy of sanitation and fungicide treatment. Spread the fruit out evenly, so that none skip the treatments. Risks related to rushing fruit through the various control points:
  - The chlorine treatment: poor disinfection, spores surviving.
  - The fungicide dip tank: loading suboptimal residue, poor infection control.
  - The wax applicator: poor wax deposition on the fruit; suboptimal residue loading, poor moisture retention, negative impact on quality.
- Limit the time from harvest to packing and the eventual introduction to the cold chain.

Some advice in managing retention fruit:

- Have a dedicated person managing this task.
- Fruit should be evaluated every day, and decayed fruit noted on the carton and removed or isolated.
  - Immediately place the infected/discarded fruit in a sealed plastic bag to reduce the risk of releasing inoculum (spores) into the packhouse atmosphere.
  - Green mould sporulation inhibition is a very important criterion to note, as the loss of sporulation inhibition indicates either fungicide resistance or poor fungicide application. To prevent spores spreading from this infected fruit, fruit exhibiting sporulation inhibition should be kept in sealed transparent plastic bags and incubated for another week to rate sporulation inhibition (white mycelium with few to no green spores).
  - When the sporulation inhibition rating is concluded, the bagged fruit must be destroyed (with the bag) well away from citrus orchards and packhouses, to prevent spores from entering any production area.
- Do not keep fruit for longer than the shipping period.

Ideally, the retention room should be some distance away from the clean area, and completely enclosed with controlled access. This room should be cleaned and treated with a suitable soap and sanitiser at least once a month.

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CHELATED FOLIAR NUTRITION PRODUCTS not the solution to avoid phytotoxicity

Foliar fertilisation remains an important tool for productive management of citrus. By Pieter Raath


Pieter Raath

The use of foliar fertilisation in agriculture dates back to 1844 (Srivastava & Singh, 2003) – not a modern concept.

The foliar fertiliser industry is characterised by many proprietary products frequently derived from common salts that are mixed, in novel ratios, with the addition of adjuvants or compounds. These "complex, chelate or bind" the salt to result in a product that can be applied to fruit trees.

Since the 1980s companies have been using synthetic chelates, e.g., EDTA, glucoheptonates, polyols, amino-acids or lignosulphonates, glucose, and fructose, to formulate foliar nutrition products that are reputed to provide superior efficiency of uptake compared to inorganic compounds.

The large variety of formulated foliar nutrient products available in SA creates confusion among citrus producers, making it difficult to select the most appropriate product. *Cutting Edge* No.356 showed that, regarding efficacy, the product choice should be based on the minimum concentration of the nutrient applied, not the formulation. However, concerns regarding the development of phytotoxicity when nitrate or sulphate formulations are applied necessitate elucidation regarding the factors that lead to phytotoxicity and how to avoid it.

Factors that lead to phytotoxicity

According to Santos et al., (2017), the phytotoxic effect of compounds is directly related to the environmental conditions at the time of application. In the case of mineral oils, it is specifically the level of radiation, e.g., the higher the light intensity, the higher the risk of phytotoxicity. Furthermore, highly concentrated sprays, especially those including salt-based fertilisers, can potentially cause leaf burn and/or drop (Qureshi & Stansly, 2021). The risk of phytotoxicity is higher when salts with a low point of deliquescence (POD) are used. This is because residues of salts with a low POD on the leaf cuticle will dissolve at lower humidity levels, raising the risk of its concentration becoming excessive (Schönherr, 2001). See **Table 1** for PODs of commonly used foliar nutrition formulations.

Formulations of mineral element solutions that include adjuvants can improve the uptake and/or bioactivity of the nutrients applied to the foliage. The risk of it causing phytotoxicity might, however, be either decreased or increased. So, when a foliar nutrient formulation is developed, fine-tuning of the nutrient active ingredients, the adjuvant compounds, and their relative concentrations are necessary to give reproducible uptake without damage to the plant. Foliar nutrition manufacturers cannot theoretically predict the performance of a mineral nutrient element in combination with a particular adjuvant. Due to the risk of phytotoxicity to leaves, they should submit every new formulation to rigorous empirical testing. Therefore, citrus producers should only use products and formulations of which the efficacy and optimal application rates have been established through proper experimentation for use on citrus trees.

Guidelines for foliar applications that maximise uptake of nutrients and minimise the risk of plant phytotoxicity

- **Adjust the pH of the spray solution** An acidic pH of the foliar nutrient spray solution improves the leaves' absorption of nutrients. A solution pH of 5.0–6.5 is suitable for most foliar applications (Coetzee, 2007). However, the optimal pH will vary between nutrients. For example, the optimal pH range for phosphorus application is 3.0 to 3.7, while the highest uptake rates by citrus leaves of foliar urea were at a solution pH of 5.5 to 6.0 (El-Otmani et al., 2000). Acidification is not always required and might even be detrimental (always read the product label carefully). Also note that residues remaining on the leaves might result in phytotoxicity if the pH of a future spray (applied within approximately seven days) is not suited.
- **Use of surfactants** A good surfactant will function as a spreader, reducing the surface tension of the spray solution. This will spread the product across a larger leaf area. A wide range of surfactants is available for foliar fertilisation that might affect citrus cultivars, according to the epicuticular and cuticular wax composition of each one. Therefore, selection of a

surfactant for regular commercial foliar application of mineral nutrients should be done with caution (Singh & Khan, 2012).

- **Ensure compatibility of product mixtures** Take note of the product specifications from the manufacturer. When combined with some adjuvants and plant protection products, the performance of foliar fertilisers can change. Use a proven combination, since the relative efficacy of a foliar-applied nutrient-adjuvant-agrochemical mixture cannot be predicted. With no specific information on the label, small quantities of the products should be mixed with water in a jar and shaken to determine the risk of precipitation. Any new mixture or individual product should be sprayed on a few trees a week, before the intended commercial treatments. Given incompatibilities among various products, combining foliar fertilisation with pesticide is discouraged. Therefore, the product labels must be carefully read to assess compatibility. For good practice, avoid combining a high rate of any fertiliser with summer spray oil and emulsifiable concentrate forms of pesticides (Qureshi & Stansly, 2021).
- **Apply foliar nutrition in suitable environmental conditions** A contact period of at least 15–20 minutes is ideal for uptake into the leaf. The lower the temperature during application, the better. Do not apply foliar nutrition when the ambient temperature exceeds 30 °C or the wind speed exceeds 15 km/hour. This will avoid increased susceptibility of the leaves to a mixture of high concentrations that might otherwise not harm the leaves. Under these conditions, as a spray solution dries on the leaf surfaces, the applied salts' (foliar fertilisers) concentration increases and may damage leaves. Avoid early morning sprays in areas where the ambient temperature rises rapidly. Night foliar sprays are more effective with lower night temperatures and higher relative humidity (RH). It is always safer to apply foliar sprays at night or late afternoon (Woolfolk et al., 2002).
- **Limit spray volumes** Avoid spraying the leaves to the point of runoff. The accumulation of the nutrient mixture on the leaf tips and edges will result in necrosis in these areas when the solution dries.
- **Do not exceed concentrations of spray mixtures beyond the safe limit** Concentrated sprays might scorch leaves. Trees in humid climates generally have thinner cuticles, which makes them more susceptible to phytotoxicity. So spray mixture concentrations must be considered more prudently in these areas. Evaluate new products to know if a foliar spray contains sufficient nutrient, to obtain – cost-effectively – a concentration in the tree that will result in a positive plant response. Refer to Table 1 for the required concentrations at which nutrient elements should be applied to be effective as foliar sprays. Any new product can be evaluated according to these guidelines, i.e., to be effective, after diluting the benchmark chemical, per label specifications, a product must have a nutrient concentration of at least 80% of the stipulated norms in Table 1. So, although additives can improve absorption, unless the nutrient concentration is ≥80% of the benchmark concentration, proof of any claim of improved or effective uptake must be available (Coetzee, 2007). The mixture provided in Table 2 may be used safely if application of multiple micronutrients is required.
- **Avoid applications during sensitive phenological stages**, i.e., full bloom to fruit set, and on late mandarins, after colour break.

Further comments to consider

- A new mixture or product must always first be tested for possible side effects or phytotoxicity by spraying a few trees a week before the intended commercial treatments.
- Avoid mixing copper oxychloride with zinc or magnesium nitrates – the last two are usually buffered in an acidic medium, which will dissolve more copper from the copper oxychloride suspension and increase the concentration of soluble copper to phytotoxic levels. As an after-petal-drop foliar nutrition application, during which copper oxychloride might also be sprayed, it is suggested that ZnSO4 or $MgSO_4$ is used instead (Coetzee, 2007).
- Foliar sprays containing >2 000 mg Cu/L water are potentially dangerous and could be toxic, causing leaf burn and leaf drop. Suspensions, e.g., copper oxychloride and copper hydroxide, contain more total Cu than soluble or chelated products. This increases the risk of dark blemishes. However, any copper product can darken blemishes on the rind of citrus fruit. Even on mature fruit, Cu sprays will accentuate any fresh blemish. It is recommended that Cu foliar nutrition should ideally be done postharvest, together with the LB urea application. On later mandarin cultivars, e.g., Nadorcott/Tango, it can be applied on small fruit, after 100% petal drop.
- Never mix Borates and sulphur containing chemicals with any type of oil (Coetzee, 2007).
- Avoid applying oils four weeks after sulphur-containing products had been sprayed (Coetzee, 2007). Also, refrain from spraying any product within seven days after foliar nutrition was applied – re-wetting the residues on the leaves can cause scorching, especially if the pH of the applied product is not appropriate for the product already on the leaves (C. Fraenkel – personal communication).
- $MnSO_4$ is compatible with $MgNO_3$, sodium borate and urea.
- Dursban and boron foliar fertilisers are not compatible (Coetzee, 2007).
- Due to the risk of fruit granulation of certain mandarins, KNO_3 should not be applied within three weeks of an application of Corasil-P®/Maxim®.
- Importantly, do not apply a foliar product containing phosphate (P) on late mandarins at, and after colour break (Marais 2017).
- After spraying, rinse the sprayer and all its parts thoroughly with clean water.

Table 1. The minimum concentrations at which several products used as foliar nutrition, must be applied to be effective (Raath, 2022)

Product	Concentration of applicable nutrient	POD*	Concentration required for each nutrient (mg/ℓ)	Dosage of product required per 100 ℓ water
Zinc nitrate	5,5% (Zn)	42%	82 (Zn)	150 ml
Zn-EDTA	10% (Zn)	-	100 (Zn)	100 g
Solubor®	20% (B)	-	300 (B)	150 g
Manganese sulphate	23% (Mn)	-	460 (Mn)	200 g
Copper sulphate	25% (Cu)	-	50 (Cu)	20 g
Potassium nitrate	38% (K)	95%	11 400 (K)	3000 g
Urea	46% (N)	75%	4 600 (N)	1000 g
MAP	26% (P), 12% (N)	-	5 200 (P)	2000 g
MKP	28% (K), 23% (P)	-	5600 (K), 4600 (P)	2000 g
Magnesium nitrate	10% (Mg), 11% (N)	56%	1250 (Mg)	1250 g

* POD: Point of deliquescence, i.e., the relative humidity (RH) threshold where a fertiliser dissolves into a liquid, and below which it remains undissolved (solid). When ambient relative humidity is higher than the point of deliquescence of the foliar applied compound, the substance will dissolve and will be available for absorption by the leaf. POD is affected by both the ambient relative humidity and the temperature (Fernández et al., 2013).

Table 2. A mixture that will ensure efficient, cost-effective, and simultaneous application of all the micronutrients without the risk of phytotoxicity (Raath, 2022)

Compound	LB Urea	$ZnSO_4$	$MnSO_4$	Copper oxychloride	Solubor
Dosage (g/100 ℓ)	500	100	100-200	75	150

Conclusions

When a foliar nutrient is applied, various factors that lie beyond the physical-chemical properties of the fertiliser formulations and the effectiveness of treatments also apply. The prevailing water pH, temperature, humidity, and leaf age/surface properties in different plant production locations may play a significant role in the performance of foliar nutrient sprays, or the risk of phytotoxicity. It is important to develop a thorough control system, and to record spray conditions on the farm, to reduce the risk of human error when applying foliar spays, e.g., applying them under low relative humidity, high temperatures, at high wind speeds, and when stomata are closed.

Fully consider the interaction of the environmental conditions, the product and the plant, to avert the risk of phytotoxicity from chelated and non-chelated products. Notably, the proven efficacy of mineral nutrient salts (see Table 2) and their very low risk of phytotoxicity and cost-effectiveness make them ideal for obtaining the desired horticultural impact in your fruit tree.

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