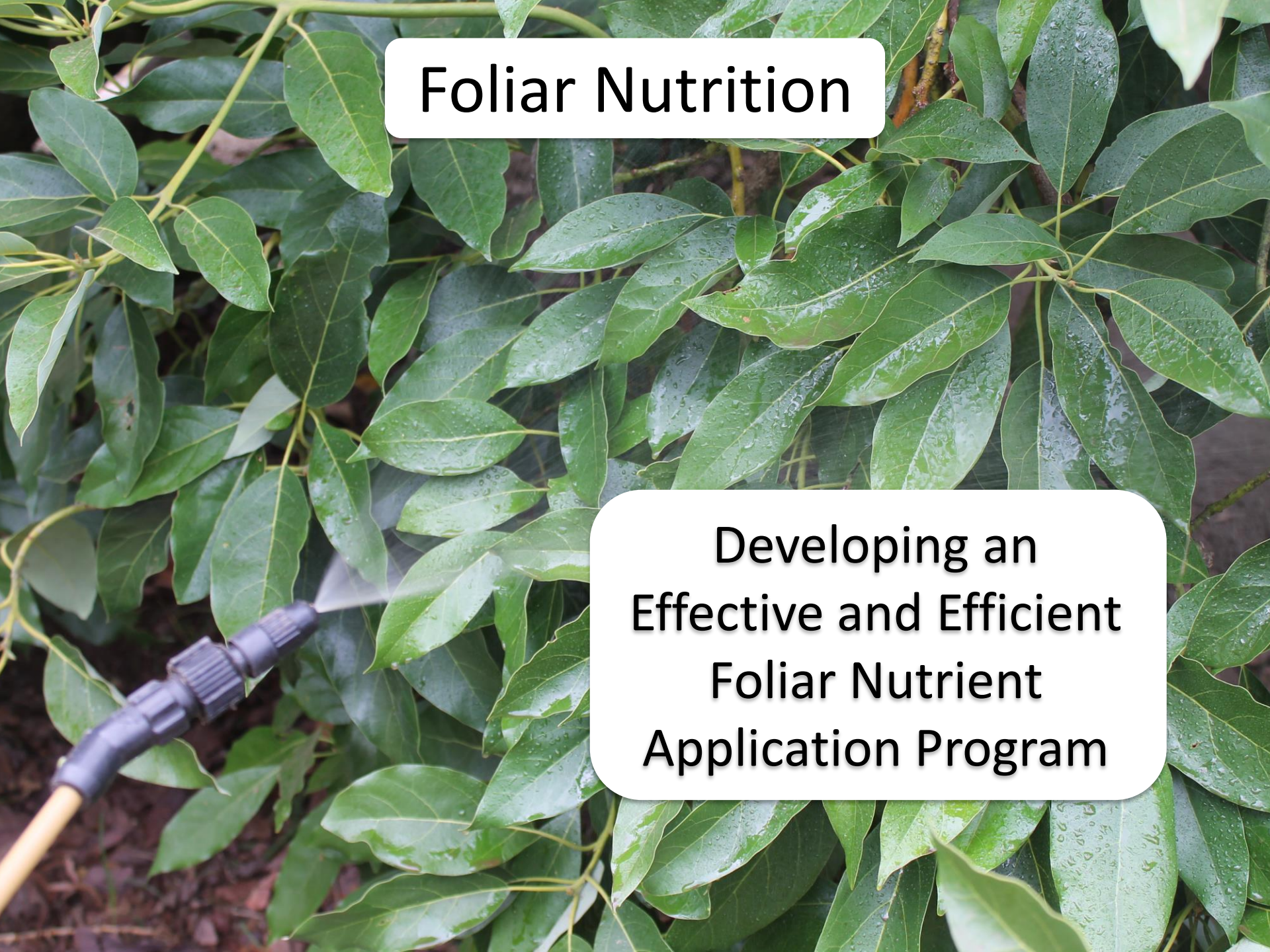
Foliar Nutrition



Developing an Effective and Efficient Foliar Nutrient Application Program

Why Foliar Nutrient Application

- Can be used to get nutrients into the plant when soil delivery is compromised by adverse conditions
- Offers efficient uptake of applied nutrients, so significantly lower quantities are needed
- Foliar applied nutrients are taken up rapidly so can be used to immediately address plant nutrient shortages, especially in leaves
- Is an effective way of getting micronutrients into plants
- A way to get soluble nutrients into plants without harming soil biology
- Low environmental impact – leaching/run off

Nutrient Use Efficiency in the Agricultural Ecosystems

Nutrient	Efficiency (%)
Nitrogen	30–50
Phosphorus	15–20
Potassium	50–60
Sulphur	8–12
Zinc	2–5
Iron	1–2
Copper	1–2
Manganese	1–2
Boron	2–3
Molybdenum	2–5

https://www.mdpi.com/2077-0472/11/4/372

Nutrient Roles in the Plant

Nutrients	Strength and Transport	Photo-synthesis	Protien Synthesis	Strong Growth	Reproductive Support	Fruit Fill & Quality
Potassium						
Calcium						
Magnesium						
Sodium						
Nitrogen						
Chloride						
Sulphur						
Phosphorous						
Silicon						
Iron						
Manganese						
Zinc						
Boron						
Copper						
Molybdenum						

Salt Index of Common Fertilizers

Fertilizer	Analysis	Salt index[a]	Relative salinity[b]
Sodium nitrate	16.5 N	100.0	100.0
Ammonium nitrate	35 N	104.7	49.4
Ammonium sulphate	21 N	69.0	53.7
Calcium nitrate	11.9 N, 17 Ca	52.5	30.1
Urea	46 N	75.4	26.7
Diammonium phosphate	21 N, 23 P	34.2	12.7
Monoammonium phosphate	12 N, 27 P	29.9	12.7
Superphosphate (single)	7.8 P	7.8	16.5
Superphosphate (triple)	19.6 P	10.1	8.5
Potassium chloride	49.8 K	116.3	38.5
Potassium nitrate	13 N, 38 K	73.6	23.6
Potassium sulphate	45 K	46.1	17.0
Calcium carbonate	40 Ca	4.7	1.9
Calcium sulphate	23 Ca	8.1	5.8
Magnesium sulphate	16 Mg	44.0	44.5

Limitations of Foliar Nutrient Application

- Have be applied more regularly, low rates, shorter lived
- Can’t supply adequate quantities of macro nutrients
- Require the equipment to get them out
- Involve post germination traffic
- Some nutrients are needed in the soil for certain biological processes i.e. molybdenum, boron, cobalt, silica, sulphur, phosphorous, calcium…

Suitable Forms of Nutrients for Foliar Application

Soluble Fine or Solution grade fertilisers are recommended foliar sprays. These products dissolve readily so are less likely to block filters and nozzles

While micronized minerals can be used in foliar sprays, application can be problematic and their effectiveness as a nutritional supplement isn’t guaranteed

Solubility

The following rules of thumb are useful for determining the solubility of fertilisers, although there may be exceptions.

- All ammonium, nitrate, potassium, sodium and chloride salts are soluble
- All oxides, hydroxides and carbonates are insoluble
- All sulfates are soluble except for calcium sulfate


ULPHA
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Product Formulae, Analyses and Solubility

Product	Formula	Typical Analysis					Solubility kg/100 L at 20^0 C
		% N	% P	% K	% S	% Other	
Urea	$CO(NH_2)_2$	46					105
Ammonium Sulfate	$(NH_4)_2SO_4$	21			24		75
MAP	$NH_4H_2PO_4$	12	26				37
MKP	KH_2PO_4		22.5	28			23
Potassium Nitrate	KNO_3	13		38.3			32
Potassium Sulfate	K_2SO_4			41.5	16.5		11
Calcium Nitrate	$5\ Ca\ (NO_3)_2\ .\ NH_4NO_3.10H_2O$	15.5				19% Ca	250
Magnesium Sulfate	$Mg\ SO_4.7H_2O$				12.4	9.6% Mg	71
Solubor	$Na_2B_8O_{13}.4H_2O$					20.5% B	9.5
Copper Sulfate	$CuSO_4.5H_2O$						32
Iron Sulfate	$FeSO_4.7H_2O$				11.2	19.7% Fe	48
Manganese Sulfate	$MnSO_4.H_2O$				19	31% Mn	70
Sodium Molydbate	$Na_2MoO_4.2H_2O$					39% Mo	65
Zinc Sulfate	$ZnSO_4.7H_2O$				11	22.7	96

Liquid Nutrient Compatibility Rules

Products such as urea, ammonium nitrate, potassium chloride (Muriate of Potash) and potassium nitrate are compatible in solution with one another, and most other fertilisers.

Phosphorus, sulphur, calcium, magnesium and trace element fertilisers are not as widely compatible and may react with other products in solution.

Examples of products that should not be sprayed together, as insoluble precipitate may form and settle to the bottom of the tank, are:

- Ammonium Sulphate - Do not mix with calcium salts, e.g. calcium nitrate and calcium chloride.
- Phosphorus fertilisers (MAP and MKP) - Do not mix either product with calcium or magnesium salts, or metallic sulphates, e.g. zinc sulphate.
- Potassium Sulphate - Do not mix with calcium salts.
- Calcium Nitrate & Calcium Chloride - Do not mix with ammonium sulphate, MAP, MKP, potassium sulphate, magnesium sulphate, metallic sulphates, boron fertilisers, or sodium and ammonium molybdate.
- Magnesium Sulphate - Do not mix with MAP, MKP, calcium salts or boron fertilisers.
- Boron Fertilisers, e.g. Solubor (sodium borate) and Borax - Do not mix with calcium salts, magnesium salts or metallic sulphates.
- Metallic Sulphates – Zinc/Iron/Manganese/Copper Sulphate - Do not mix with MAP, MKP, calcium salts, boron fertilisers, sodium or ammonium molybdate.

Fertilisers in Solution - Compatibility Chart

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Compatibility chart for commonly used fertilisers in solution

Ingredient	Urea	Ammonium Sulfate	MAP & MKP	Potassium Nitrate	Potassium Sulfate	Calcium Nitrate &Calcium Chloride	Magnesium Sulfate	Solubor	Metallic Sulfates	Metallic Chelates	Ammonium & Sodium Molybdate
Urea	OOO	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Ammonium Sulfate	✔	OOO	✔	P	✔	X	✔	✔	✔	✔	✔
MAP & MKP	✔	✔	OOO	✔	✔	X	X	✔	X	✔	✔
Potassium Nitrate	✔	P	✔	OOO	✔	✔	P	✔	✔	✔	✔
Potassium Sulfate	✔	✔	✔	✔	OOO	X	✔	✔	✔	✔	✔
Calcium Nitrate & Calcium Chloride	✔	X	X	✔	X	OOO	X	X	X	✔	X
Magnesium Sulfate	✔	✔	X	P	✔	X	OOO	X	✔	✔	✔
Solubor	✔	✔	✔	✔	✔	X	X	OOO	X	✔	✔
Metallic Sulfates (Cu, Fe, Mn, Zn)	✔	✔	X	✔	✔	X	✔	X	OOO	NR	X
Metallic Chelates, e.g. Iron, Zinc	✔	✔	✔	✔	✔	✔	✔	✔	NR	OOO	✔
Ammonium & Sodium Molybdate	✔	✔	✔	✔	✔	X	✔	✔	X	✔	OOO

✓ Compatible **X** Incompatible **P** Precipitate may form in concentrated solutions

NR Not Recommended

Application Rates and Spray Concentrations

Incitec Pivot Fertilisers

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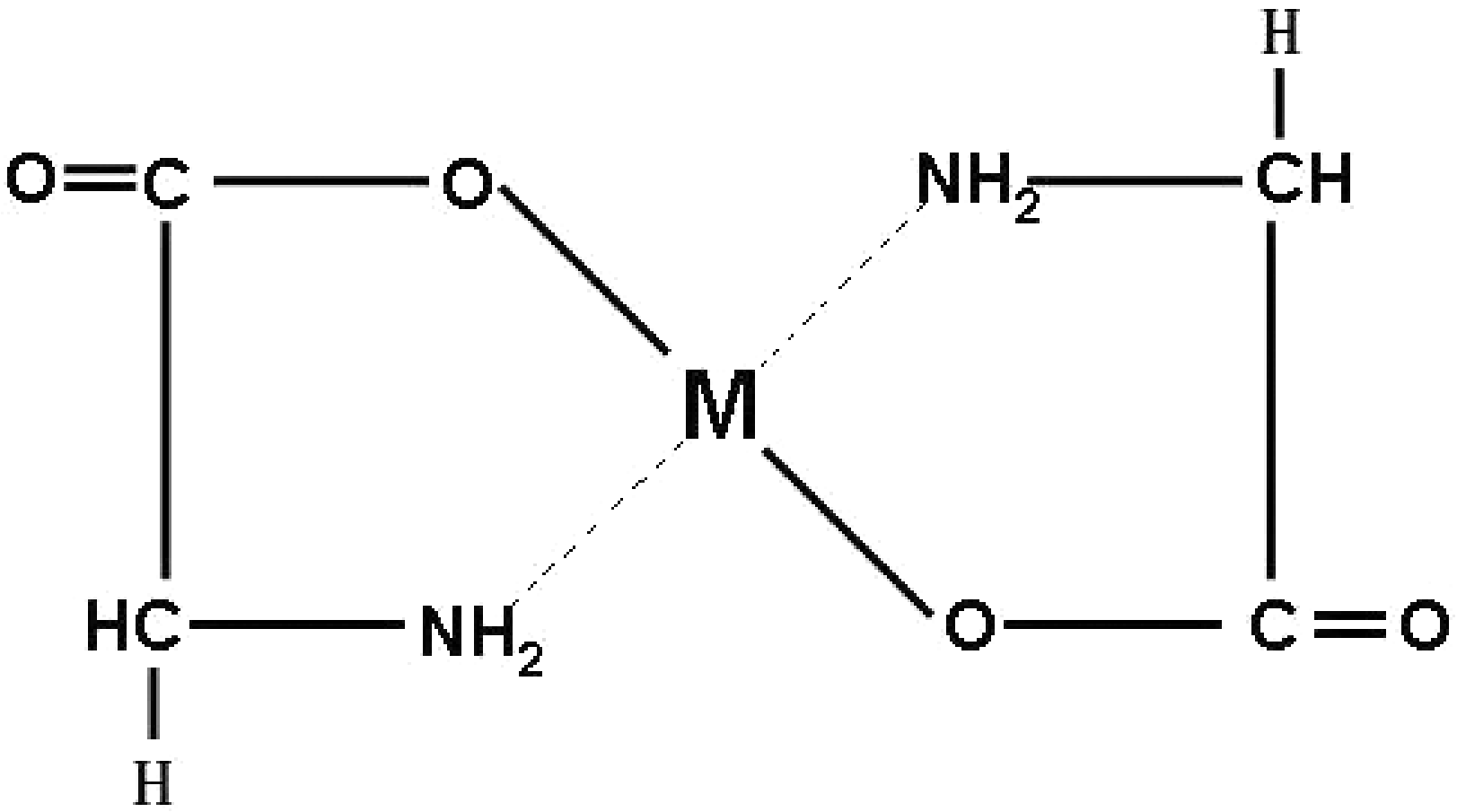
Solubor	0.5 – 2.5	1 - 2	0.2 – 0.5	0.1 – 0.25	Two or more sprays during critical growth stages, to apply 1 – 7.5 kg/ha of Solubor in total through the growing season or per annum. The lower rates are used on sensitive and low boron demanding crops.
Copper Sulfate	0.5 - 1	1	0.05 – 0.1	0.05 – 0.1	One or two sprays in early growth stages; one spray to spring flush in tree crops. In cereals, a late spray prior to pollination may be required.
Iron Sulfate	1		0.1	0.05 – 0.1	Iron is immobile in plants. Three or four sprays may be required during the growing season.
Manganese Sulfate	1 - 2	1	0.1 – 0.5	0.1 – 0.2	One or two sprays early in growing season, or to the spring flush. Two sprays at up to 3.5 kg/ha at 6 - 8 and 12 - 14 weeks after seeding are recommended in grain crops on calcareous soils in South Australia.
Sodium Molybdate	50 g		0.05 – 0.1		One or two sprays at seedling stage at 30 – 100 L/ha, enough to wet foliage.
Zinc Sulfate	1	1 - 2	0.2 – 0.25	0.1	Two sprays after emergence or transplanting. One spray to spring flush in tree crops.

Products	Rate kg/ha per spray	Typical Spray Volume (L/ha) & Spray Concentration (kg/100 L)			Comments
		Grain & Field Crops **50 L/ha**	Vegetables **500 L/ha**	Trees, Vines, Flowers **1,500 L/ha**	
Urea	10	10 - 20	1 - 2	0.5	Up to 30 kg/ha (20 – 30% solution at 100 L/ha) can be used in winter cereals at mid-tillering. Use low biuret urea in sensitive horticultural crops where applied regularly or at high rates.
MAP MKP	2.5 - 5	-	0.5 – 1.5	0.25 – 0.5	Phosphorus is less commonly applied in foliar sprays than nitrogen and potassium. It is not readily leached from the soil, and is important in the early stages of plant growth. Hence, in annual crops, the complete crop requirement is normally applied as a basal soil dressing at planting.
Potassium Nitrate	5 - 10	Cotton: Ground 5%; Air 10 – 20%	0.5 - 2	0.5 - 1	Up to 20 kg/ha of potassium nitrate may be used in a single spray in tolerant tree and field crops, e.g. cotton. Potassium sulfate may be used, but it is less soluble, and is therefore not generally recommended. It is used through high volume spray equipment in pineapples. Potassium nitrate is recommended in low volume sprays.
Calcium Nitrate	5	-	0.8	0.5	Regular, e.g. weekly, sprays are required during the fruit filling period as calcium is immobile in plants.
Magnesium Sulfate	2 - 5	2 - 5	0.25 - 1	0.25 - 0.5	Some authorities recommend 1 % (1 kg/100 L) sprays in horticultural crops. Fortnightly sprays are often required during critical growth stages.

Winning Combinations

Nutrients can be mixed with organic formulations to improve nutrient availability, stability, bio-suitability, uptake, energy status & metabolism

Chelation



Organic Chelating/Complexing Agents, Biostimulants & Inoculants

Fulvic Acid
Citric Acid
Amino Acids
Fish Hydrolysate
Liquid Seaweed
Molasses
Bioferments
Vermicast Extracts
Compost Teas
Potassium Silicate

Liquid Trace Element Mix

Amount	Product	% Nutrient in Product	Final Shuttle Percentage
50kg	Manganese Sulphate	31.50%	1.58%
50kg	Iron Sulphate	20%	1.00%
40kg	Zinc Sulphate	23%	0.92%
25kg	Copper Sulphate	25%	0.62%
30kg	Boric Acid	17%	0.51%
2.5kg	Cobalt Sulphate	21%	0.05%

1) Mix 20kg Fulvic Acid and 15kg Citric Acid with 800L water in a shuttle.
2) Add the above nutrients, one at a time to the 1000L shuttle and mix until dissolved.
3) If required, you can also add up to 1kg of Nickel Sulphate to this mix.
4) Top up with water, then close and store out of direct sunlight.

Ingredients may settle a little over time so give the barrel a good stir before use.

Application Rate:
Foliar Application - 10-20L/Ha as needed

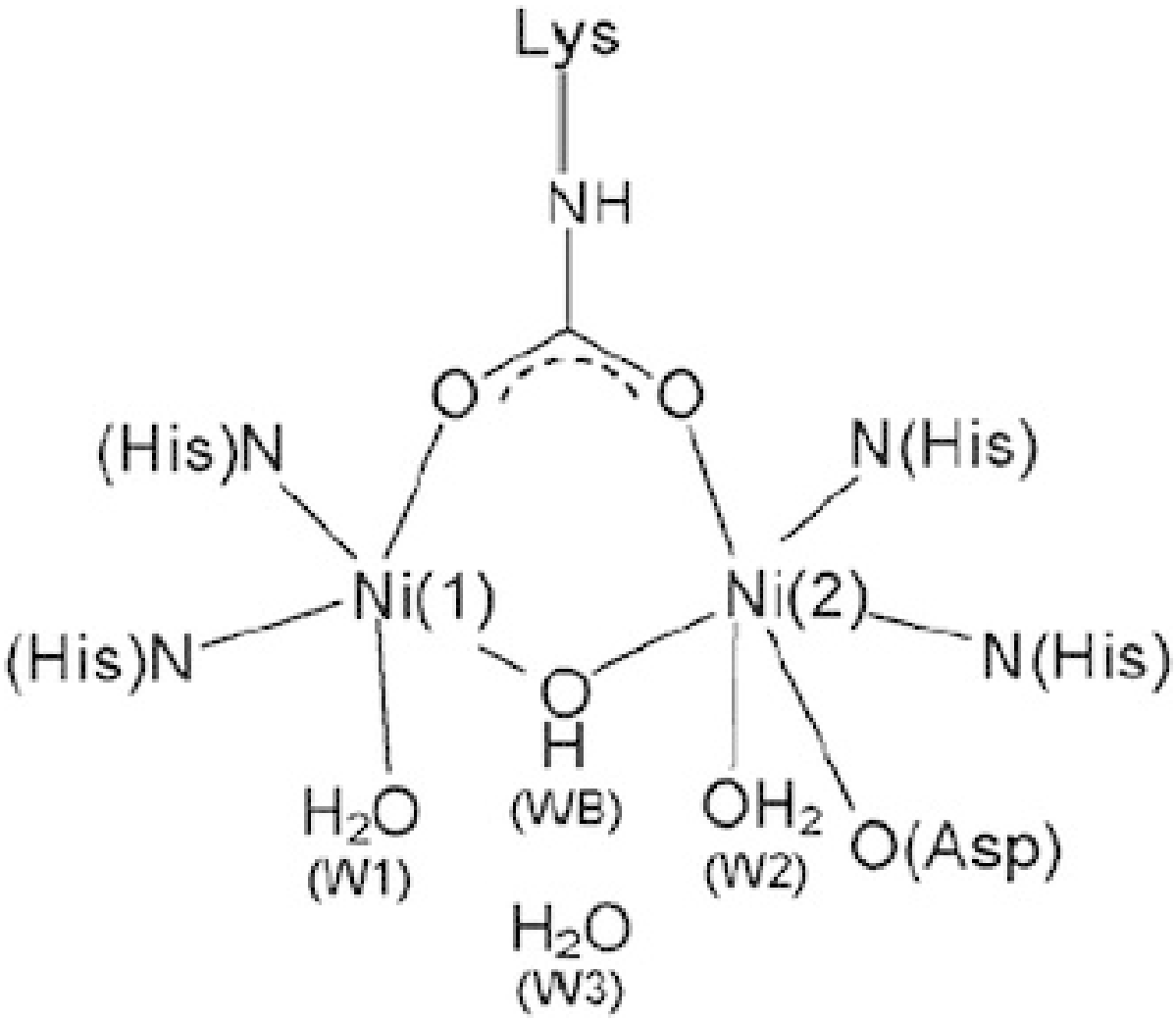
Other optional inputs that can be added to the diluted spray tank mix prior to application include:
10-15kg/Ha Urea
5-7.5kg/Ha Potassium Sulphate
5-7.5kg/Ha Magnesium Sulphate or 2.5-5 kg/Ha MAP (not compatible with one another)
2-4/Ha Fish Hydrolysate
2-4L/Ha Molasses
2-4L/Ha Fermented Seaweed (Acidic)
25-50g/Ha Sodium Molybdate

Note: this mix can be applied at higher rates to the soil, but the uptake of soil applied trace elements is generally much poorer.

Efficient Protein Synthesis

- It takes lots of energy to convert nitrate to ammonia to amino acids and proteins, there must be an adequate supply of carbohydrates to fuel these reactions
- Certain nutrient co-factors are needed to make the enzymes involved in these conversion processes i.e. Sulphur and Molybdenum are part of the nitrate reductase enzyme, Nickel is part of the Urease enzyme
- Other nutrients besides nitrates are needed to assemble the full spectrum of necessary protiens i.e. Sulphur to form Methionine & Cysteine

Urease Enzyme



Liquid Nitrogen Mix – 1000L

Add the following ingredients one at a time to 800L water in a 1000L shuttle and thoroughly mix until dissolved in solution. Top up the barrel with water, mix again, close and store in a cool, shaded environment:

- Fulvic acid powder - 25kg
- Urea - 500kg
- 25kg Sulphur (i.e. 100kg Ammonium Sulphate/150kg Sulphate of Potash/200kg Magnesium Sulphate)
- Sodium Molybdate – 2.5kg
- 1kg Nickel Sulphate

Ingredients may settle over time so give the barrel a good stir before use. The following products are compatible with and can be combined with this mix before application, at the following recommended rates:

5kg/Ha MAP/MKP
500g/Ha Solubor
20L/Ha Liquid Chelated Sulphate Trace Elements
2L/Ha Molasses
Fish Hydrolysate - 2.5L/Ha
Fermented (Acidic) Kelp - 2L/Ha

Application
Foliar application - 20L/Ha
Soil application – 50L/Ha

Preferably apply in mild conditions during the early part of the day before it warms up, or towards dusk when it starts to cool down.

Alkaline Foliar Formulations

The following alkaline soluble ingredients are compatible with one another and can be combined in water to make customised spray mixes.

- 1.5L/Ha Potassium Silicate
- 500g/Ha Soluble Seaweed Powder
- 10kg/Ha Urea
- 500g/Ha Solubor
- 50g/Ha Sodium Molybdate
- 500g/Ha Soluble Potassium Humate
- 2L/Ha Molasses
- 100g Concentrated Sea Minerals or 1L Seawater

Add appropriate amounts of chosen ingredients, one at a time, to a container with enough water to dissolve, and mix thoroughly until suspended in solution. Before application, stir the mix, let it come to rest, then decant, leaving behind/filtering out any solids that settle on the bottom

It's recommended to apply with no less than 750L/Ha water to avoid excessive concentrations of certain ingredients, that can cause leaf burn.

Micronized Lime, Dolomite, Gypsum, Silica, and Rock Phosphate/Guano products can also be put out with this mix at recommended rates but they don't remain in suspension, so require some agitation during application, and must be fine enough to not block nozzles/drippers.

To introduce a biological component, add the extract of 2kg/Ha compost/vermicast to the tank mix. Once the compost/vermicast extract has been added it must be put out within a couple of hours.

Preferably apply in mild conditions during the early part of the day before it warms up, or towards dusk when it starts to cool down.

Plant Leaf Testing

Leaf Tissue Tissue and/or Plant Sap Analysis are the diagnostic methods commonly used to determine foliar nutrition requirements

NUTRIENT ELEMENT BALANCE CHART

		Result		Deficiency	Marginal	Normal	Above Normal	Excess	Target	
Nitrogen		3.38	%						2.75-5.00	%
Nitrate - N		<30	mg/kg						#	mg/kg
Sulfur	S	0.37	%						0.25-0.45	%
Phosphorus	P	0.21	%						0.28-0.45	%
Potassium	K	1.13	%						3.20-4.50	%
Magnesium	Mg	0.26	%						0.20-0.35	%
Calcium	Ca	0.340	%						0.250-0.500	%
Sodium	Na	0.54	%						0.20-0.50	%
Chloride		0.60	%						2.5-2.8	%
Iron	Fe	86	mg/kg						25-100	mg/kg
Aluminium	Al	14	mg/kg						#	mg/kg
Manganese	Mn	44	mg/kg						60-150	mg/kg
Boron	B	8.2	mg/kg						8.0-15	mg/kg
Copper	Cu	5.1	mg/kg						8.0-12	mg/kg
Zinc	Zn	21	mg/kg						25-60	mg/kg
Cobalt	Co	<0.16	mg/kg						#	mg/kg
Molybdenum	Mo	2.9	mg/kg						0.30-0.40	mg/kg

Differential Leaf Sap Analysis

Mineral		Current Level	Optimum	
Total Sugars	%	1,5	2,1 - 2,9	1
	%	2,1		2
pH		3,5	3,2 - 3,7	1
		3,3		2
EC	mS/cm	6,4	6,5 - 8,3	1
	mS/cm	5,8		2
K - Potassium	ppm	1948	1475 - 2275	1
	ppm	1359		2
Ca - Calcium	ppm	238	295 - 1180	1
	ppm	409		2
K / Ca		8,20		1
		3,32		2
Mg - Magnesium	ppm	402	510 - 830	1
	ppm	682		2
Na - Sodium	ppm	80	18 - 92	1
	ppm	110		2
NH4 - Ammonium	ppm	197	70 - 170	1
	ppm	112		2
NO3 - Nitrate	ppm	<20	30 - 50	1
	ppm	<20		2
N in Nitrate	ppm	<5	7 - 11	1
	ppm	<5		2
N - Total Nitrogen	ppm	742	460 - 720	1
	ppm	849		2
Cl - Chloride	ppm	204	110 - 330	1
	ppm	283		2
S - Sulfur	ppm	314	130 - 430	1
	ppm	436		2
P - Phosphorus	ppm	319	340 - 590	1
	ppm	225		2
Si - Silica	ppm	9,2	90,0 - 146,2	1
	ppm	21,0		2
Fe - Iron	ppm	1,77	7,40 - 22,80	1
	ppm	7,07		2
Mn - Manganese	ppm	5,57	10,90 - 29,90	1
	ppm	11,33		2
Zn - Zinc	ppm	5,91	4,55 - 15,15	1
	ppm	9,57		2
B - Boron	ppm	1,88	2,80 - 12,30	1
	ppm	4,01		2
Cu - Copper	ppm	0,31	0,45 - 3,15	1
	ppm	0,35		2
Mo - Molybdenum	ppm	<0,05	0,05 - 0,25	1
	ppm	0,06		2
Al - Aluminium	ppm	4,05		1
	ppm	3,16		2

Consult your advisor for appropriate fertilizer recommendations.

Nutrient Mobility in Plants

Nutrient mobility in plants

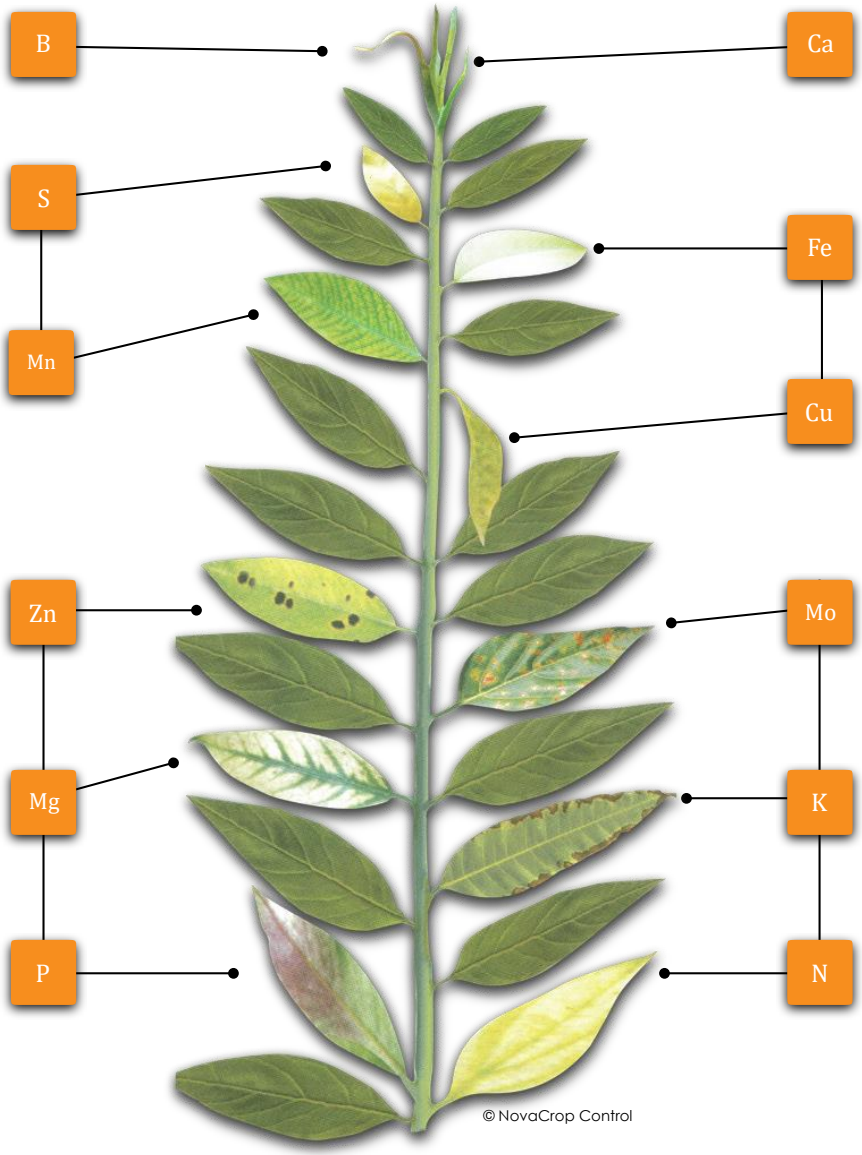
Very mobile – Nitrogen, Phosphorus, Potassium, Magnesium (Deficiency symptoms often appear first in older leaves and quickly spread throughout the plant)

Moderately mobile – Sulfur, Copper, Iron, Manganese, Molybdenum, Zinc (Deficiency symptoms first appear in new growth but do not readily translocate to old growth)

Immobile – Boron, Calcium (Calcium is very immobile)

Growth and Mineral Nutrition of Field Crops, Third Edition. By Nand Kumar Fageria, Virupax C. Baligar, Charles Allan Jones, 2011. CRC Press, Taylor and Francis Group.

Nutrient deficiency based on the position in the plant:



Top of the plant: Ca, B **Young Leaves:** Cu, S, Fe, Mn **Old Leaves:** N, P, K, Mg, Zn, Mo

Field Diagnostic Tools

Water Quality

Factors such as conductivity, pH, hardness and suspended solids affect the suitability of water for use in foliar sprays.

EC

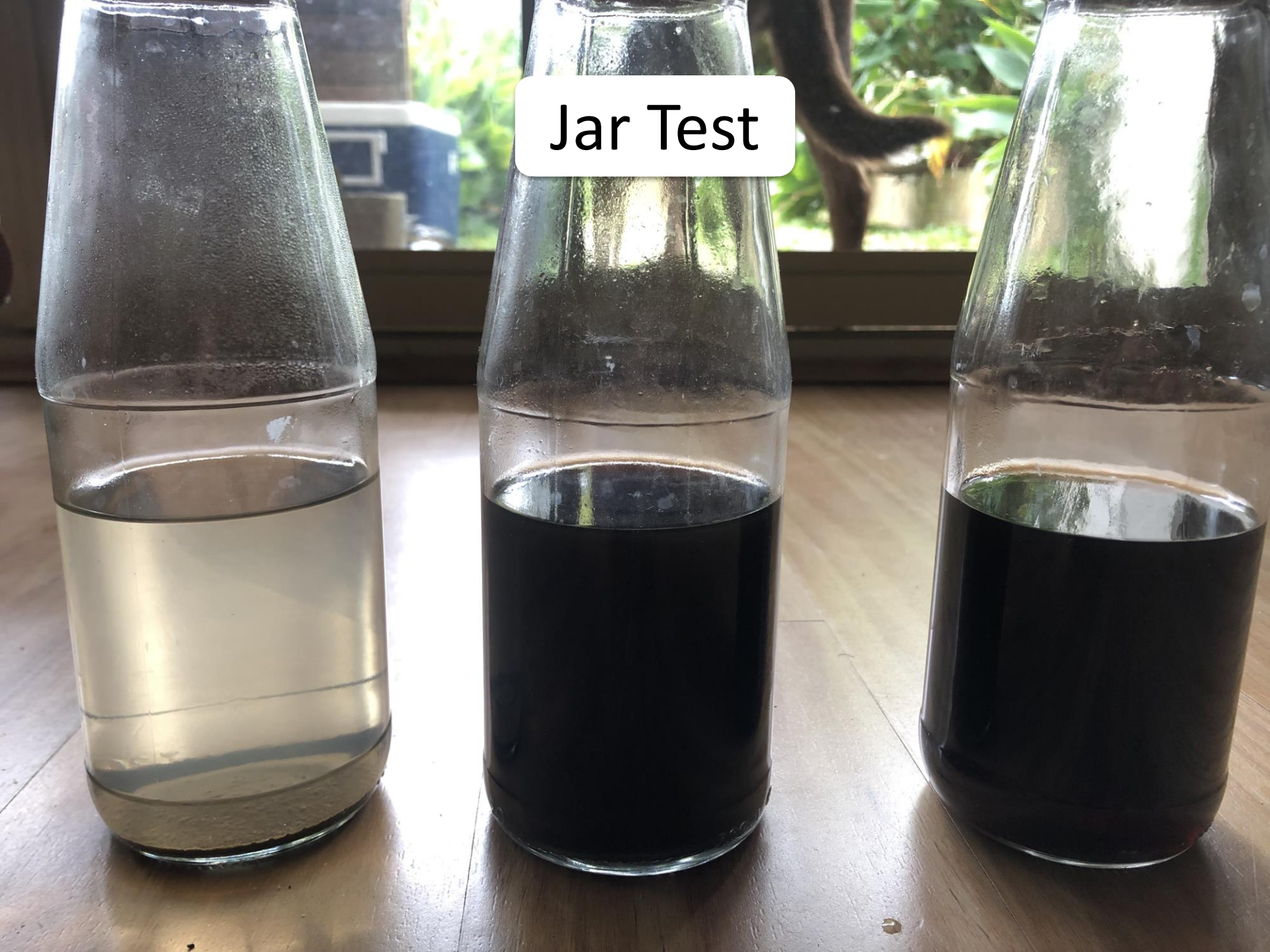
If the water has high conductivity, i.e. it is high in soluble salts such as sodium and chloride, spraying it on the foliage may affect plant growth. Adding fertiliser to the water will add to the concentration of salts, and increase the likelihood and severity of foliar burn. For regular applications it is best to keep the EC below 3800ppm.

pH

- The ideal pH range for most foliar sprays is between 5 and 6.5
- Water that is too acid or too alkaline may harm the foliage
- If the water is alkaline or hard (>70ppm), precipitates, e.g. of calcium sulfate; calcium borate; calcium molybdate; and calcium, magnesium or metallic carbonates or hydroxides; may form, reducing nutrient uptake by leaves and the effectiveness of the spray
- The addition of fertilisers can change the pH
- Can adjust the pH with acidifying (i.e. citric acid) or alkalising (i.e. sodium carbonate) agents

Tank Mixing Order

1. Clean Water
2. Pesticides
3. Fertilisers
4. Biostimulants
5. Biology
6. Surfactants

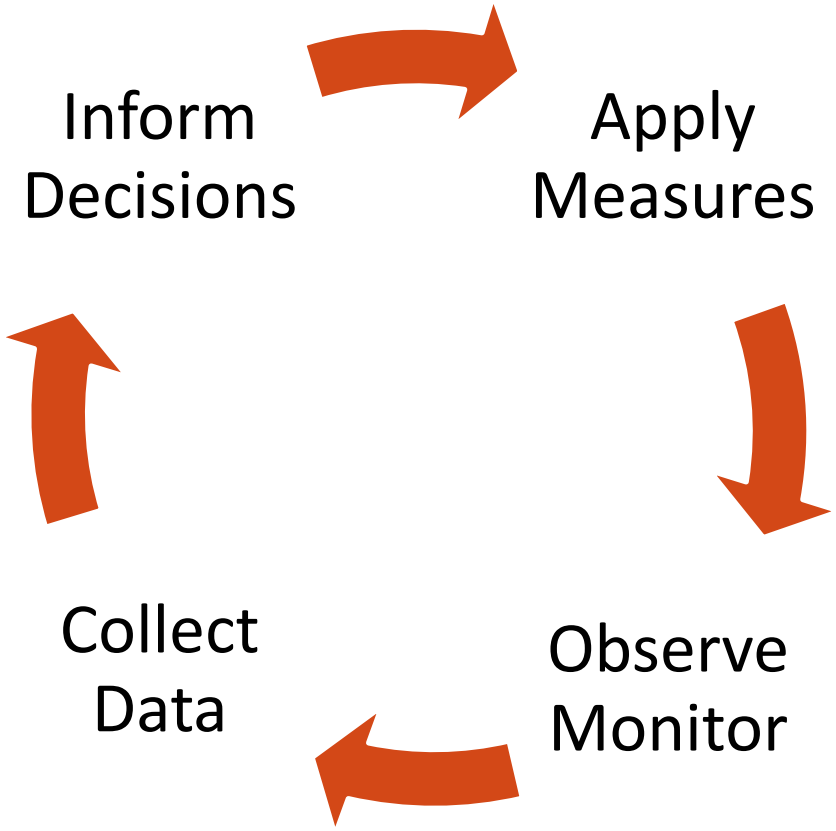

Jar Test

Application

Foliar sprays are best applied:

- early in the morning or later in the afternoon
- in dry conditions
- when it’s not too windy
- with equipment that enables you to get good leaf coverage, on both the underside and tops of the leaves
- regularly enough to maintain nutrient levels

Whole Season Approach



Questions ?

Point of Deliquescence ?

Adding a small amount of material with a high point of deliquescence helps the spray liquid stay moist on the leaves for longer.

These include:

- Magnesium chloride
- Potassium nitrate
- Calcium nitrate/chloride
- Sea minerals