Incitec Pivot Fertilisers

AGRITOPIC

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FOLIAR FERTILISERS

1. USE OF FOLIAR SPRAYS

Incitec Pivot Fertilisers does not market a complete range of soluble solid fertilisers for use in the preparation of foliar sprays. The company, however, recognizes that foliar fertilisers have an important role to play in balanced fertiliser programs, and has prepared this Agritopic to assist customers in developing their fertiliser programs.

It is often necessary to apply nutrients to the foliage of crops. This may be necessary to augment the soil and soil applied fertilisers. In other cases, foliar sprays may be more effective than soil applications, and be the preferred way to apply nutrients.

With few exceptions, foliar fertilisers cannot be used to replace soil applications of the major nutrients, such as nitrogen (N) and potassium (K). These nutrients are required in large quantities by plants. Attempts to feed the complete crop requirements for these nutrients through the foliage would result in leaf/foliar burn. Foliar sprays are used to supplement rather than replace soil applications of these nutrients.

Perennial evergreen tree crops, such as citrus, are more suited to foliar application of nutrients than deciduous and annual crops, as they have a large leaf surface area for nutrient absorption. High spray volumes are required to wet the leaves, allowing less concentrated nutrient solutions to be applied.

Pineapple is another crop in which nutrients are often applied in solution. Pineapples are grown in wide beds, making soil application of dry granular fertilisers through conventional equipment difficult. Boom sprays are often used to apply nitrogen and potassium over the plants. Where high volume spray equipment delivering 2 500 L/ha or more is used, some of the spray will run off the plants and into the soil. Nutrient uptake will be from both the soil and the foliage.

Foliar sprays are often used as supplements during peak demand periods, e.g. fruit filling, and during times of stress, e.g. when availability of the nutrient in the soil or plant uptake by the roots is reduced. Nitrogen sprays, for example, are sometimes used in irrigated field crops such as cotton, to help overcome temporary nitrogen deficiency due to waterlogging.

Foliar sprays also allow quick remedial action to be taken where unexpected nutrient deficiencies occur. Foliar sprays are particularly suited to the application of micronutrients or trace elements such as boron (B), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo) and zinc (Zn).

Because trace elements are required in small amounts, the crop's complete requirements can often be fed through the foliage, without burning the leaves. Such sprays are normally applied early in the life of an annual crop, or to an expanding spring flush in tree crops. Nutrient uptake and utilisation is greatest in young leaves.

Applying trace elements in solution allows nutrients to be delivered uniformly in the field, ensuring all plants receive the nutrient. This is not always possible when granular trace element fertilisers are applied dry to the soil, at low rates.

In the case of iron and manganese, which can be rapidly fixed in the soil and converted to forms that are not available for plant root uptake, foliar applications are usually more cost-effective than soil applications.

In summary, foliar fertilisation can be convenient, allows quick responses to be obtained, and in the case of trace elements, allows these nutrients to be applied evenly at low rates.

2. CHOICE OF PRODUCTS FOR FOLIAR APPLICATION

"Soluble Fine" or "Solution" grade fertilisers should be used in the preparation of foliar sprays. These products dissolve readily, and contain minimal insolubles, so they are less likely to block filters and nozzles.

Generally speaking, the finer or smaller the particle size, the more quickly the product will dissolve. This does not mean that more concentrated solutions can be prepared, simply that less agitation and time is required to dissolve the fertiliser. Sometimes, the product will be available in the prilled or granular forms, rather than as a powder. This is necessary for products that are prone to absorbing moisture in storage, and setting in the bags.

Many commonly used dry solid fertilisers are unsuitable for foliar application, the reasons being:

(i) The fertiliser is insoluble, contains part of its nutrient content in insoluble forms, or has low solubility. e.g. Oxysulfates, SuPerfect.

(ii) The fertiliser is soluble, but contains insoluble impurities, granulation or coating agents, which may block filters and nozzles.

The granular grades of MAP and DAP sold by Incitec Pivot Fertilisers, for example, contain in excess of 10% insolubles, which will be deposited as a sediment on the bottom of mixing tanks. They are intended for dry application to the soil only.

Incitec Pivot Fertilisers Gran-am® (granulated ammonium sulfate) contains granulation and coating agents, which may cause a sediment to be precipitated on the bottom of the tank, and a scum to form on the surface of the water in the mixing tank. This may not be a problem when irrigating through equipment with large nozzles, e.g. travelling irrigators, but is likely to cause problems with blockages of filters and nozzles in boom sprays (or when irrigating through equipment with fine apertures, e.g. micro-jets in drip and trickle irrigation systems). Gran-am is not recommended for use in the preparation of foliar sprays.

(iii) Alternative products are available that are either more soluble in water (allowing higher concentrations to be achieved), or dissolve more quickly, e.g. have a finer particle size.

Granular grades of urea, for example, are chemically identical to prills, but do not dissolve as readily as the granules are harder and larger.

(v) The fertiliser contains constituents, such as chloride in Muriate of Potash or biuret in normal grades of urea, which if applied at high rates or on a regular basis, may damage the foliage.

3. NUTRIENTS

3.1 Nitrogen

Foliar sprays are used to supplement, rather than replace soil applications of nitrogen, though in pineapples, a good part of the crop's total nitrogen requirement may be foliar applied.

Urea is the most commonly used fertiliser where nitrogen is applied as a foliar spray. It is a non-ionic compound, and is less likely to burn the foliage than ionic compounds (electrolytes or salts) such as ammonium nitrate. Urea is also economical, costing less per kg of nitrogen (N). Urea is available in granular and prilled grades, and in ready prepared solutions. Prills dissolve more readily than granules, on account of their smaller particle size.

Urea [$CO(NH_2)_2$] contains biuret [$C_2H_5N_3O_2$], an impurity that is formed during its manufacture, as a result of the condensation of two molecules of urea. Biuret is absorbed but is not broken down and utilised by plants when foliar-applied. It remains in the leaves. Biuret is however, readly broken down is soils. Biuret is a cumulative toxin. Damage is more likely to occur in evergreen trees and other plants in which the leaves remain on the plant for a long time, eg. citrus and pineapples, and regular sprays are applied.

Commercial grades of urea, i.e. those applied to the soil, contain up to 1.5% biuret. Low biuret grades of urea, containing up to 0.45% biuret, are recommended where urea is foliar-applied at high rates, or applied regularly, particularly in high value horticultural crops, and in perennial tree crops.

The normal grades of urea, which cost less, can be used where one or two sprays of urea are applied in annual field crops, e.g. wheat or cotton. This is also the case where urea is applied at low concentrations and rates, e.g. as an adjuvant in micronutrient sprays two or three times a season.

Urea and nitrate fertilisers, e.g. ammonium nitrate, potassium nitrate and calcium nitrate, are endothermic. They cause the temperature of fertiliser solutions to fall as they dissolve in water. The colder the temperature, the more difficult it becomes to dissolve the fertiliser.

3.2 Phosphorus

In annual crops, phosphorus is best applied to the soil at planting, banded with or near the seed or transplants. Phosphorus is important in stimulating root growth and is required early in the growing season. If supplementary phosphorus is applied as foliar sprays after planting vegetables, or to tree crops, either monoammonium phosphate (**MAP**) or monopotassium phosphate (**MKP**) may be used.

MAP supplies some nitrogen (N) and MKP some potassium (K), allowing the amount of these nutrients applied in other forms to be reduced. MAP may also be used as a buffering agent where other constituents of the spray mix produce an alkaline solution.

3.3 Potassium

Potassium is second to nitrogen in the amount required by crops, and in a few crops, is required in greater quantity, e.g. bananas, and cotton during the boll-filling period.

Muriate of Potash (potassium chloride) is the most commonly used potassium fertiliser where potassium is applied to the soil. Muriate of Potash, however, cannot be used in foliar sprays, as the chloride will burn the foliage.

Soluble/solution grades of **potassium nitrate** (Nitrate of Potash) or **potassium sulfate** (Sulfate of Potash) may be used where supplementary potassium is to be applied in foliar sprays. Potassium nitrate is the more soluble (easier to dissolve) of the two, and is the more commonly recommended of the two, particularly where low volume sprays are used, and highly concentrated solutions are to be applied, e.g. cotton.

Potassium sulfate is used in combination with urea in pineapples in high volume sprays in pineapples. The solubility of potassium nitrate and potassium sulfate in water is compared in the following table:-

Solubility (kg/100 L) of potassium nitrate and potassium sulfate in water at various temperatures.

Product	**10^{0}C**	**20^{0}C**	**30^{0}C**
Potassium Nitrate	21	32	45
Potassium Sulfate	9	11	13

Potassium nitrate is endothermic. It will cause the temperature of the spray solution to drop as it dissolves. Potassium nitrate is compatible in solution with calcium nitrate and calcium chloride. Potassium sulfate is not. Calcium sulfate (gypsum) will be precipitated from the spray mix if potassium sulfate and calcium nitrate (or chloride) are added to spray mixtures. Hard Water, due to calcium content, may also cause calcium sulfate (gypsum) to be precipitated from spray mixtures with potassium sulfate.

3.4 Sulfur

If sulfur is to be foliar applied, ammonium sulfate (Sulfate of Ammonia) may be used, either on its own, or in combination with urea to achieve the desired N:S ratio. Plants need ten or more times as much nitrogen as sulfur.

Technically pure grades of ammonium sulfate are available for such use. Incitec Pivot Gran-am, a granulated grade of ammonium sulfate, is not recommended for use in the preparation of foliar sprays, as the granulation and coating agents used in its manufacture may block filters and nozzles. If potassium is required, the use of potassium sulfate will supply both potassium and sulfur.

3.5 Calcium

Calcium deficiency is often linked to soil acidity, and associated problems such as aluminium and manganese toxicity. In these situations lime will need to be applied to the soil, to raise the pH.

There is a place for foliar sprays of calcium in fruit and vegetable crops, where soil uptake of calcium is impaired, e.g. when plants are moisture-stressed in hot dry weather. As calcium is not readily relocated from old to young tissue, plants are dependent on continuous uptake of calcium from the soil. Anything that affects root growth and nutrient uptake, even in soils with an adequate calcium supply, can result in calcium deficiency, eg. blossom-end rot in tomatoes.

Regular sprays of calcium during critical uptake periods help prevent calcium deficiency from occurring. In some crops, foliar sprays of calcium may need to be applied once, if not twice a week. Calcium can be applied as calcium nitrate or calcium chloride. Calcium nitrate is preferred, as calcium chloride is more likely to burn the foliage. Calcium chloride is used in red apples (where the extra nitrogen in calcium nitrate may affect fruit colour).

3.6 Magnesium (Mg)

Magnesium sulfate (Epsom Salts) is commonly used where magnesium is to be applied to the foliage. Unlike calcium, magnesium is mobile in plants. Consequently, the majority of magnesium issues are likely to be adequately addressed by applying magnesium to the soil.

3.7 Boron (B)

Foliar sprays are often preferred to soil applications of boron, as it is quite easy to induce boron toxicity if boron fertiliser is applied unevenly to the soil or too close to plants. Like calcium, boron is relatively immobile in plants. Where a deficiency is likely to occur, regular sprays throughout the growing season are sometimes advocated, although not as frequently as for calcium.

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In annual crops, several preventative sprays may be required from early in the growing season. In tree crops, the first spray is generally applied to new growth, e.g. a spring flush, followed by a number of repeat sprays at two to four week intervals.

Solubor (disodium octaborate tetrahydrate) and **Boric Acid** are commonly used to apply boron in fertigation. For foliar application only use Solubor, as boric acid's pH is likely to cause burn issues. Solubor contains 20.5% B, and boric acid 16.5 – 17.5% B.

3.8 Metallic Trace Elements

The metallic trace elements are copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn). There are a number of ways in which they may be applied:

- Sulfates
- Suspensions
- Chelates

The **Sulfates** are soluble in water, economical, and are the most common way in which these nutrients are applied:

- Copper sulfate pentahydrate (Bluestone)
- Iron sulfate heptahydrate
- Manganese sulfate monohydrate
- Zinc sulfate heptahydrate

The sulfates do not have as wide compatibility with other fertilisers in solution, and can be corrosive to equipment, particularly Copper Sulfate.

Insoluble copper compounds (oxides and hydroxides) that are less corrosive may be substituted for copper sulfate, but must be applied as a **microfine suspension** grade product (e.g. wettable powders and flowable concentrates). A fine particle size is essential, firstly, for the product to remain in suspension, and secondly, for the copper to be absorbed though the leaf pores (stomata).

Chelates are organic compounds that form a claw-like ring around metal ions such as zinc. The word chelate is derived from the Greek word "chela" which means claw. When applied to the soil, the chelate protects the metallic ion, delaying the formation of insoluble compounds. Plant roots are able to absorb the trace element directly from the chelate. Chelates are typically several times more expensive than other trace elements.

For foliar application, there is likely to be little difference between chelates and inorganic soluble salts, e.g. sulfates, in their efficacy in preventing or correcting trace element deficiencies. Once the trace element has entered the plant, it will be metabolised the same way, regardless of its source. Similar rates of trace element nutrient to those applied as sulfate may therefore need to be applied where chelates are used for foliar sprays.

Chelates are less likely to cause foliar burn than simple inorganic salts, e.g. iron chelate v iron sulfate. A probable explanation is that leaf uptake is slower with the chelates due to the size and complexity of the molecule. The chelates have wider compatibility in solution than the sulfates. They can, for example, be mixed in solution with MAP, MKP and Solubor, whereas the metallic sulfates cannot. Chelates will decompose in direct sunlight.

Copper and Zinc

Foliar sprays are an effective way of preventing or correcting copper and zinc deficiency in many crops. Foliar sprays of copper and zinc need to be applied early in the growing season, i.e. in the first few weeks after emergence in annual crops, or to a new flush of growth in tree crops. Yield will be lost if a deficiency is allowed to develop before spraying. Prevention is better than cure.

Iron and Manganese

While these two elements are classified as trace elements as far as plant uptake is concerned, they are present in relatively large amounts in the soil. Often deficiency is not a result of the soil containing inadequate iron and manganese, but because the amount present is fixed or tied up in forms which plants cannot use. Fixation is greatest at high pH (alkaline soils). The same fate will await soil applications of iron and manganese fertiliser. They will be quickly converted to plant-unavailable forms. Where practical, it is therefore recommended that iron and manganese be applied to the foliage rather than the soil, where required.

Manganese deficiency most commonly occurs on alkaline soils. Iron deficiency in crops is often temporary, and induced by changed soil moisture conditions. Remedial foliar sprays can be used in such situations.

3.9 Molybdenum

Of all the essential plant nutrients, molybdenum is required in the least amount. It is also very mobile in plants, and is readily relocated from old to young tissue. In legume based pasture, molybdenum is best applied as molybdenum fortified superphosphate.

Foliar sprays are the best way to apply molybdenum in horticultural crops that are sensitive to molybdenum deficiency, e.g. cauliflower and cucurbits. One or two molybdenum sprays in the seedbed and/or the early growth stages in the field will be enough to meet the requirements of most annual crops.

With some large-seeded crops, e.g. beans, maize, there may be enough molybdenum in the seed to meet the molybdenum requirements of the next crop, provided the seed came from a crop with an adequate molybdenum supply.

Sodium molybdate and ammonium molybdate are soluble sources of molybdenum suitable for foliar application.

3.10 Formula, Analyses and Solubility

The chemical formulae, analyses and solubility of the main products discussed above are listed in the following table.

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 Molybdate	$Na_2MoO_4.2H_2O$					39% Mo	65
Zinc Sulfate	$ZnSO_4.7H_2O$				11	22.7	96

The solubility data in the above table are for saturated solutions, and are maxima. They are presented for comparative purposes. It is not practical to achieve these concentrations on farm. No more than one-half of these concentrations (or perhaps one-quarter for products which are endothermic and cause the temperature to fall, e.g. urea, potassium nitrate and calcium nitrate) should be used when preparing fertiliser solutions.

Solubility is more of an issue when concentrated fertiliser solutions are being prepared for use in fertigation programs. Low concentrations are generally used for foliar sprays. The solubility of fertilisers in solution may be reduced further when two or more fertilisers are dissolved together.

4. FOLIAR APPLICATION RATES AND SPRAY CONCENTRATIONS

Foliar application rates are dependent on many factors including the type of crop, its demand for the nutrient in question, and its susceptibility to leaf burn. Higher rates of fertiliser can be applied to the foliage of tolerant crops than those sensitive to foliar burn. Cotton is one of the most tolerant crops, followed by cereals. Among the vegetable crops, brassicas and cucurbits are reasonably tolerant, while beans are among the most susceptible crops.

The concentration at which the fertiliser is applied will depend on the spray volume. High concentrations are used with low volume sprays, low concentrations with high volume sprays, so as to apply the desired amount of nutrient per hectare. As a rule of thumb, micronutrients (trace elements) are applied as 1 % solutions (1 kg/100 L) in low volume sprays (< 100 L/ha) in field crops, and as 0.1 % sprays (100 g/100 L) in high volume sprays in horticultural crops. Macronutrients are applied at higher concentrations, typically in the range of 5 – 10 % w/v in field crops (5 – 10 kg/100 L), 1 – 2 % in vegetables (1 – 2 kg/100 L), and 0.5 % in tree crops (500 g/100L).

Typical spray volumes in horticulture, wetting the leaves to the point of run-off, are 500 – 800 L/ha in vegetable crops, and 1 500 L/ha in tree crops. Seek local district and crop advice on spray programs.

In the absence of such advice, the table on the next page may be used as a guide and a quick reference to application rates and spray concentrations for commonly applied foliar fertilisers. Lower rates may be required in sensitive crops, e.g. strawberry.

Spray concentrations and application rates may need to be reduced where two or more fertilisers are foliar-applied simultaneously. Repeat sprays may be required to make up for the shortfall. Check that the fertilisers are compatible in solution before they are mixed. Unless instructed otherwise, avoid spraying during flowering, as fruit, nut and seed set may be reduced.

More detailed advice on nutrient application rates can be found in the Incitec Pivot Fertilisers Agritopics on the individual nutrients. Where specific information is not available for the crop and fertiliser in question, test spray before use, to check for signs of crop damage. Crops vary in their nutrient demands and susceptibility to foliar burn.

Products	Rate	Typical Spray Volume (L/ha) & Spray Concentration (kg/100 L)			Comments
	kg/ha per spray	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.

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.

5. SPRAY VOLUMES

Low volume sprays are used in field crops, and high volume sprays in horticultural crops. Examples of typical spray volumes are shown in the following table.

Foliar Spray Volumes

Volume	Use	Rate	Comments
Low	Grain Cotton	100 L/ha	Spray volumes are typically lower, often around 30 to 50 L/ha. Where the recommended nutrient concentration is based on a spray volume of 100 L/ha and a lower volume is used, the concentration should be increased, so as to apply the required amount of nutrient per hectare.
High	Vegetables	500 L/ha	Spray volume increases as crop matures, from 250 up to 1 000 L/ha. Most trace element sprays are applied in the early stages of growth, often at 400 to 500 L/ha.
	Trees	1,000+ L/ha	

In horticulture, nutrient sprays are often applied in combination with crop protection sprays, in sufficient water to wet the foliage without run-off to the soil.

6. COMPATIBILITY IN SOLUTION WITH OTHER FERTILISERS

Products such as **urea** and **potassium nitrate** are compatible with each other, and most other fertilisers in solution. Phosphorus, calcium, boron and other trace element fertilisers do not have as wide compatibility with other fertilisers 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 sulfate - 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 sulfates, e.g. zinc sulfate.

Potassium sulfate - Do not mix with calcium salts.

Calcium Nitrate & **Calcium Chloride** - Do not mix with ammonium sulfate, MAP, MKP, potassium sulfate, magnesium sulfate, metallic sulfates, boron fertilisers, or sodium and ammonium molybdate.

Magnesium sulfate - Do not mix with MAP, MKP, calcium salts or boron fertilisers.

Boron Fertilisers, e.g. Solubor (sodium borate) - Do not mix with calcium salts, magnesium salts or metallic sulfates.

Metallic sulfates, e.g. Zinc sulfate - Do not mix with MAP, MKP, calcium salts, boron fertilisers, sodium or ammonium molybdate, or metallic chelates. With some fertilisers, reaction products that, while still soluble, are less soluble than the original salts, may form. In concentrated solutions, the reaction product may be precipitated, and settle to the bottom of the tank. This will not happen with dilute solutions.

Should a precipitate from, it can be redissolved by adding water to the tank, and agitation. A precipitate may form when potassium nitrate (solubility in water of 32 kg/100 L) is mixed with either ammonium sulfate (75 kg/100 L) or Epsom Salts (71 kg/100 L).

At potassium nitrate concentrations much above 10% (10 kg/100 L), potassium sulfate will be precipitated. This is about one-third of the concentration of a saturated solution of potassium nitrate. The other reaction products in these examples, ammonium nitrate (192 kg/100 L) and magnesium nitrate 70 kg/100 L) have high solubility. All the solubilities in these examples are at 20^{O} C.

Compatibility information for commonly used fertilisers in solution is summarized in the table below.

7. COMPATIBILITY WITH FARM CHEMICALS

7.1 Label Information

Mixing soluble fertilisers with crop protection sprays offers a convenient and time saving way to apply nutrients, either to the soil, e.g. with pre-emergent herbicides, or directly to the foliage, e.g. with insecticides and fungicides.

Compatibility problems, however, may occur. The fertiliser may affect the standability of the crop protectant, causing it to settle in the tank, or interfere with its action, producing poor results in the crop. Before mixing fertilisers and crop protectants, refer to all product labels for compatibility information and mixing instructions, and adhere strictly to this advice.

Unfortunately, compatibility information is often not available from either the manufacturers or suppliers of soluble and liquid fertilisers or crop protection companies. There are many reasons for this. Often, it will be thought that products are compatible, but there is insufficient research or field experience over the full range of application procedures and environmental conditions under which the products may be applied.

It is also difficult to anticipate and test all the product combinations that may be used on the wide variety of crops being grown. Two products that are known to be compatible may be rendered incompatible by the addition of a third or fourth product to the spray mix; or by a slight formulation change; or when using another manufacture's product. Sometimes, a product combination that proves to be satisfactory may subsequently present problems if water quality or environmental conditions change.

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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

Water pH, hardness, and salinity levels can all influence the compatibility and standability of spray mixtures. Even water temperature may have an effect, some product combinations being more stable in cold water, i.e. 1 – 10^0 C, others in warmer water, i.e. > 20^0 C. In general, salting out (precipitation) is most likely to occur in cold water, and in low volume sprays. Variations may also be found between different manufacturers' formulations of the same active ingredient.

Sometimes, the compatibility of a product may change from one batch or season to the next simply because the manufacturer changes the formulation, e.g. the choice of solvent. Consequently, compatibility information is hard to come by, and suppliers are reluctant to make claims on compatibility beyond their own products. The following guidelines may be of use where compatibility information is not available.

Incitec Pivot Fertilisers stresses that it cannot provide definitive use directions for other company's products, and that changed circumstances may give variable results. If compatibility information is not available, do not combine the sprays unless experience confirms the mixture is compatible and that the product's label say is it compatible to do so.

7.2 Compatibility

When mixed together, fertilisers and crop protectants may have antagonistic and synergistic effects. As a result, the effectiveness of the crop protectants in controlling weeds, pests and disease may be reduced; or crop phytotoxicity may occur – even if physical compatibility is tested as suitable.The effects are not always negative. The addition of technically formulated grades of ammonium sulfate to glyphosate sprays, for example, enhances the herbicides efficacy, resulting in improved weed control.

Products may prove incompatible for a variety of reasons:

Physical – in which unstable solutions or suspensions are formed and phase separation occurs. Layers form in the spray mix if it is left to stand without agitation.

Chemical – where the spray additives react together. Sometimes a precipitate will form, and a sediment will settle to the bottom of the tank if the mix is left to stand. On other occasions, the chemicals will remain in solution or suspension, but they will be chemically altered, so that the efficacy of the crop protectant is affected.

Biological – where one component's activity blocks the activity of another.

As a general rule, water-soluble powders and solutions are more likely to be affected by poor quality water or the addition of fertilisers to the spray solution than are emulsifiable concentrates. This particularly applies to sodium salt formulations, which may be affected by hard water, or the addition of calcium or magnesium fertilisers. Flowable, wettable powder and water dispersible granule (WDG) formulations, in which the active ingredient is suspended in water, are the least likely to be affected.

Urea, other nitrogen and potassium fertilisers are compatible with many crop protection products, although in some instances, the pH of the spray solution may need adjustment. Problems are more likely to be encountered with calcium and magnesium fertilisers, e.g. calcium nitrate and magnesium sulfate, which will make the water harder. Hardness is a measure of the amount of calcium and magnesium in the water. Problems may also be encountered with phosphate fertilisers (MAP and MKP), Solubor and metallic sulfates, e.g. zinc sulfate.

Chelated trace elements have wider compatibility with other fertilisers and crop protectants than the metallic sulfates. Some specific points to keep in mind are:

- Gran-am is unsuitable for use with glyphosate sprays. It contains insoluble impurities that may block strainers and nozzles, but more importantly, the granulation agent used in its manufacture will interfere with the effectiveness of the herbicide.
- Ammonium fertilisers, including EASY N (UAN solution), are not compatible with 2,4-D Amine.
- Solubor is not compatible with oil-based solutions.
- Zinc sulfate and other metallic sulfates should not be mixed with glyphosate, paraquat, diquat or phenoxy herbicides, e.g. 2,4-D.

7.3 Compatibility (Jar) Tests

If compatibility information is not available, or compatibility is likely to be affected by environmental conditions or water quality, jar tests followed by test sprays on a small area of the crop are recommended to check for signs of:

- Phase separation or sedimentation after the spray mix has been allowed to stand;
- Crop phytotoxicity;
- A loss of effectiveness in the control of target weeds, pests or disease.

Field observations should be continued for several days. Jar tests can be conducted in the following way,

<u>For spray volumes of 50 L/ha, e.g. field crops</u>

1. Place 500 mL of the water to be used in a clean jar.
2. For every 100 mL/ha or 100g/ha of the crop protectants or fertilisers to be used, add 1 mL or 1 g to the jar, in the prescribed order.
3. Replace the lid on the jar and shake vigorously for about 5 minutes.
4. Check when the solution has become still, and again 30 minutes later for any signs of precipitation (sedimentation on the bottom of the jar) or phase separation (layering).
5. If sedimentation or layering is not evident and the mixture remains uniform, this would indicate that the products are physically and chemically compatible, though it is possible that the biological effectiveness may be altered.
6. If minor sedimentation or phase separation occurs, which can be corrected by shaking the jar, it may be possible to use the mix if good agitation is available.
7. If the layering or sedimentation on the bottom of the jar reforms quickly, the mixture should not be used.

<u>For spray volumes of 500 L/ha, e.g. vegetable crops</u>

1. Use the same procedure as described above, except this time a volume of 5 L of water should be used.

2. Then, for every 100 mL/ha or 100g/ha of the crop protectants or fertilisers to be used, add 1 mL or 1 g to the water, in the prescribed order.

3. Mix thoroughly, then take a portion of the mix, e.g. 500 mL, and place it in a clean jar or bottle, and follow the procedures already described.

Note: If two or more fertilisers and crop protectants are physically and chemically compatible, there may still be adverse effects on the crop protectants' biological activity.

8. PREPARATION OF SPRAY MIXTURES

8.1 Nutrient Sprays

When preparing fertiliser solutions, fill the tank with water to near capacity, leaving space for the added fertiliser, which should then be added slowly while agitating. This is of most importance when preparing concentrated fertiliser solutions, e.g. for macronutrients such as nitrogen and potassium. It is less critical when dilute solutions are being prepared, e.g. trace elements that are applied at lower concentrations.

Fertilisers should not be pre-mixed in a small amount of water before being added to the tank, as is the practice with some agricultural chemicals. This makes it harder to dissolve the fertiliser. The lower the concentration, the easier it is to dissolve fertiliser, the reason it should be added directly to the spray tank.

Fertiliser solutions should be prepared just prior to use, and not allowed to stand for an extended period, to minimise sediment formation and settling in tanks.

Urea solutions should be used soon after preparation, particularly where surface water from dams or streams is used. If urea solutions are allowed to stand for an extended period of time, e.g. overnight, the urea can be converted to other compounds that are much more likely to harm the foliage than urea itself, e.g. ammonium isocyanate (NH_4CNO) by bacteria, and ammonium carbonate [$(NH_4)_2CO_3$] by enzymatic activity (urease).

At high pH, ammonium carbonate may form free (gaseous) ammonia as the spray droplets dry on the plant foliage. Ammonia is toxic to foliage at low concentrations. Urea itself raises the pH of solutions to which it is added. If the water is of good quality and/or other spray additives are acidic, urea is unlikely to have a detrimental effect. However, if the pH of the water is already high, urea may compound any associated problems, and increase the potential for ammonia toxicity.

8.2 Crop Protection Sprays

Usually, fertilisers should be added to the spray mix last, after the crop protectants. Fill the tank to about one-third to one-half of its capacity, add the crop protectants, then top up the spray tank while continuing to agitate. If high concentrations of fertilisers are being used, they will be easier to dissolve if added when the spray tank is nearly full. Fertilisers do not require pre-mixing before addition to the spray tank.

It is important that the labels of all products to be used in the spray mix be checked, and the advice provided be followed. If specific instructions are not available, the following guidelines may be used where a number of different crop protectant formulations and fertilisers are to be added to the spray tank:

If spray adjuvants (water conditioners or buffers) are recommended or required, these should be added first, e.g. to buffer the pH. Then, it is generally recommended that crop protectants be mixed in the order of least likely to most likely to have compatibility problems. If more than one crop protectant is to be used, it is best to choose “like” formulations if possible, e.g. mix wettable powders with wettable powders.

Spraying oils and surfactants should be added after the crop protectants. The usual mixing order is:

1. Water Conditioners or Buffers;
2. Water Dispersible Granules (WDG);
3. Wettable Powders (WP);
4. Flowables or Suspension Concentrates;
5. Emulsifiable Concentrates (EC);
6. Water - Based Solutions and Soluble Concentrates;
7. Oils and Wetters (Surfactants).

An improper mixing sequence may result in incompatibility problems, blocked strainers and nozzles, and a loss in efficacy, e.g. if oil based products are added before dry suspension or dispersible products, the oil may coat the surface of the dry particles, preventing their dispersion in water.

It is normally recommended that fertilisers be added after the crop protectants (though this is not advocated by all crop protectant manufacturers or for all crop protection products). If fertilisers are added before crop protectants, any effects the fertilisers have on water pH will be more marked, which may affect the standability and efficacy of the crop protection spray. Crop protectants often have buffering and conditioning agents incorporated into their formulation. When added first (before fertilisers), they help stabilise the pH.

The ideal pH for most foliar sprays is 5.0 – 6.5. A pH meter can be used to check the pH of the final solution, and a little acid (to lower the pH) or alkali (to raise the pH) added if necessary. This will often not be necessary where crop protectants have been used.

Spray solutions should be prepared immediately prior to use, and kept agitated. Do not allow to stand for long periods, e.g. several hours or overnight, as this increases the risk of adverse physical or chemical changes. As a result, blockages of filters or nozzles and/or changes in the biological effectiveness of the active ingredients in the crop protectants may occur.

8.3 Summary – Your Check List Before Spraying

- Know your water quality and test it regularly;
- Check product labels for compatibility information, and order of mixing;
- If no compatibility information exists, conduct a jar test, and spray a small area of the crop to check for signs of efficacy and crop damage;
- Add water conditioning agents, crop protectants, and oils and wetters first, in this order; fertilisers last;
- The ideal pH for most foliar sprays is 5.0 – 6.5. If necessary, buy a pH meter, keep it calibrated, and adjust the pH of the final spray solution;
- Prepare spray mixtures just prior to use, do not allow to stand for extended periods.

9. WATER QUALITY

Water should be tested if its quality is unknown. Factors such as conductivity, pH, hardness and suspended soilds may affect its suitability for use. 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.

The pH of the water can also affect its suitability for use. Water that is too acid or too alkaline may harm the foliage. The addition of fertilisers can change pH, and may necessitate its being adjusted. The desirable pH range for most foliar sprays is 5.0 to 6.5. If the water is alkaline or hard, 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 precipitate may also settle in tanks, or block filters and nozzles.

10. SPRAY ADDITIVES

10.1 Wetting Agents

The addition of a wetting agent, at label recommended rates, will facilitate uptake of nutrient sprays. **Note:** Foliar sprays may be relatively ineffective compared to soil applications in some tree crops with waxy leaves, in which nutrient uptake via the leaves is poor.

10.2 Urea

Urea helps open the stomata (pores) in the leaves, and keep them open at low light intensities. Foliar-applied nutrients enter leaves through the stomata. In the absence of more specific crop information, the rates of addition detailed in the table below can be used as a guide. Urea is generally used at 1 kg/100 L (1% w/v) in low volume sprays; or added to the spray at a similar concentration to the trace element. Higher rates can be used if additional nitrogen is required, provided the rate is not excessive so as to cause fertiliser burn.

Suggested/Typical Rates of Addition of Urea to Foliar Trace Element Sprays

Crop	**Rate**	
	Amount / 100 L	**% w/v**
Field Crops	1 kg/100 L	1.0 %
Vegetables	500 g/100 L	0.5 %
Tree Crops	100 g/100 L	0.1 %

The normal grades of urea (up to 1.5 % biuret) can usually be used at these concentrations. There is no need to choose a low biuret grade. Low biuret urea (maximum of 0.45 % biuret), is recommended where repeated sprays of urea are made or urea is applied at higher concentrations so as to supply a significant part of the crop's nitrogen requirements through the foliage. While biuret toxicity may occur in a variety of crops, it is most likely in trees and crops where the leaves remain on the plant for a long period of time, e.g. evergreen tree crops such as citrus, and pineapples.

10.3 pH Correction

Fertilisers may alter the pH of spray solutions. The effect depends on the product, its source of manufacture, and the concentration at which it is used. Urea, potassium nitrate and Solubor solutions are typically alkaline, i.e. the solution will have a high pH. Iron sprays are typically quite acidic.

At low concentrations, e.g. high volume sprays, any change in pH will normally be small and not of great consequence. However, if the spray concentration (where low volume sprays are used) or the application rate is higher, or the water is already acid or alkaline, or weakly buffered, the pH may need to be adjusted. For most crops and products, the optimum pH range is 5.0 to 6.5. However with iron sulfate sprays, a lower pH may need to be accepted, as iron may precipitate in this pH range.

If the pH is alkaline (above 7.0), precipitates, e.g. of hydroxide or carbonate, are more likely to form; and if the spray contains ammonium salts, e.g. ammonium nitrate or ammonium sulfate, free ammonia may form. As discussed previously (Section 9.1), ammonia is toxic to foliage at low concentrations.

If the pH of the spray solution is alkaline and/or precipitate forms in the tank, e.g. zinc carbonate, a propriety acid solution can be added slowly to the spray solution to reduce pH and dissolve the sediment. Sulfuric acid and other strong acids & are to be avoided for workplace, health and safety reasons. Always add acid to water, never water to acid. Only use propriety acid solutions specifical formulated fo this purpose. Monoammonium phosphate (MAP) can be used as a buffering agent with alkaline fertilisers such as potassium nitrate. This is discussed in more detail in the next section (11.4).

If the pH of the spray solution is acid and needs to be raised, sodium carbonate (soda ash or washing soda) can be used. Pre-mix some sodium carbonate in water, and then add this solution slowly to the tank while agitating. Hydrated lime (calcium hydroxide) can also be used to raise the pH, but it is less soluble than sodium carbonate. An early use of hydrated lime was in mixtures with copper sulfate to prepare Bordeaux mixture for disease control.

A pH meter should be used to check the pH of the spray solution, as it is quite easy to over-adjust the pH. Meters should be adjusted and calibrated according to the manufacturer's instructions prior to use, to ensure correct readings are made.

10.4 Use of MAP as a Buffering Agent

The optimum pH for most foliar sprays is in the range of 5.0 - 6.5. At higher pH, leaf burn is more likely to occur, e.g. ammonia toxicity; and precipitate (sediment) is more likely to form in the spray tank. In addition, the efficacy and stability of many crop protection products is adversely affected in alkaline solutions.

MAP (technical grade) can be used as a buffering agent to adjust the pH of nutrient spray solutions when alkaline fertilisers such as potassium nitrate are being applied. About 2 - 3 kg of Technical Grade MAP is required for each 100 kg of potassium nitrate. Expressed another way, this equates to about 250 g/100 L of MAP in the more concentrated potassium nitrate sprays used in cotton (containing 5 - 20 kg/100 L potassium nitrate), while in high volume sprays used in horticultural crops (containing 0.5 - 2 kg/100 L potassium nitrate), 50 - 100 g/100 L of MAP may be adequate.

As many agricultural chemicals are affected by alkalinity (high pH), the chemicals should be added to the spray tank first, followed by the fertilisers. Add MAP before adding alkaline fertilisers such as urea and potassium nitrate. This will minimise any pH changes and exposure of the agricultural chemical to high pH. MAP is not compatible in solution with calcium, magnesium or metallic sulfate fertilisers.

10.5 FERTILISER BURN

Fertiliser burn following the application of a foliar spray may be attributable to various causes, including:

i. The spray solution may be too concentrated (exerting a high osmotic pressure on plant cells).

ii. The spray solution may be too acid or alkaline.

iii. The spray may contain or form specific compounds or ions, such as biuret, ammonia and chloride, which if present at too high a concentration, may harm foliage.

iv. The nutrient itself may be applied in excessive amounts, or in amounts that the plant is incapable of utilising in the short term, causing toxicity or inducing imbalances with other nutrients.

Water quality and the prevailing weather conditions also influence the likelihood of fertiliser burn. Fertiliser burn is more likely to occur when poor quality water is used.

<u>Susceptibility/Crop Tolerance</u>

It is quite easy to burn the foliage, flowers and fruit when applying nutrient sprays. This is most likely to occur when low volume (high concentration) sprays are applied. Among the most sensitive plants are strawberry, French bean, navy bean, carrot, sunflower, lychee and ornamentals such as African violets. Cotton appears to be more tolerant than most other field crops.

If applying a foliar fertiliser for the first time, or applying it to a new crop, or should the application procedures, equipment or the water source change, test spray on a few plants or trees beforehand, and observe for signs of phytotoxicity for 3 to 4 days, before spraying the entire crop. If foliar burn occurs, or is thought likely to occur, reduce the concentration, e.g. by one half, and be prepared to spray on a more regular basis.

<u>Salt (Osmotic) Effects</u>

The most important factor determining whether fertiliser burn occurs is the electrical conductivity (EC) or salt concentration of the spray solution. Most fertilisers (urea is an exception) are salts, and therefore add to the conductivity of spray solutions. The higher the fertiliser concentration, the higher the electrical conductivity of the solution, and the greater the likelihood of foliar burn. This is the primary reason why crop demands for macronutrients, such as nitrogen and potassium, can not usually be met exclusively through foliar sprays, and soil applications are necessary.

In contrast, trace elements are often foliar-applied. Trace elements are required in small amounts, and can therefore be applied at lower concentrations which are safe to the crop yet satisfy the plant demand. Fertiliser burn, however, may still occur, or toxicity may be induced with trace element sprays. Foliar burn is more likely to occur where a combination of fertilisers is applied, as these collectively add to the salt concentration of the spray solution.

To some extent, the incidence of foliar burn may be reduced by and increasing the spray volume, i.e. applying more water. This reduces the spray concentration (and electrical conductivity). However, it may be necessary to not only reduce the spray concentration, but also the overall application rate per hectare. Repeat or more regular sprays may be required to make up for the shortfall. However, there are limits to how often nutrient sprays can be applied, both from a practical and crop safety viewpoint.

Note: While urea is a non-electrolyte, and does not contribute greatly to electrical conductivity when dissolved in water, it may still burn plant foliage.

<u>Weather Conditions</u>

Foliar burn is more likely to occur under adverse environmental conditions. Hot dry weather (high evaporative conditions) at the time of application greatly increases the risk of foliar burn by causing water to evaporate from spray droplets before nutrients have an opportunity to enter the leaves. This concentrates the nutrient solution remaining on the foliage. It is best to spray in the early morning.

Sprays can also be applied in cloudy weather, or late in the afternoon or evening, provided the humidity is not low. Avoid spraying in the heat of the day, i.e. under high evaporative conditions. Do not spray under hot, dry or windy conditions, when the humidity is low.

<u>Plant Health & Growth Stage (Physiological Effects)</u>

Foliar sprays should only be applied to actively growing plants, and not stressed plants. Not only does this maximise absorption and utilisation of applied nutrients, it also minimises the risk of foliar burn. Spraying stressed crops may result in foliar burn as the leaves will not be able to properly assimilate the applied nutrients.

While young plant leaves and buds are often more susceptible to foliar burn, foliar burn may be more apparent on old rather than young leaves. Old leaves have a lower moisture content, so those nutrients that enter the leaves have a greater impact on internal electrolyte concentrations. In addition, as mature leaves are no longer actively growing, the absorbed nutrients cannot be diluted in new growth.

<u>Application Hints to Minimize Foliar Burn</u>

The risk of fertiliser burn to plant foliage can be minimised by paying attention to the following points:-

(i) Before using a nutrient spray for the first time or applying it to a new crop, or should application procedures, equipment or the water source change, test spray on a few plants or trees beforehand, and observe for signs of phytotoxicity, before spraying the entire crop,

(ii) If leaf burn occurs, be prepared to reduce the spray concentration, e.g. by one half. It may be necessary to spray more often at reduced rates, but cumulatively, problems may still occur. Test-spray again to ensure the mixture is safe before treating large areas.

(iii) A test spray may also be required if applying a repeat spray soon after a recent application.

(iv) Do not spray under hot, dry or windy conditions, when humidity is low.

(v) The best time to spray is in the early morning. Sprays can also be applied in the late afternoon or evening, or under cloudy conditions, provided the temperature is low and humidity is high. Do not spray in the heat of the day, when evaporative conditions are at their highest.

(vi) Unless otherwise directed, avoid spraying while plants are flowering, particularly in those crops with a short flowering period, unless leaves protect the flowers from the spray. Flowers are particularly sensitive to fertiliser burn, and any phytotoxicity at this stage may reduce fruit and nut set.

(vii) Use good quality water.

11. CARE OF SPRAY EQUIPMENT

Spray equipment should be thoroughly rinsed after applying foliar sprays, to reduce the risk of corrosion to brass, aluminium and other metal fittings and parts. If spray equipment is to be stored for any length of time before reuse, consider coating with dilute soluble oil. Refer to the equipment manufacturer's Operator Manual and ensure these instructions are followed. **Note:** Operating pressures and droplet size may affect the efficacy and likelihood of fertiliser burn with foliar sprays.

12. WARNING

The information contained in this Agritopic is for use as a guide only. The use of fertilisers is not the only factor involved in producing a high yielding pasture or crop. Local soil, climatic and other conditions should be also taken into account, as these can affect pasture or crop responses to applied fertiliser.

Before using fertiliser seek appropriate agronomic advice. Fertiliser may burn and/or damage crop roots or foliage. Foliar burn to the leaves, fruit or other plant parts is most likely to occur when different products are mixed and sprayed together, the water is of poor quality, or the spray is applied under hot dry conditions, e.g. in the heat of the day.

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