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Making and applying foliar fertiliser and pesticide solutions

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Abstract

This protocol describes how foliar and pesticide solutions can be made and applied to growing crops.

Foliar solutions (foliar fertilisers) can be either made using water soluble fertilisers (e.g. urea), inorganic salts (e.g. KCl, K_2SO_4) or by using readymade manufactured concentrated foliar solutions that could be in the form of chelated compounds of metallic ions. Their application rates are often simply stated as a percentage of the nutrient to be applied in solution form e.g. a 1 - 2% Zn foliar fertiliser solution. This protocol describes how to determine the amount of chemical material needed to make a specified concentration of a foliar solution mixture using various sources. Although not always stated, except on manufactured foliar solutions, foliar fertilisers should be ideally applied over a specified area to ensure that plants receive a sufficient volume of foliar solution. This protocol thus also describes how to make a foliar solution taking into consideration the area over which they shall be applied. Like readymade manufactured foliar solutions, pesticides also have instructions on how to make and apply their solutions over a specified area. How pesticide solutions should be made and applied according to specified instructions will hence also be shown.

Instructions for making foliar and pesticide solutions can be a little tricky to follow if you are not accustomed to the technical language. This protocol has been designed to give people some help with this.

Guidelines

It is important for you to thoroughly clean all equipment used before and after use to avoid contamination. Sprayers need special cleaning especially to prevent clogging in nozzles from debris and precipitated particles. Ensure that the water placed in the sprayers is clean and free from particles; try not to be messy when mixing solutions in sprayers to prevent the introduction of dirt in sprayers. Also ensure complete dissolution of added chemical reagents in water.

Ensure that the spray output is adjusted according to recommendations (between a full spray to a more stream-like output); this should be indicated in the instructions/directions for use, if not adjust it to what you think is suitable. Once set, do not adjust the nozzle size (spray output) during spraying, as this affects the volume of sprayed mixture, making spray quantities uneven across a crop field.

Pay attention to the instructions on how many sprays are needed for the product to be effective and also on the various crop stages that spraying must be carried out.

Materials

- Water soluble metallic salts that are readily plant available e.g. $FeSO_4$, $MnSo_4$
- Water soluble fertilisers e.g. urea
- Pesticide (fungicide, insecticide)
- Measuring cylinder
- Analytical balance
- Sprayers (e.g. garden sprayers of 1 L, 8 L or backpack/knapsack sprayers of 15 L)
- Clean tap water
- Soap
- Volumetric flask
- Beakers
- Stirring rod

Safety warnings

Handle all chemicals and their solutions well and use protective clothing. Read the instructions on the safe use of all products.

Before start

This protocol is not exhaustive of all requirements on how to spray and use foliar fertilisers and pesticides. You will still need to read the instructions written on manufactured products. The protocol only helps you to understand how you can make the chemical solution mixtures.

1 **Making foliar fertiliser and pesticide solutions from manufactured products**

Getting the application of foliar fertilisers and pesticides right starts with making correct chemical solution mixtures of foliar fertilisers and pesticides. A series of steps are however needed to achieve this. The steps shall be described below using worked out examples.

Fig 1 and 2 show samples of instructions on product labels of manufactured foliar fertilisers and pesticides. Read the instructions and take note of key information indicated on the labels. Notice that the formulation and application of foliar solutions can be specific to things like crop type, level of nutrient deficiency, plant growth stages, etc. and that of pesticide solutions can depend on pest types, pest populations, levels considered safe for the environment, etc.

Source: Yara (2008)

YaraVita Zintrac 700

Guaranteed analysis: total Zinc (Zn) 40% (700 g/L)

Typical recommendations:

Maize: 1 L/ha from 3 to 8 leaf stage. For severe deficiency repeat applications should be made at the above rate at 10 to 14 day intervals. Water rate 30 to 200 L/ha.

Fig 1: Part of the instructions on a product label for a manufactured zinc foliar fertiliser

Source: Arysta Lifescience (2011)

CYPERMETHRIN

Weekly application for prevention of all bollworms, i.e. American, Red and Spiny bollworm and Stainers.

Instructions for Ground application

Apply 75 ml/100 L water: With boom and nozzles. Ensure thorough coverage of the plants. For plants smaller than 60 cm apply 100 litre spray mixture per hectare. For taller plants increase the mixture to 200 litre per hectare for mature cotton. Do not use less than 150 ml CYPERMETHRIN EC per hectare on mature cotton.

Fig 2: Part of the instructions on a product label for a manufactured pesticide

Using the example in Fig 1, it can be seen that the zinc foliar solution should be made by mixing 1 L of foliar concentrate to about 30 to 200 L of water (Fig 1). Notice that the instructions mention that the foliar concentrate should be applied over a 1 hectare (ha) area of crop field (1 L/ha). The instructions on the label further mentions the amount of water to which the foliar concentrate should be added, note that this amount should also be sprayed over a 1 ha area of crop field (30 to 200 L/ha). Notice that the volume of water is indicated as a range; this allows the user to make foliar solutions with a range of concentrations, according to the level of nutrient deficiency observed in the maize crop. Alternatively, in Fig 2 it can be seen that the pesticide should be made by mixing 75 ml of pesticide concentrate to 100 L of water (75 ml/100 L water) per hectare of crop field. The foliar and pesticide solutions are thus only dilutions of their respective concentrates. Note that the foliar and pesticide concentrates are both precise concentrations of the nutrient or active ingredient in them, respectively.

Although the above steps are not complicated, a little complication may come in when your sprayer does not exactly have a 30, 100 or 200 L capacity for making the dilutions. You will hence have to do some calculations if you will be using a sprayer with a different tank storage capacity e.g. 2 L, 8 L, 15 L etc. An example of a sprayer with a 15 L storage capacity is shown in Fig 3.

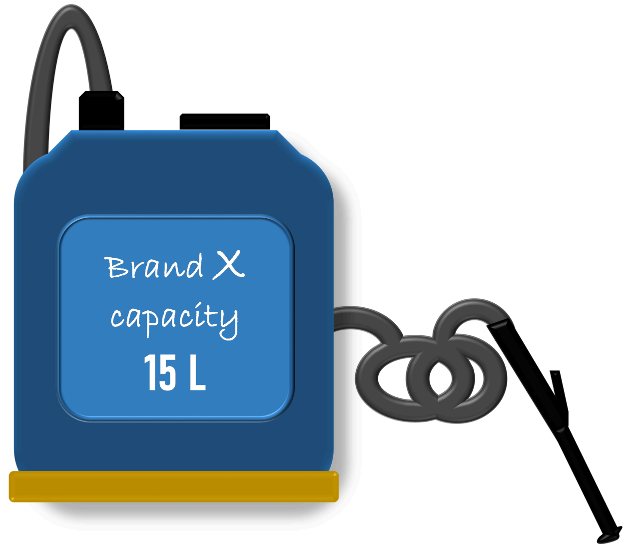

Fig 3: Backpack sprayer with a 15 L capacity

Let us assume that you have a sprayer with a 15 L capacity and that you want to make (i) a foliar solution of 1 L of foliar concentrate per 200 L of water (1 L/200 L water) and (ii) a pesticide solution of 75 ml of pesticide concentrate per 100 L of water (75 ml/100 L water). Your calculations will be based on ratios of proportion based on the recommended solution mixture for the foliar or pesticide solution. When carrying out the calculations you must thus ask yourself that if volume *X* of concentrate needs to be dissolved in a given volume of water, then what volume of concentrate will have to be dissolved in a desired volume of water to produce a solution with the same concentration? The calculations are shown below and they show that 75 ml of foliar concentrate will need to be added per 15 L of water (75 ml/15 L water), while 11.25 ml of pesticide concentrate will need to be added per 15 L of water (11.25ml/15 L water).

(i) **Determining the equivalent amount of foliar concentrate to be added to 15 L of water**

$$\frac{\mathbf{1}\ \boldsymbol{L}\ \boldsymbol{foliar\ concentrate}}{\boldsymbol{x}} = \frac{\mathbf{200}\ \boldsymbol{L}\ \boldsymbol{water}}{\mathbf{15}\ \boldsymbol{L}\ \boldsymbol{water}}$$

$$=> \boldsymbol{x} = \frac{\mathbf{1}\boldsymbol{L}\ \boldsymbol{foliar\ concentrate} \times \mathbf{15}\ \cancel{\boldsymbol{L}\ \boldsymbol{water}}}{\mathbf{200}\ \cancel{\boldsymbol{L}\ \boldsymbol{water}}}$$

$$= \mathbf{0.075}\ \boldsymbol{L}$$

$$= \mathbf{75}\ \boldsymbol{ml}\ \boldsymbol{foliar\ concentrate}$$

Equation 1

(ii) **Determining the equivalent amount of pesitcide concentrate to be added to 15 L of water**

$$\frac{\mathbf{75}\ \boldsymbol{ml}\ \boldsymbol{pesticide\ concentrate}}{\boldsymbol{x}} = \frac{\mathbf{100}\ \boldsymbol{L}\ \boldsymbol{water}}{\mathbf{15}\ \boldsymbol{L}\ \boldsymbol{water}}$$

$$=> \boldsymbol{x} = \frac{\mathbf{75}\ \boldsymbol{ml}\ \boldsymbol{pesticide\ concentrate} \times \mathbf{15}\ \cancel{\boldsymbol{L}\ \boldsymbol{water}}}{\mathbf{100}\ \cancel{\boldsymbol{L}\ \boldsymbol{water}}}$$

$$= \mathbf{11.25}\ \boldsymbol{ml}\ \boldsymbol{pesticide\ concentrate}$$

Equation 2

Note that each sprayer will have a specified amount of foliar or pesticide concentrate added to it and water will then be added to bring the solution mixture to the 15 L level. This is how dilutions are made. The solution mixture will hence be 15 L and not 15.075 L (15 L + 0.075 L) or 15.1125 L (15 L + 0.1125 L) for the foliar and pesticide solutions, respectively.

We now want to determine the area (ha) of crop field that will be covered by 15 L of foliar or pesticide solution. We shall continuing with the example above, to see how this is done. The required calculations are shown below. Notice that ratios of proportion are again used to arrive at the answer. This time we however ask that if the recommended volume of foliar (200 ml) or pesticide (100 ml) solution was going to cover a 1 ha area then how many hectares will a 15 L volume of solution cover?

(i) Determining the area (ha) that 15 L of foliar solution will cover

$$\frac{200\ L\ foliar\ solution}{15\ L\ foliar\ solution} = \frac{1\ ha}{x}$$

$$=> x = \frac{1\ ha \times 15\ \cancel{L\ foliar\ solution}}{200\ \cancel{L\ foliar\ solution}}$$

$$= 0.075\ ha$$

$$= 750\ m^2$$

Equation 3

(ii) **Determining the area (ha) that 15 L of pesticide solution will cover**

$$\frac{100\ L\ pesticide\ solution}{15\ L\ pesticide\ solution} = \frac{1\ ha}{x}$$

$$=> x = \frac{1\ ha \times 15\ \cancel{L\ pesticide\ solution}}{100\ \cancel{L\ pesticide\ solution}}$$

$$= 0.15\ ha$$
$$= 1500\ m^2$$

Equation 4

Our next interest is determining the number of times that a sprayer with a capacity of 15 L will have to be filled to cover a crop field. Fig 4 shows an example of a crop field covered by an experiment. Notice how the total area of the field is determined; the area occupied by the gaps between the experimental blocks are not included in the calculation. Note that the crop field that you will be working with does not necessarily have to be a field experiment; it could be an ordinary garden or even a pot experiment. Whatever it is, it will be important for you to know its exact area or even a rough estimate of its area if you have to spray foliar fertiliser or pesticide solutions over it.

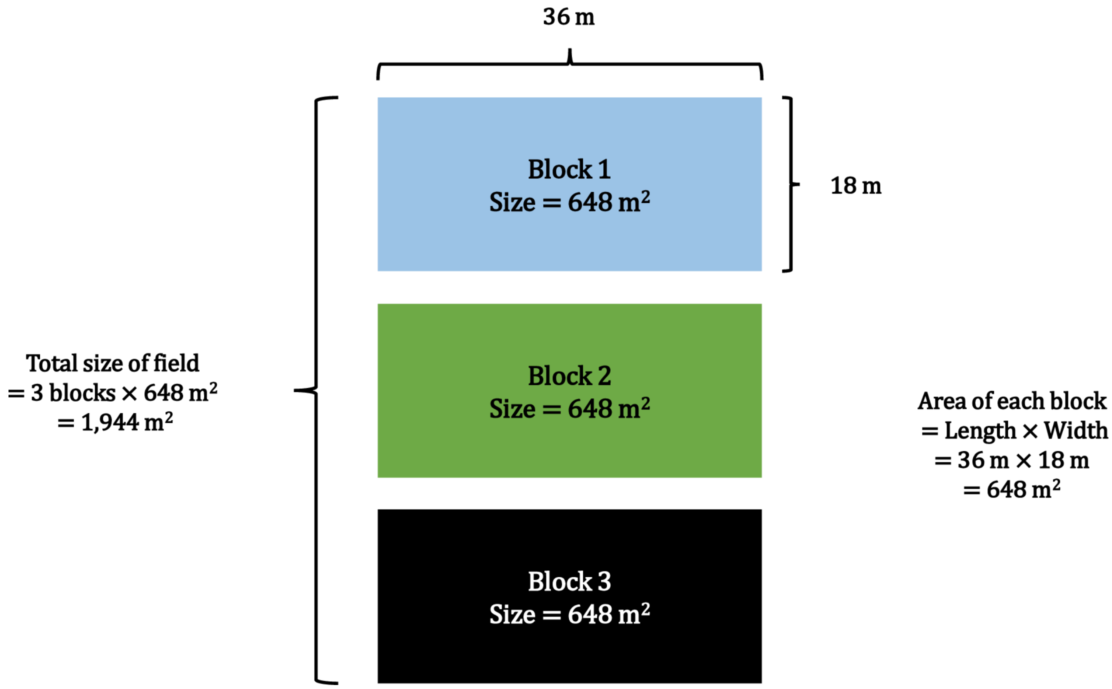

Fig 4: An example of crop field laid out as a replicated experiment

Continuing with our example we shall now determine the number of times that a sprayer with a 15 L capacity will have to be filled to cover a crop field with a size of 0.1944 ha (1 944 m^2). The needed calculations are shown below. Notice that proportionality ratios are again the basis of our calculations. The thinking behind the calculation is based on the knowledge of the area to be covered by one full 15 L spray tank of foliar or pesticide solution. We then try to find out how many of full spray tanks will be able to cover a required area.

(i) **Determining the number of full 15 L spray tanks of foliar solution needed to cover a specified area**

$$\frac{1\ full\ spray\ tank}{x} = \frac{0.075\ ha}{0.1944\ ha}$$

$$=> x = \frac{1\ full\ spray\ tank \times 0.1944\ \cancel{ha}}{0.075\ \cancel{ha}}$$

$$= 2.592\ full\ spray\ tanks$$

$$\approx 2.6\ full\ spray\ tanks$$

Equation 5

(ii) **Determining the number of full 15 L spray tanks of pesticide solution needed to cover a specified area**

$$\frac{1\ full\ spray\ tank}{x} = \frac{0.15\ ha}{0.1944\ ha}$$

$$=> x = \frac{1\ full\ spray\ tank \times 0.1944\ \cancel{ha}}{0.15\ \cancel{ha}}$$

$$= 1.296\ full\ spray\ tanks$$

$$\approx 1.3\ full\ spray\ tanks$$

Equation 6

Once we know the number of 15 L full spray tanks needed to cover the entire crop field, we can now easily calculate the volume of foliar and pesticide concentrate needed to cover the entire crop field, as shown below. We shall again continue using our two examples. Note that the volume of foliar/pesticide concentrate needed to be added to 1 full 15 L spray tank will be used in the calculation; remember that it was previously determined. Also note that the volumes of concentrate calculated below are only for one spray event. You thus have to multiply each obtained volume of concentrate by the expected number of spray times for you to know the total amount of concentrate needed throughout the entire crop growing period; this is useful for determining how much foliar/pesticide concentrate will need to purchase.

General equation

$$Volume\ of\ concentrate\ needed\ to\ cover\ crop\ field$$
$$= number\ of\ full\ 15\ L\ spray\ tanks \times volume\ of\ concentrate\ to\ be\ placed\ in\ 1\ full\ 15\ L\ spray\ tank$$

$$Volume\ of\ foliar\ concentrate\ needed\ to\ cover\ crop\ field$$
$$= 2.6\ full\ 15\ L\ spray\ tanks \times 75\ ml$$
$$= 195\ ml$$

$$Volume\ of\ pesticide\ concentrate\ needed\ to\ cover\ crop\ field$$
$$= 1.3\ full\ 15\ L\ spray\ tanks \times 11.25\ ml$$
$$= 14.625\ ml$$

Equations 7 and 8

The total volume of solution to be sprayed can be calculated in a similar way as the amount of concentrate; that is by simply multiplying the number of times that a full spray tank will be filled by the volume of the spray tank (15 L). See the calculation below:

General equation

$$Volume\ of\ solution\ needed\ to\ cover\ crop\ field$$
$$= number\ of\ full\ 15\ L\ spray\ tanks \times volume\ of\ 1\ full\ 15\ L\ spray\ tank$$

$$Volume\ of\ foliar\ solution\ needed\ to\ cover\ crop\ field$$
$$= 2.6\ full\ 15\ L\ spray\ tanks \times 15\ L$$
$$= 39\ L$$

$$Volume\ of\ pesticide\ solution\ needed\ to\ cover\ crop\ field$$
$$= 1.3\ full\ 15\ L\ spray\ tanks \times 15\ L$$
$$= 19.5\ L$$

Equations 9 and 10

You now know how to determine a number of things that are needed for you to successfully make foliar or pesticide solutions using manufactured products.

Note: When making the solutions, it is recommended that you initially add some water to the spray tank (about a quarter of the required volume) before adding the foliar/pesticide concentrate; this helps with the complete dissolution of the concentrate. Thoroughly mix the contents after each addition of water while bringing the solution to its required volume. Make sure that you again mix the contents well once the solution has been brought to volume.

2 Applying foliar fertiliser and pesticide solutions (Spraying)

You now need to gain some knowledge on spraying. Note that some information needed for this has already been determined and explained above. Now let us assume that you are applying the foliar or pesticide solution manually by ground application. If the field is large (about 1 ha) spraying it evenly with a number of spray tank fillings may be a little difficult. This is because it is sometimes necessary for you to go back and respray all the crops when you still have some solution remaining. All the solution made must be completely sprayed equally on the entire crop field. Thus to make the spraying easier and more even, it is better to have the crop field divided into equal manageable parts; using our example each block of the crop field could be a manageable part. The amount of solution needed to be sprayed to the entire crop field should be simply divided by the total number of manageable parts of the crop field (e.g. three) to determine the quantity of solution to be applied to one manageable portion of crop field with the recommended amount of foliar/pesticide solution. See the calculations below:

General equation

$$\textit{Amount of solution needed to cover } 1 \textit{ manageable part of crop field}$$

$$= \frac{\textit{total volume of solution needed to cover entire crop field}}{\textit{total number of equal manageable parts of the crop field}}$$

$$\textit{Amount of foliar solution to be applied to } 1 \textit{ manageable part of crop field}$$

$$= \frac{39\ L}{3 \textit{ equal manageable parts}}$$

$$= 13\ L \textit{ per manageable part}$$

$$\textit{Amount of pesticide solution to be applied to } 1 \textit{ manageable part of crop field}$$

$$= \frac{19.5\ L}{3 \textit{ equal manageable parts}}$$

$$= 6.5\ L \textit{ per manageable part}$$

Equations 11 and 12

The results show that 13 L of foliar solution would need to be sprayed over each manageable portion of crop field. This volume is 2 L less than 15 L; the volume is less than 1 full spray tank. You now need to determine the volume of foliar concentrate to add to 13 L of water using ratios of proportion (see Equation 1). The results additionally show that 6.5 L of pesticide solution would need to be sprayed over each manageable portion of crop field. This volume is far less than 1 full 15 L spray tank. If you can, it would be better to use a sprayer with an 8 L or 10 L capacity. This is because it is not advisable to deliver small solution volumes using sprayers with a large capacity. Another solution for this could involve dividing the crop field into two manageable portions instead of three.

Make sure you apply all the needed foliar/pesticide solution to each manageable portion of the crop field (one of the three parts), even if this means evenly spraying the solution over and over again on plants to completely used it up. Your aim is to ensure that all plants get equally sprayed with all the solution. Try to carry out the spraying using a constant speed, as this helps ensure that all plants receive an equal amount of solution. All plants should be completely soaked with the foliar/pesticide solution by the end of the spraying. Do not over spray one part of the field leaving nothing in the spray tank for the remaining plants. When you notice that you only have a little of the spray mixture left, try to quickly spray the remaining solution over all plants; ensure that every plant gets some of the remaining solution. You should always monitor the volume of solution left in the spray tank and assess how much of the field you can be sprayed with it. Always spray all plants in each manageable portion, before repeating the spraying. Do this even if spraying has to be done more than once, twice, etc.

3 **Applying foliar fertilisers and pesticides in one solution mixture**

Foliar sprays are often mixed with pesticide solutions during spraying. However, as we have seen from the two examples, foliar and pesticide solution volumes applied over a given area, can greatly differ. An ideal way of solving this problem would involve the adjustment of the volume of concentrate to fit the desired volume of water. Using our examples the desired volumes could be either 100 L or 200 L of water. For example if you decide to dissolve the foliar concentrate into 100 L then the 1 L of foliar concentrate to be added to 200 L of water will be adjusted to 0.5 L of foliar concentrate per 100 L of water. Notice that the old and new foliar concentrations are the same; the former solution concentration is hence still maintained. We can thus add 0.5 L of foliar concentrate and 75 ml of pesticide concentrate to 100 L of water. If we choose to dissolve both the foliar and pesticide concentrates into 200 L of water, we would then add 150 ml of pesticide concentrate per 200 L of water; notice that the solution concentration is still equal to 75 ml/100 L of water. Note that ratios of proportion can be used to determine the new volume of concentrate to add to the desired amount of water (Check Equation 1 and 2).

However, if it is still impossible to reconcile the two into one foliar-pesticide solution mixture, then you must consider making separate applications of the foliar and pesticide solutions.

4 **Making your own foliar fertilisers**

You may sometimes have to make your own foliar solutions, which is possible with access to analytical chemical reagents and laboratory equipment. Foliar solutions are simply solutions containing ions of nutrients that are essential for plant growth. The ions exist as inorganic salts or as chelates and can be introduced into solution by dissolving soluble inorganic salts or chelates that contain these ions into water. Foliar fertilisers are more common for micronutrients (iron, copper, manganese), but certain macronutrients (nitrogen, potassium) can also be applied through foliar application.

Solutions of foliar fertilisers are often stated as percentages, it is thus important to first understand how to convert solution concentrations from a molarity or parts per million (ppm) form to a percent (%) or parts per hundred form. The conversions below are important for the calculations that follow.

$$1\ mg = 1 \times 10^{-6} kg \quad or \quad 1\ kg = 1 \times 10^{6} mg$$

$$1\ ml = 1 \times 10^{-3} L \quad or \quad 1\ L = 1 \times 10^{3} ml$$

$$1\ ppm = 1\ mg\ of\ pure\ element\ per\ litre\ of\ solution = 1\ mg/L$$

Equation 13

Converting 1 ppm to parts per hundred (%)

$$parts\ per\ hundred\ (\%)$$

$$= 1\ ppm \times 100$$

$$= {}^{1\ mg}/_{1\ L} \times 100$$

$$= \frac{1 \times 10^{-6}\ kg}{1\ L} \times 100$$

$$= 10^{-4} kg/L$$

$$= 0.0001\%$$

$$note\ that\ the\ molarity\ in\ {}^{mg}/_{L}\ has\ to\ be\ converted\ to\ either\ {}^{kg}/_{L}\ or\ {}^{mg}/_{ml}\ before\ determining\ \%$$

Equation 14

Note that the molarity in mg/L has to be first converted to either kg/L or mg/ml (or their equivalent forms) before the percentage can be calculated. This is because percentages are calculated when parts have equal units. If it was a percentage of a mass of substance out of another mass, the units would be changed to g/g before percentage conversions can be made and thus for concentrations it is kg/L or mg/ml (or their equivalent forms).

We shall now try to work out an example. The example involves making a 2% zinc (Zn) foliar solution using $ZnSO_4.7H_2O$. We first start by determining the amount of $ZnSO_4.7H_2O$ to be added to 1 L of water to introduce 1 g of Zn.

$$\textit{Relative molecular mass } (M_r) \textit{ of } \mathrm{ZnSO4.7H_2O}$$

$$= Zn + S + 11(O) + 14(H)$$

$$= 65.39 + 32.066 + 11(15.9994) + 14(1.00794)$$

$$= 287.457\ g/mol$$

Equation 15

With knowledge of the molecular weight of $ZnSO_4.7H_2O$ and of the mass of Zn in it, we can now calculate the equivalent mass of $ZnSO_4.7H_2O$ that can give 1 g of Zn as follows:

$$\frac{X\ g\ \mathrm{ZnSO_4.7H_2O}}{1\ g\ Zn} = \frac{287.457\ g\ \mathrm{ZnSO_4.7H_2O}/mol}{65.39\ g\ Zn/mol}$$

$$=> X\ g\ \mathrm{ZnSO_4.7H_2O} = \frac{287.457\ g\ \mathrm{ZnSO_4.7H_2O}/\cancel{mol} \times 1\ \cancel{g\ Zn}}{65.39\ \cancel{g\ Zn/mol}}$$

$$= 4.396\ g\ \mathrm{ZnSO_4.7H_2O}$$

Equation 16

The results indicate that 4.396 g of $ZnSO_4.7H_2O$ should be added to 1 L of water to come up with 1 g Zn per litre of water (1 g Zn/L = 1000 mg Zn/L = 1000 ppm). Note that 1 g Zn/L is not the concentration that will necessarily give the 2% Zn foliar solution; more calculations are needed to arrive at this. A concentration of 1 g/L is used only becuase it helps to create a known reference relationship between a known molarity and its parts per hundred concentration. We shall thus now convert 1 g Zn/L into its percentage form, as follows:

$$1\ \mathrm{g}\ Zn/L\ into\ parts\ per\ hundred$$

$$= 1\ g\ Zn/1\ L \times 100$$

$$= 1000\ mg\ Zn/1\ L \times 100$$

$$= \frac{1000\ \cancel{mg}\ Zn\ \times \left(1\ \times 10^{-6}\ kg \middle/ 1\ \cancel{mg}\right)}{1\ L} \times 100$$

$$= 10^{-1} kg\ Zn/L$$

$$= 0.1\%\ Zn$$

Equation 17

A concentration of 1 g Zn/L is hence only 0.1% Zn. We now know the amount of $ZnSO_4.7H_2O$ that can be added to 1 L of water to give 0.1% Zn. We can thus use this to calculate how much of the $ZnSO_4.7H_2O$ should be added to 1 L of water to come up with a 2% Zn solution. See the calculation below:

$$\frac{4.396\ g\ \mathrm{Zn}SO_4.7H_2O}{x} = \frac{0.1\%\ Zn}{2\%\ Zn}$$

$$=> x = \frac{4.396\ g\ \mathrm{Zn}SO_4.7H_2\mathrm{O} \times 2\cancel{\%\ Zn}}{0.1\cancel{\%\ Zn}}$$

$$= 87.92\ g\ \mathrm{Zn}SO_4.7H_2\mathrm{O}$$

Equation 18

The result of the calculation shows that 87.92 g of $ZnSO_4.7H_2O$ should be added to 1 L of water to make a 2% Zn solution.

Note that these solutions should be made with high accuracy; analytical balances should be used to determine the mass of salts to be added and solutions should be made up in volumetric flasks.

If your garden or pot experiment is small a 1 to 2 L solution is often sufficient for spraying, but if you are spraying a crop field a 1 to 2 L solution volume is not sufficient. Volumes of solutions to be sprayed over crop fields are best made by considering the volume of the sprayer to be used. It is however not advisable to add the solid salt directly into the sprayer and this is why concentrated solutions are made; just like the manufactured foliar products. We can hence determine the molarity of a concentrated solution that will be able to produce a 2% Zn solution in 15 L of water. Remember that we are working with a 15 L capacity sprayer. The formula below can help us arrive at the answer.

$$\textit{This equation applies to all dilution problems}$$

$$\textit{Dilution Formula}: C_1 \times V_1 = C_2 \times V_2$$

$$C_1\,(\textit{initial conc}) \times V_1\,(\textit{initial volume}) = C_2\,(\textit{final conc}) \times V_2\,(\textit{final volume})$$

$$C_1 \times 1\,L = 2\%\,Zn \times 15\,L$$

$$\Rightarrow C_1 = \frac{2\%\,Zn \times 15\,\cancel{L}}{1\,\cancel{L}}$$

$$= 30\%\,Zn\,solution$$

Equation 19

The results show that 1 L of a 30% Zn foliar solution can be added to 15 L of water to give a 2% Zn solution in the sprayer. A 30% concentrated Zn solution must hence be first made in the lab for this purpose. The mass of $ZnSO_4.7H_2O$ to be added to 1 L of water to produce the 30% Zn solution however needs to be calculated as shown below:

$$\frac{87.92\ g\ \mathrm{ZnSO_4.7H_2O}}{x} = \frac{2\%\ Zn}{30\%\ Zn}$$

$$=> x = \frac{87.92\ g\ \mathrm{ZnSO_4.7H_2O} \times 30\cancel{\%\ Zn}}{2\cancel{\%\ Zn}}$$

$$= 1318.8\ g\ \mathrm{ZnSO_4.7H_2O}$$

Equation 20

The results show that 1 318.8 g of $ZnSO_4.7H_2O$ will have to be dissolved in 1 L of water to produce a 30% Zn solution.

Note that there are no instructions on the area over which the foliar solution should be applied. However, most foliar applications are based on a 1 ha area of crop field. An application rate 15 L of Zn foliar solution per hectare of crop field could hence be used to ensure uniformity in how the foliar solution is applied across the crop field.

Note: Ensure that you only make enough solution for a single spray period. Freshly made solutions are best and have lower chances of precipitating. Also note that foliar fertilisers from salts will need a little soap added to them to help make their solutions stick on plant leaves thus allowing for the proper absorption of nutrients. I shall however not explain how this should be done in this protocol. Try to read about it. Manufactured products are often made to overcome this problem.

5 **Making your own foliar solution concentrations using manufactured foliar products**

You may sometimes have to make your own foliar solutions independent from the general instructions given on product labels. This could arise when you want to be surer of the concentration of the foliar solution being recommended to be sprayed on plants by the manufacturer. Sometimes the quantities of salt to be dissolved when making a concentrated solution are also impossible to obtain and their use unrealistic; your only option would hence be using manufactured foliar products. You will however need knowledge on how to convert recommended foliar solutions into units that help you understand how much is actually being added. The first step is selecting the foliar product suited to your plant nutrient needs. Note that manufactured foliar concentrates can contain several other nutrients other than the nutrient you are looking for, hence be very careful when selecting the product you will use. Note that all foliar fertilisers will also have their respective nutrient compositions (concentrations) clearly indicated on them.

Using our example in Fig 1, it can be seen that the foliar solution was composed of 40% Zn or 700 g Zn/L; it was a single nutrient foliar solution. Its concentration is close to the 30% Zn concentrate that we had made (Equation 19). Let us work out an example to see how much of the concentrate should be added to 15 L of water to make a 2% Zn solution using the 40% zinc foliar concentrate. We shall have to use the dilution formula to arrive at the answer.

$$C_1 \times V_1 = C_2 \times V_2$$

$$40\% \times V_1 = 2\%\ Zn \times 15\ L$$

$$=> V_1 = \frac{2\%\ Zn \times 15\ L}{40\%}$$

$$= 0.75\ L$$

$$= 750\ ml$$

Equation 21

The results show that 750 ml of the 40% Zn concentrate should be added to 15 L of water to make a 2% Zn foliar solution. We shall not use the water application rates on the label as these would adjust the concentration of our foliar solution. Instead we shall apply 15 L of solution per ha to ensure uniformity in how we apply the zinc foliar fertiliser across our crops.

6 **Making your own foliar solution concentrations using fertilisers**

You may sometimes have to also make foliar solutions using solid fertilisers. The main thing is to find out how much fertiliser can be added to introduce 1 g of needed nutrient to 1 L of water, much like what was done when making foliar fertilisers with inorganic salts (Equation 16). I will not go into detail on this as most of it will be a repetition. You will however need to know how to make fertiliser calculations to determine a 1 g of desired nutrient from them, follow this link to get help with this [https://dx.doi.org/10.17504/protocols.io.4ifgubn]. Note that not all fertilisers can be used for this purpose. It is best to use highly water soluble fertilisers.

7 **Bibliography**

Dhanlal De Lloyd (2000). Parts per million conversions. [delloyd.50megs.com/ppm.html] date accessed 28/11/2019.