the TREE LINE
the official monthly publication of the BONSAI SOCIETY of PORTLAND

Upcoming Events

June
2018

June 26 6-9pm **BSOP monthly meeting**, Milwaukie Center

August 11 12-4pm **BSOP Summer Picnic**, Milwaukie Center Picnic Area

September 9 10-2 **Mentorship 102A,** Milwaukie Center

September 14-16 **Northwest Bonsai Rendezvous** Milwaukie Center

September 30 10-2 **Mentorship 102B,** Milwaukie Center

Words From Your President

Summer has pretty much invaded the NW and as our trees grow with the warmth and longer days the BSOP generally slows down with its activities. Note I said "generally." That is because this year is the year of the "Rendezvous." September 14 to the 16th our club will be the host to hundreds of bonsai enthusiasts from near and far. So please go to our website and volunteer to assist and or sign up for the many activities that are available.

Summer is also the time for our Annual Picnic. The date will be August 11 and will be held in the picnic area of the Milwaukie Center. There will an article coming out about the picnic so I will keep this short. The picnic is for everyone! Members who have just joined or have been in the club for 50 years and all those in between. I would love to see you there.

I know I bring this up on all my letters but I am just that passionate about it. Please continue to step up and take a turn to volunteer for your club. In addition, please take the time to thank those who you see at our meetings and activities that give so much of their time to your club.

A note of kind words recently said: I recently made a couple of mistakes, I do that a lot. When I approached the person it involved and apologized, the person floored me by stating that having a friend was much more important than being upset about the mistake. That kind of loyalty is not found just anywhere. I hope that helps you to understand that being right is much less important than being happy and having loving friends.

Well the summer is making me want to do postponed projects so I better go.

As always thank you for your trust

Lee

Programming Report

Thanks to all for coming to May's monthly meeting, where we learned of the adventures and insights of our guest, Maliea Chiem. Hailing from the other Portland—in Maine, that is—Maliea brought her stories of apprenticeship and growth from her eight years in bonsai.

Beyond tales of long winters, Maliea shared her fundamentals to bonsai: asking "who, what, where, when, and why?" about trees; the seven aesthetic principles of wabi-sabi; and Bushido—a Japanese samurai code of honor and morals—as guidance for sustainable practices.

Up next in June we are reviving a fun, productive, and sociable meeting format that BSOP hasn't seen in a few years—the "Whack n' Chat." Additional details will come, but this will be an evening of rotating, peer-to-peer instruction with feedback, critique, and work on trees from your peers. The Board is excited to get members making introductions, exchanging ideas, and moving around the Milwaukie Center meeting space.

In summary: the monthly meetings are a showcase of the breadth and depth of talents and capabilities of our membership. Your assistance with setup and cleanup, patience and flexibility with the silent auction, and engagement with our guests of honor are what make the monthly meetings such a fulfilling event. Thank you for being part of such a welcoming, active, and highly functional scene!

Reid Parham, Program Facilitator

Mentorship

Mentorships 102A (Basic skills in place) and 102B (Basic skills in place) met on June 3 and 10 respectively. There was no specific lesson this month, rather everyone brought trees to work on. It is past repotting season, and not yet time for wiring, so mostly we pruned and trimmed. Our "Whack n' Chat" assistants were seasoned members Lee, Steve Wilcox, Dave Kidd, and Ron Cascisa. Steve Leaming was on hand selling tools.

All mentorships will be on summer recess until September. As of this writing, the September Mentorship dates on the calendar are:

102A on September 9

102B on September 30

And of course the big event in September is Rendezvous, the NW regional convention that we are hosting September 14-16

Have a great summer everyone!

Elisabeth (***Liz***) Hardy

Rendezvous Exhibit Submissions

The Rendezvous is just a few shorts months away, so I wanted to remind everyone before our summer break that the deadline for submissions to the Rendezvous exhibit is **August 1st**. Fill out a quick form with basic information, and we need a photo or two. It's that simple. We plan to make this exhibit the best in the Northwest since the Artisan's Cup, maybe better for some trees. We are taking trees big and small, but we have a limited number of slots - just 26.

Selections will be juried by our own Lee Cheatle, Dennis Vojtilla, and Scott Elser. Remember to get your applications in soon. Just a month and a half away. All submitters will be notified by August 15th. See the Rendezvous website for more details.

RENDEZVOUS VOLUNTEERS

It's hard to believe that our Rendezvous Bonsai Convention is just around the corner! The excitement is really building for what is a great opportunity to showcase our special NW brand of Bonsai. We're getting close to having all the volunteer spots filled, but need one last "push" to fill some remaining positions:

* Take a look at Saturday afternoon and evening positions. We're having a Social Hour and Banquet that still needs some "set up" and attendance help.

* Our Will Call Table needs to be manned from 7am-9:30pm on Saturday evening; this is a crucial position as many attendees will need to check their purchases, etc.

* There are various openings for Sunday Morning and afternoon, including Registration Desk , Bonsai Rodeo Set Up and General Help with the Rodeo. (The Rodeo is going to be so much FUN!)

We are so grateful for all of the generous volunteers that have stepped forward; it's a wonderful way show your appreciation for all that BSOP does for us. If you're a newer member, take the plunge and sign up for a position or two. You won't regret it!

Feel free to contact me via email or phone if you have questions or would like some additional help.

The Rendezvous takes place this fall, on September 14,15,16 . Our Volunteer Sign Up link is available on the BSOP web site, or by following this link;

https://www.signupgenius.com/go/20f0445ada62ba3fb6-2018

My email is tm4170399@aol.com and phone # is 503-954-2038.

THANKS FOR VOLUNTEERING! Patrice Morrow/ Volunteer Coordinator

Thank-you, ***Patrice***

Satsuki zalea "Koyo"
Ron Yasenchak

June Haiku

Satsuki best in May
Flowers bloom both pink and white
What more can you say

Ron Yasenchak

What in the Heck is Whack n' Chat?

I'll tell ya what it is…it's back.

Whack and Chat is a sort of meet and greet and socializing way to do bonsai at our meetings. Members bring trees to work on and their tools to do it. Other members generally assist the less experienced ones and many choose to just watch or wander about and socialize, bid and buy at the vendor and auction areas.

Whack and Chat was created years ago as a way to have activity at our meetings when we do not have a planned visiting artist and that will be the case in **JUNE**.

So bring a tree or two, get some advice on it and we can whack while we chat.

June 26 at the Milwaukie Center. See you then.

Lee

Rendezvous Volunteer Tee Shirt

The Rendezvous is only three months away! Wow! Volunteer tee shirts are now available to order. Purchase of these shirts is **strictly optional**. You do not need a tee shirt to work your volunteer shift. But they're kind of cool, don't you think?

Delivery of the shirts will be at the Rendezvous, when you check in for your shift(s). The shirts are Gildan Heavy Cotton, 90% cotton/10% polyester to reduce wrinkles. The shirts will have the Rendezvous logo in white print on forest green. The back is plain. Men's sizes only, from small to 3XL. Priced at $20 each.

Order at the June 26 BSOP meeting or on the BSOP website under Resources, and log into Member Services. Or contact Jan at janhettick@comcast.net or 503-504-7760. Deadline for ordering will be August 12, 2018.

The Resurrection

I have two wisteria that I have been growing for several years. Their varieties are different but they are usually tracking on the same schedule and routine throughout the year. I was a bit alarmed this spring when one blossomed and leafed out as usual, but the other one did nothing. I did see a few balls of green, where a few wimpy flower buds were slowly surfacing – that's the first thing that you see in spring on a wisteria. The flower buds usually swell to almost golf ball size before elongating. But these were more like a pencil eraser.

I told my wife that the tree was probably toast, and I was a bit sad as it came from my long time bonsai buddy, Alan Taft. But I left it on the bench and kept watering it, though cautiously. The branches were very dry looking, very dead. I had been having trouble with both wisteria the last two years, as with some other deciduous trees, not being as vigorous as I had hoped, so this was not a complete surprise. But later in the spring, I started to see more little green dots appear on the wood, which was quite unexpected. Then I started seeing more specks and they began elongating. You see them in the first photo.

Notice the dead buds at the tip of the branch. Those were flower buds last fall. This is happening all over the tree, and once it began, the trees eschewed the few flower buds for foliar growth. It's growing gangbusters now, maybe growing twice as fast and more vigorously than it ever has. If you look at the second photo, you will see it is crowding everything out on the bench. The other wisteria is to the left, with simple, restrained growth (low fertilizer). The tree in question though, is busting out all over. It usually puts out but a few tendrils a year, but you can clearly see them crawling all over everything at the moment, reaching over to other trees on adjacent benches. You can kind of tell that it's a semi-cascade by looking where the end of the bench stops, and the tree just keeps on going.

Now, I have no real explanation for what has happened with this tree, but similar things happen once in awhile. Something known or unknown impacts the tree to where it is near death, or appears to be. Then it summons all of its power from within and bursts forth with new growth. We have to be careful, as it is expending all it's reserves to survive. When it happens, the tree is usually budding back on older wood, many times in a place where we were unable to make it bud previously. It can be fortuitous. We sort of do this in a controlled, predictable fashion when we decandle a black pine, or defoliate a maple tree, and to lesser degree with regular pruning. Rarely though, do we impact a tree beyond where we have total confidence of recovery. I would not induce this on purpose, but it can actually turn out making the tree better in the long run – if it doesn't die in the process.

All of this is a long introduction into summer care. What could I possibly be talking about? If you have grown bonsai for even one season, you have probably had the experience of a tree beginning to wilt, and then watering it and watching it perk back up. That's usually in the spring as a tree is elongating and hasn't hardened off yet – that is, built the outer protective

layer called a cuticle. But then there is that instance during the summer where inevitably there is going to be a tree that gets scorched in the hot sun and acquires a bit of color, like when we get some sunburn ourselves. We just deal with it but it's not life threatening. Then there is that time when things start to get crispy. That's bad news. Sometimes it's just a portion of the tree, or in other cases, the whole shebang. So my admonition is to be patient. If you see the sudden collapse of a tree, don't panic. Soak it in a tub to quickly get it hydrated. Then stop watering until it starts to get dry. A tree that was healthy before the incident has plenty of reserves to rebuild with. You will likely see some new growth peeking out in a few weeks.

However, if the tree is slowly going downhill over several weeks and is starting to dry up, the cause is something other than a single let down in watering or over exposure. You will have to discover it quickly and the tree may even be gone at that point. If the branches are starting to desiccate, that's not a good sign. Moisture is withdrawing and slowly dying back. It is very likely a root issue. It could be a systemic fungus like Phytophthora, which can be hard to deal with. Specific chemicals like Allude, Aliette, and Subdue Maxx, Agri-Fos can help.

But that is a last resort. Healthy trees and good watering practices are the key here. If it is just looking scorched and yellow/rust colored mottling on the outer portions, it may a fungus like pythium, anthracnose and others. I have long desired to work on a more comprehensive guide, but alas, the time. Check back in the archives of this column for additional info. Just don't give up hope too quickly.

Other issues can be self-induced. This is the time of year to evaluate the spring growth and prune where necessary. Saving length where you need it, cutting back where you don't and slowing the tree down. Your trees may be in different stages of development, so the pruning will change accordingly.

The thing to remember here is that if you open up the canopy to the interior, those leaves don't have the same cuticle and solar protection that the outer leaves had. It also opens up the trunk to sun scald, a problem I have encountered myself. So if you thin the tree extensively, think about protecting it in light shade until new leaves grow or existing leaves become acclimated to the new found sunlight. While you are doing the pruning, it's also a great time to wire your deciduous trees. Just be sure to watch them for cutting in. Enjoy the summer of bonsai.

Scott Elser

Juniperus chinensis/ Chinese Juniper bonsai by Luis Vallejo. Bonsai pot: Tokoname

From bonsai4me.com

FERTIGATION: Applying fertilizer via Irrigation

An injector takes a fertilizer solution out of a concentrate tank and injects it into irrigation water. To determine the amount of fertilizer being applied, one must know (1) the concentration of fertilizer in the tank (lb of fertilizer per gallon of concentrate) and (2) the rate or ratio at which the concentrate is being injected into the irrigation water (gallon of concentrate per gallon of irrigation water).

For example, if 50 lbs of a 15-10-20 soluble fertilizer is dissolved in water making 30 gallons of concentrate, the concentration of fertilizer is 50 lb/30 gallons in the concentrate. And, the concentration of N in the concentrate is 7.5 lb/30 gallons. Likewise the concentration of phosphate, P205, is 5 lb/30 gal, and that of potassium oxide or potash, K20, is 10 lb/30 gal. The concentration of P is 2.2 lb/30 gal (43.7% of P205), and that of K is 8.3 lb/30 gal (83.0% of K20). [The values 43.7% and 83.0% are explained below under Fertilizer Calculations.]

Further, if the rate that this concentrate is being injected into the irrigation water is 1 gallon of concentrate for each 80 gallons of irrigation water, the injection ratio is 1 to 80, or 1/80. Thus the concentration of the fertilizer in the irrigation water is (50 lb/30 gal) X (1/80) = 50 lb/2400 gal = 1 lb/48 gal. And, the concentration of N in the irrigation water is (7.5 lb/30 gal) X (1/80) = 7.5 lb/2400 gal = 1 lb/320 gal. Likewise the concentration of phosphate in the irrigation water is 5 lb/30 gal) X (1/80) = 5 lb/2400 gal = 1 lb/480 gal, and that of potash is 10 lb/2400 gal = 1 lb/240 gal. The concentration of P in the irrigation water is 2.2 lb/2400 gal = 1 lb/1100 gal, and that of K is 8.3 lb/2400 gal = 1 lb/289 gal.

Injection ratios vary even for similar injectors due to variations in manufacturing, wear, and operating conditions. Thus, injectors should be tested (at least once per year) to determine their true injection ratio. Additionally, non-proportional type injectors like canister injectors (e.g., EZ -Flo and Rainbow) and siphon injectors (e.g., Hozon, Syphonject, and Mazzei) should be tested using the same operating conditions that they will experience in use.

US Liquid Equivalents

1 lb = 16 oz

1 oz = 2 tbsp

1 cup = 8 oz = 16 tbsp = ½ lb

1 pint = 2 cups = 1 lb

1 quart = 2 pints = 2 lb

1 gal = 4 quarts = 8 pints = 128 oz = 4 lb

1 gal = 3.785411784 liter

1 liter = 0.26 gal = 1.06 qt = 2.11 pt = 33.81 oz = 2.11 lb

Fertilizer Calculations

Plant fertilizer nutrients/elements are present in various compounds (e.g., urea, ammonium nitrate, phosphoric acid, calcium phosphate, potassium chloride). The composition as a percentage by weight of each of the ‘big 3’ elements present in a fertilizer must be stated on the bag/container. This is referred to as the fertilizer guarantee, which expresses each of elemental N, phosphate, and potash as a percent by weight of the fertilizer.

For example, suppose a fertilizer (guarantee) has the numbers 10-5-8. This fertilizer contains 10% (1st number) elemental nitrogen, 5% (2nd number) available phosphate (P2O5) and 8% (3rd number) water soluble potash (K2O). The remainder of the fertilizer material is comprised of other elements and filler. The filler helps to assure accurate/uniform application/ spreading of the small amounts of the nutrients to relatively large crop areas. The filler often includes ground limestone, to offset the acid potential of the fertilizer.

In order to make sure that these values are understood, let's calculate the amount of elemental N, P and K in a 100 pound bag of 10-5-8 fertilizer.

Begin with N, the easier calculation. The 10-5-8 fertilizer is 10% N by weight. Convert 10% to a decimal (0.1) and compute the weight of N in the 100 lb bag of 10-5-8 fertilizer: 100 lb X 0.1 = 10 lb N

Likewise there is 5 lb of N in a 50 lb bag of 10-5-8, and 20 lb of N in a 50 lb bag of 40-5-8.

Elemental P is more difficult, requiring another step. The guarantee (5%) is expressed as percent by weight of phosphate (P2O5). We need to find out how much P is in P2O5.

Atomic weights are: P = 31 and O = 16, P2O5 has two atoms of P, so 2 X 31 = 62

P2O5 has five atoms of O, so 5 X 16 = 80, Atomic weight for P2O5 is [62 + 80] = 142

Therefore, the proportion of P in P2O5 is [62 / 142] = 0.437 = 43.7%

Thus the 100 lb bag of 10-5-8 contains 5 lb of P2O5 of which P is 5 lb X 0.437 = 2.18 lb.

Elemental K requires a step similar to P. The guarantee (8%) is expressed as percent by weight of potash (K2O). We need to find out how much K is in K2O.

Atomic weights are: K = 39 and O = 16, K2O has two atoms of K, so 2 X 39 = 78

K2O has one atom of O, so 1 X 16 = 16, Atomic weight for K2O is [78 + 16] = 94

Therefore, the proportion of K in K2O is [78 / 94] = 0.830 = 83.0%

Thus the 100 lb bag of 10-5-8 contains 8 lb of K2O of which K is 8 lb X 0.830 = 6.64 lb.

Fertilizer Application Rates for Individual Plants/Trees

How many ounces of a 33-15-15 fertilizer should be applied to a tree/area to supply 2 oz of elemental N? Algebraically this can be written as:

0.33 X F = 2 oz, where F is the amount of fertilizer needed. Thus, F = 2 oz / 0.33 = 6.06 oz, so, about 6 oz or 12 tablespoons of 33-15-15 fertilizer provides 2 oz N.

Now, if 6.06 oz of 33-15-15 fertilizer is added to a tree, how much elemental P and K are also added? First, 6.06 oz of 33-15-15 fertilizer contains 15%P2O5 or 0.15 X 6.06 oz = 0.909 oz, and P2O5 contains 43.7% P. Thus 0.437 X 0.909 oz = 0.397 oz of elemental P is applied when 2 oz of elemental N is applied. Likewise, the 6.06 oz of 33-15-15 fertilizer contains 15% K2O or 0.15 X 6.06 oz = 0.909 oz, and K2O contains 83.0% K. Thus 0.830 X 0.909 oz = 0.754 oz of elemental K is applied when 2 oz of elemental N is applied.

And, how much of 46-0-0 fertilizer would need to be applied to a plant/area to provide 5 oz of N? (Note that the amount of P and K applied would be none.)

Answer: F = 5 oz / 0.46 = 10.87 oz or 22 tablespoons = 0.7 lb = 0.7 pint = 1.4 cups = 1/3 L

FOLIAR FEEDING

Another Successful Way of Feeding Plants

Foliar feeding is a reliable method of feeding plants when soil feeding is inefficient. In this article, the author highlights when foliar feeding should be considered, how nutrients actually penetrate plant tissue, and some technical limitations to this method of plant feeding.

By Eyal Ronen

Plant nutritionist have traditionally considered the obvious way to feed plants is through the soil, where plant roots are meant to uptake water and nutrients, but in recent years foliar feeding has been developed to supply plants with their nutritional needs.

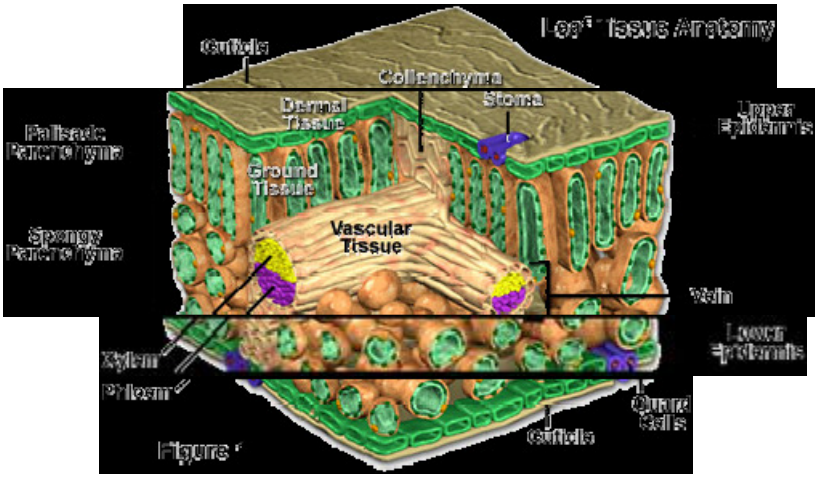
The development of pressurised irrigation equipment such as drip irrigation has promoted the need for water-soluble fertilisers, as clean and purified as possible in order to diminish the possibility of emitters clogging. It is not really clear when foliar feeding started, but after the development of water-soluble and liquid fertilisers farmers have begun to use these fertilisers with sprayers, the same as it is used with applications of pesticides. At the beginning, this technique of spraying nutrients was used for correcting deficiencies of minor elements. However, fast curing has shown that plants can absorb some elements through their tissue. As a result, foliar feeding has gone through further development.

These days foliar feeding is considered among the major techniques used for plant nutrition, supplementing the ground application. In this article I will review the whole concept of foliar application - when it should be considered, how nutrients actually penetrate plant tissue, and some technical limitations of this method of plant feeding.

The case for foliar feeding

Foliar feeding is a 'by-pass' approach, overtaking conventional ground fertiliser applications whenever it does not perform well enough. Foliar application overcomes soil fertilisation limitations like leaching, insoluble fertiliser precipitation, antagonism between certain nutrients, heterogenic soils unsuitable for low dosages, and fixation/absorption reactions like in the case of phosphorus and potassium. Foliar feeding can also be used to overcome root problems when they are suffering from limited activity due to low/high temperatures ($<10^0$, $>40^0$C), lack of oxygen in flooded fields, nematode attack damaging the vascular system, and a decrease in root activity during the reproductive stages where more of the photosynthetic creation is transferred for reproduction with less for root respiration (Trobisch and Schilling, 1970). Foliar feeding has proved to be the fastest way of curing nutrient deficiencies and boosting plant performances at specific physiological stages. With plants competing with weeds, foliar spraying focuses the nutrient application on the target plants. Fertilisers have also been found to be chemically compatible with pesticides, thus saving labour costs. Certain types of fertilisers can even slow down the hydrolysis rate of pesticides/growth hormones (GA3) owing to lowered pH of the solution and this may improve performance or cut costs. Fertilisers applied through the plant leaf canopy have to face several structural barriers, unlike pesticides which are mainly oil-based and don't face difficulties to penetrate the leaf tissue. Nutrients, which are salt based (cations/anions)

may face some problems penetrating the inner plant tissue cells. General leaf structure is based on several cellular and non-cellular layers. The different layers support protection against desiccation, UV radiation and various kinds of physical, chemical and (micro) biological agents. Several layers can be identified in *Figure 1*.



The different layers are characterised by electrical negative charge, which influences the way and rate of penetration of different ions. Some layers are hydrophobic and therefore repulse water-based spray (see *Figure 2*).

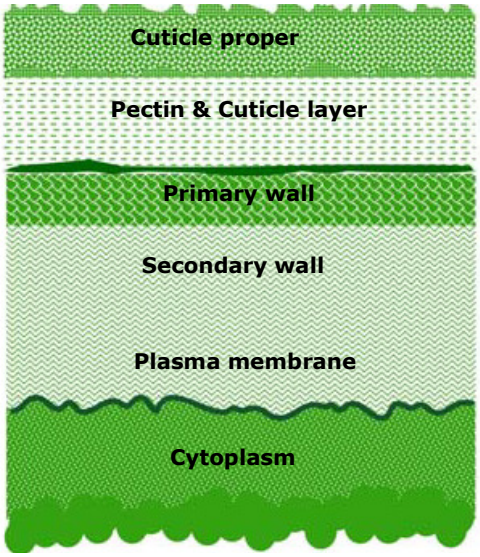


Figure 2

The first layer from outside is a wax layer, which is extremely hydrophobic. The epidermal cells synthesize the wax and it crystallises in an intricate pattern of rods, tubes or plates. The wax layer can change during the plant growth cycle.

The second layer, referred to as the 'cuticle proper', is a non-cellular protective layer surrounded by wax to the upper side and the bottom one as well and made mainly from 'cutin' (macromolecule polymer consisting of long-chain fatty acids creating a semi-hydrophilic character).

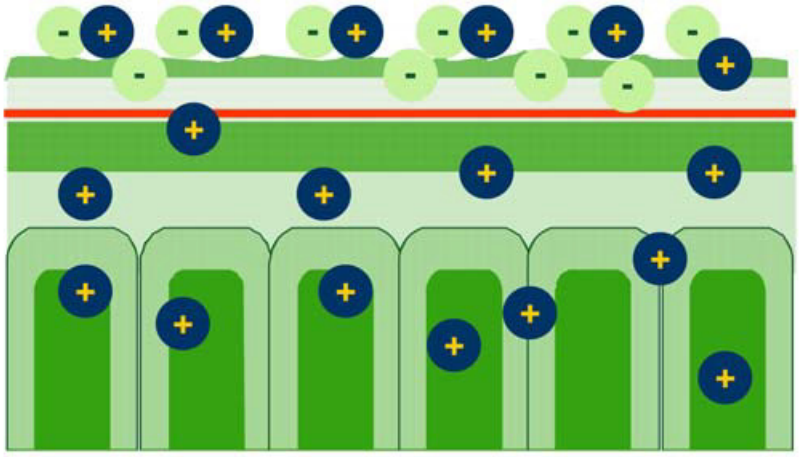
The following layer is 'pectin', negatively charged and made of Polysaccharides that form sugar-acid based gel-like tissue (cellulose and pectic materials).

Next is the outer side of the cells starting with the primary wall. The cuticle has negative charge density as well due to the pectin and cutin (Franke, 1967; Marschner, 1986).

How do nutrients penetrate plant tissue?

When we refer to penetration of nutrients we can define two movements – into the tissue from outside, which is referred to as absorption, and movement from the point of penetration to other parts of the plant that is referred to as translocation.

Penetration/absorption can be done through several organ elements that exist in the tissue. Main penetration is done directly through the cuticle. The penetration is done passively. First to penetrate are the cations as they are attracted to the negative charge of the tissue, and they move passively in accordance to the gradient – high concentration outside and low one inside. After a certain period the cations that have moved inside change the electrical balance in the tissue causing it to be less negative and more positive. From this point on the anions start to penetrate the tissue in the same manner as described for the cations (Figure 3). Since the penetration is a passive one, the rate of diffusion across the membrane is proportional to the concentration gradient, therefore achieving a high concentration without scorching the tissue - may dramatically improve the penetration.



Penetration also occurs through the stomata, which are aperture controlled for gas exchange and transpiration. It is known that these apertures differ between different plant species, their distribution, occurrence, size and shape. In broadleaf crops and trees, most of the stomata are on the lower leaf surface, while grass species have the same number on both surfaces. Size may differ, for example, sorghum stomata are four times larger than bean stomata. High penetration is estimated to be due to high cuticle pore density in cell walls between guard cells and subsidiary cells (Maier-Maercker, 1979). In addition, the pores near the stomata guard cells

seem to have different permeability characteristics (Schonherr and Bukovac, 1978). An opposite opinion exists, claiming that penetration through open stomata does not play a major role since a cuticle layer also covers the surface of the guard cells in stomata cavities and because ion uptake rates are usually higher at night when the stomata are relatively closed.

Another path that nutrients can penetrate is through hair-like organs known as 'trichomes', which are epidermal outgrowths of various kinds. The importance of this pathway depends on the trichomes rate and position, dependent on leaf age and its origin (Hull *et al*., 1975; Haynes and Goh, 1977).

After the ions have penetrated, transportation to different parts of the plant starts and this is referred to as translocation. Translocation is done through two mechanisms: cell-to-cell transport is referred to as 'Apoplast movement', and transport through the vascular channels is referred to as 'Symplast movement'.

The Apoplast movement describes the ion movement from one cell to another. This is done by three mechanisms (*Figure 4*):

- Passive transport involves diffusion according to the gradient and mass flow through the water/fluid movement between cells.
- Absorption by cytoplasm membrane surface via plasmodesmata, which are microscopic channels connecting one cell wall to another, enabling transport and communication between them.
- Active transport (ATP) against the gradient, enabled due to energy investment of ATP molecules.

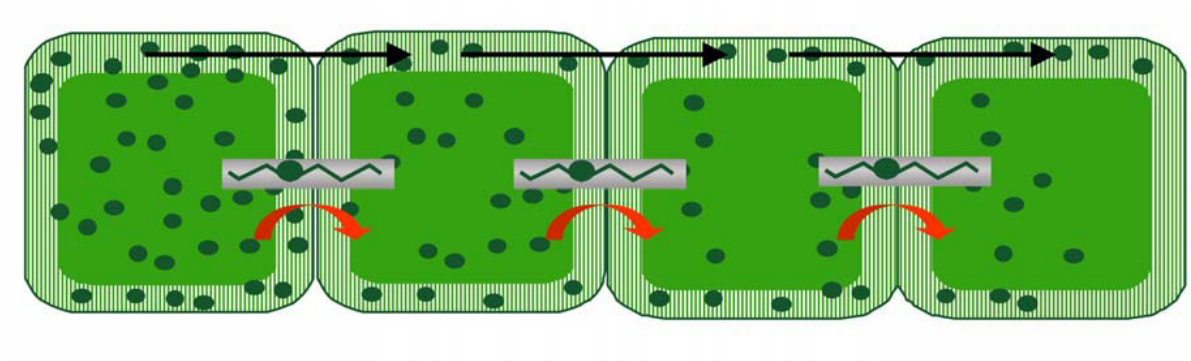


Figure 4

The Symplast movement describes the ion discharge into the vascular system. This is done through two systems (Figure 5):

- Phloem – translocation is energy dependent and more suitable to the divalent cations (C^{2+}); anions are very limited since the cell wall is negatively charged (Van Steveninck and Chenoweth, 1972). Phloem transport is important for distribution from mature leaves to growing regions in the roots and shoots. Phloem movement regularly follows the 'sink-source' relationship, from locations where carbohydrates are created (source) to places where they are consumed (sink).

• Xylem – translocation is flux regulated and driven by water potential differences between soil, leaf and atmosphere.

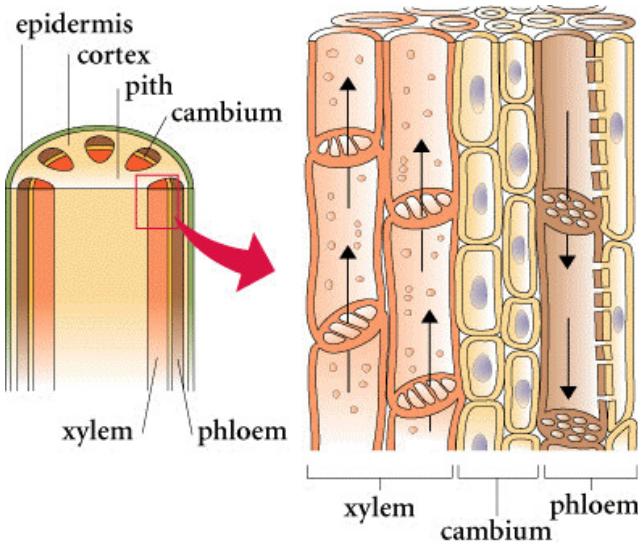


Figure 5

Translocation differs between different ions, thus, nutrients are divided into three groups (Bukovac and Wittwer, 1957) – mobile, partially mobile and not mobile.

Table 1.

Mobility	Plant nutrients				
Mobile	N	P	K	S	Cl
Partially mobile	Zn	Cu	Mn	Fe	Mo
Not mobile	Ca	Mg			

(Bukovac and Wittwer, 1957; Kunnan, 1980)

Although foliar feeding is described as a very powerful application method that may overcome a lot of problems, which may be encountered through ground application, it is not a perfect way and has its own limitations:

- Low penetration rates, particularly in leaves with thick wax/cuticles.
- Run-off from hydrophobic surfaces.
- Washing off by rain.
- Rapid drying of spray solutions disabling the penetration of solutes.
- Limited rates of translocation of certain mineral nutrients.
- Limited amounts of macronutrients, which can be supplied by one foliar spray.

- Possible leaf damage (necrosis and burning). Forcing extra cost and time for repeated applications.
- Spray drift on non-targeted sites.
- Limited available effective leaf area (seedlings or damaged plants).

The effectiveness of foliar feeding may be subjected to several factors. These factors can be divided into four major groups – spray solution, environmental conditions, leaf characteristics and plant state.

Several factors play a role for spray solution:

- Solution pH – pH mainly affect the solubility level of several elements such as phosphorus, which improves its solubility as pH decreases. pH may affect the ionic form of the elements and this may affect the penetration rate as well. Regardless of the penetration aspects, low pH may reduce the alkaline hydrolysis rate of different pesticides (*Table 2*).

pH has its effects on the tissue as well. Plant cuticles are polyelectrolytes with isoelectric points of around 3.0. At pH values below the isoelectric point, cuticular membranes carry a net positive charge and are selective to anions and above the isoelectric point; they carry a net negative charge and are selective to cations (Schonherr and Huber, 1977). These findings support the hypothesis of 'hydrophilic channel', which is used by some surfactants.

Table 2

Trade name	Common name	Solution pH	50% breakdown
Benlate	Benomyl	7.0	1 hour
		5.6	>30 hours
Guthion	Azinphos-methyl	9.0	12 hours
		7.0	10 days
		5.0	17 days
Captan	Captan	10.0	2 minutes
		4.0	4 hours
Furadan	Carbofuran	9.0	78 hours
		7.0	40 days
		6.0	200 days

- Ionic stage/molecule type – materials with high molecular weight penetrate much slower than those with low molecular weight (Haile, 1965; Kannan, 1969)
- Solution water tension – decrease in the interfacial surface tension of a water droplet increases the exposure sites for uptake into the leaf (Leece, 1976). Lower water tension improves penetration through the stomata as well (Greene and Bukovac, 1974). Usage of surfactants may help in reducing the water tension as they carry a non-polar lipophilic tail (oil lover),

which aligns itself with the cuticle and the hydrophilic head (water lover) with the water droplet causing it to spread its contact angle and reach higher wetting surface with the leaf.

- Spray droplet size – different drop size may affect the interaction with the targeted surface and the possible drift of the solution from the targeted plant. Bigger drops may resist drift but decrease penetration through the plant canopy.

The environment can influence leaf absorption, cuticle development or physiological reactions related to active absorption mechanism (Flore and Bukovac, 1982), among major factors:

- Humidity – it has direct influence on the rate of dehydration of the spray drop. In high humidity, the solution will be active for a longer period enabling solutes to penetrate before it dries completely. To a certain extent, dehydration may accelerate the penetration rate as it increases the concentration of the solutes, thus the gradient increases until it is dry when penetration is delayed and the solutes crystallise. Humidity influences the development and physiological status. In low humidity conditions, stomata are closed and plants may develop a thicker cuticle, yet in high humidity conditions the stomata are open and plants may develop a thinner cuticle.
- Temperature – when solution dehydration is not a limiting factor, temperature rise increases absorption (Jyung *et al.*, 1964). Temperature may have negative relations with humidity - as temperature decreases, humidity may rise (Cook and Boynton). Another idea claims that increased temperature lowers the cuticle viscosity thereby increasing the penetration ratio.
- Light – in high light levels the cuticle and the wax layers are thick compared to low light levels (Macey, 1970; Hallam, 1970; Reed and Tuley, 1982), yet the light effect can be related to the stomata opening and the temperature resulting from the radiation.

Effects of the plant characteristics, mainly leaf structure:

- Leaf age – as the leaf ages it tends to thicken with more wax and broader cuticle tissue. This increased barrier reduces penetration rate.
- Leaf surface – some plants have high density hairs (trichomes), which may cause the spray drops not to contact with the actual leaf surface – the water drops ‘stand’ on the hairs. Leaf surface texture may differ between plants. Smoother surfaces allow the spray to slide for a lower wetting rate, while rough surfaces hold the spray drop and have a greater wetting rate.
- Leaf disposition –leaf angle towards the ground influences spray solution retention on the leaf surface (De Rutter *et al.*, 1990).
- Leaf shape – different leaf shapes may determine the effective surface in contact with the spray drops.
- Plant species – Plants can be divided into those that grow in wet habitats (hydromorphic) and dry habitats (xeromorphic) and differ in cuticle thickness, stomata position (adaxial=upper side/abaxial=lower side), and shape.

The physiological state of plants may have an effect, where plants with lower metabolic activity have been shown to have a lower ‘sink’ activity, resulting in lower translocation.

* * * * *

It is clear that reaching a successful foliar feeding application is dependent on many factors; some are within the control of the grower and may be wisely used and some are not. In general spraying during early morning or late afternoon is recommended when radiation and tempera-

ture are low (18-19^{0}C; ideal 21^{0}C), wind speed is low (less than 8kph), and humidity is high (greater than 70% relative humidity). Better timing will be late afternoon as it enables more effective absorption hours before the solution becomes dry and inactive. Even when following the rules described in this article, some problems may still exist, which should be handled in the following way:

- Drift – if spray drifts away from the target, droplet size should be increased.
- Poor coverage – if coverage is poor, larger spray volumes should be used with higher spray pressure.
- Poor wetting or cuticular penetration – addition of low surface tension surfactant may help.
- Poor retention – spray droplet size should be decreased and solution viscosity should be increased by addition of polymeric stickers.
- Rapid drying – eventually inhibits further penetration as the solution dries. The addition of oil and emulsifier may preserve the needed moisture.
- Non-effective concentration – importance is high as the penetration is done passively, dependent on the gradient. Application should follow the highest concentration possible without burning/scorching the leaves. Pre-test to determine phytotoxicity and threshold of damage. If lower concentration is in use, compensation should come with high number of applications.

Phototoxicity mainly appears as leaf burning. The toxicity results from the osmotic effect of a highly concentrated salt solution when water evaporates from the spray droplets. In addition, the local nutrient imbalance in the leaf is another factor that may cause the toxicity. For example, urea damage can be prevented by adding sucrose, despite the additional increase in the osmotic potential of the foliar spray (Barel and Black, 1979).

It has to be stated that if phytotoxicity is not immediately observed, it can appear in later stages of the crop if spray applications are too rapid and the interval is too short, resulting in tissue accumulation of toxic elements. Plants may show phytotoxicity symptoms even when solution concentration is in the right level when they are physiologically stressed, either because of thirst, attack by insects, or disease occurrence.

Conclusion

In this article I have reviewed the concept of feeding plants through foliar spraying. It is obvious that foliar feeding is a good, reliable method of feeding plants when ground application is not efficient enough. However, it is important to understand that this method cannot substitute the supply of nutrients through the root system when the uptake of all plant nutrients through leaves involves considerable labour with a high risk of phytotoxicity. The foliar application method has its limitations and in some cases it may be considered a laborious approach. Nonetheless, over the years foliar feeding has captured a place of honour in different plant feeding schemes. Using highly soluble fertilisers and pure nutrients is essential to achieve the best performance from this approach. As mentioned earlier, fertilisers and pesticides are compatible and can be mixed in the same sprayer to save labour costs, and this advantage should be used whenever pesticides are sprayed.

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