Foliar fertilization

REVIEW OF LITERATURE

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cultivating innovation

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INTRODUCTION 1

Foliar fertilization is an important tool for farmers and its goal is not to replace basic granular fertilization; it is rather intended to be complementary to it. [1,2,3,4*] Many research results show that foliar fertilization has a significantly positive effect on the growth, development and yield of crops. [5,6,7,8,9]

Foliar fertilization makes it possible to obtain quick responses from the crop at advantageous costs, especially when adverse conditions are present. Foliar fertilization is effective and it allows smaller amounts of nutrients to be added at precise moments during plant growth. This technique is used in certain well-defined situations and it aims for very specific goals:

- correct *or prevent* the appearance of mineral deficiencies when soil conditions limit the availability of nutrients (soils that are alkaline, acidic, deficient in any mineral element, unbalanced, etc.) [10];
- correct *or prevent* the appearance of mineral deficiencies when unusual climatic situations (poorly drained and flooded soils, frost, hail, cold, drought) prevent an adequate mineral supply that can be spread out over short to longer periods [11];
- amplify certain physiological characteristics (flower and fruit size, pollen quality of the flower, weight of the fruit, skin colouring of the fruit, firmness of the fruit, quality of the grain, percentage of proteins, etc.) [12];
- trigger the occurrence of a delayed phenological stage (flowering, veraison, maturation, etc.) or conversely *delay* a too early entry into the maturation process (prevent the potato foliage from "falling out" too quickly, finishing of the onion bulb, etc.) [13];

* These numbers refer to the works listed in the bibliography.

- support the plant in its growth by regular spraying of one or certain fertilizers specifically chosen according to the current phenological stage (nitrogen for foliage production and protein content; boron and phosphorus for flowering; calcium and potassium for fructification, etc.) and the mineral requirement specific to the cultivated species (boron and molybdenum for cruciferous plants; manganese for legumes; magnesium for solanaceae (nightshades) and cucurbits; boron and calcium for rosaceae, etc.).

To maximize the return on investment from these applications, **it is essential to know the factors governing the effectiveness of foliar fertilization**.[14,15] Several factors can influence the effectiveness of a foliar application. They can be grouped into the following three main categories.

The characteristics of the plant on which the foliar application is carried out

The shape of the leaf, the composition of the leaf cuticle, the presence of hairs, the growth stage of the plant, the mobility of the nutrient in the plant, and the presence of abiotic stresses can influence the absorption of nutrients and biostimulants.[10]

Environmental conditions at the time of application

Relative humidity, water supply, light and temperature are all factors that influence the foliar absorption of molecules.[16]

The physicochemical properties of fertilizers/biostimulants

Solubility, size of the molecule, electric charge, pH, surface tension, retention, and point of deliquescence are all factors that influence the absorption capacity of the molecule by the leaf.[17]

These factors interact with each other and will influence the absorption and mobility of nutrients in plants and, ultimately, the crop's response to applications of foliar fertilizers and biostimulants.

THE CHARACTERISTICS OF THE PLANT

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The epidermis of the leaves is protected and covered by a cuticle that protects plants against abiotic and biotic stresses, and that is **essential to minimize water loss by evapotranspiration**. This cuticle is made up of lipids, a cutin and wax matrix, and carbohydrates. The exact composition of the cutin varies from one species to the next and it will be determined by the age of the plant and climatic conditions. **Cutin is hydrophobic (which repels water) and negatively charged**. However, the leaf's epidermis is covered with stomata, trichomes, and hydrophilic (water-attracting) pores [10] that allow nutrients to penetrate the foliage.

Nutrients and biostimulants are absorbed through the epidermis of the leaf by diffusion; the nutrients on the foliage (high concentration areas) pass through the epidermis of the leaf to go towards the interior of the leaf (low concentration areas).

a. Size of the molecule

Nutrients and biostimulants can penetrate the leaf through the hydrophilic pores and stomata. The number of pores on the foliar surface is estimated at more than 10,000,000,000 /cm^2. The number of stomata is estimated at approximately 35,000/cm^2 on the foliar surface. These openings allow **small-size** molecules (less than 1 nanometre, or 1/10,000,000 cm) to penetrate the leaf. [18] Trichomes are excrescences on the cells of the epidermis of plant leaves. They protect plants against abiotic and biotic stresses and, because they are less hydrophobic than the cuticle, they absorb water and nutrients in solution more easily.[19]

b. Electric charge of the molecule

The cuticle being negatively charged, the electric charge of the nutrient can have an influence on the speed at which these nutrients and biostimulants can possibly penetrate the leaf. **Positively charged molecules are retained on the surface of the leaf and accumulate**, limiting the absorption of nutrients and thus can potentially cause burns on the leaves. Molecules not electrically charged (neutral charge) can be absorbed more easily than positively charged molecules.[20] That is why chelates are used in formulations to neutralize molecules (see section 4).

c. Growth stage of the plant

The age of leaves has important effects on the composition and quantity of wax produced. Because an older leaf has reached its optimal level of maturity and has thus completely developed its epidermis layers, it is normal to conclude that an older leaf has a power of absorption of mineral elements that is less than that of a younger leaf.[21]

However, reasearch done by Mengel in 2002 demonstrated that older leaves may have a greater power of absorption of mineral elements than younger leaves. According to this experiment, older leaves have a larger foliar surface area, which optimizes the absorption surface area of minerals. In addition, more mature leaves can be partially damaged and thus contain interstices allowing soluble elements to pass through by diffusion.[3]

On the other hand, for leaves of the same physiological age, depending on the time of the season, there is a different response regarding the absorption of foliar fertilizers. It is generally accepted that the cuticular penetration rate of nutrients is faster in young leaves[22], while the translocation of these elements is more efficient in older leaves.[23] It is important to note that mobile nutrients could be translocated towards younger tissues only when older leaves have finished developing.

d. Nutritional status of the plant

The proportion of nutrients passing through the epidermis of the leaf also depends on the nutritional status of the plant. Thus, Marschner demonstrated in 1995 that a plant deficient in a nutrient absorbed more of this element than a non-deficient control plant[24], as demonstrated by the example shown in table 1.

Table 1.
Foliar absorption and translocation of phosphorus ^{32}P by barley plants (µm ^{32}P/g of dry matter)

	Plant not deficient in ^{32}P	Plant deficient in ^{32}P
Foliar absorption	5.29 µm ^{32}P ± 0.54	9.92 µm ^{32}P ± 2.17
Translocation in the plant	2.00 µm ^{32}P ± 0.25	5.96 µm ^{32}P ± 1.08
Translocation in the roots	0.63 µm ^{32}P ± 0.04	4.38 µm ^{32}P ± 0.42

ENVIRONMENTAL CONDITIONS 3

Any climatic factor acting on the **permeability or thickness of the cuticle, the size and number of leaves** will have an influence on the absorption of nutrients by the foliage.

a. Luminosity

Light increases the thickness of the cuticle and increases stomata activity. It has been demonstrated that the thickness of the cutin and the presence of wax on the surface of the leaf's epidermis are higher under conditions of high intensities of luminosity in eucalyptus[25], cabbage[26] and Brussels sprout.[27]

The same goes for the influence of light on the degree of stomata opening.[28] Stomata play an important role in the foliar penetration of nutrients; the penetration rate of mineral elements into the stomata is higher in the presence rather than in the absence of light.[29]

The pre-illumination of the leaves of an ornamental plant called "harping Johnny" *(Sedum telephium)*, has increased the penetration rate by a factor of 1.5 to 36 compared with that of leaves kept in the dark.[29]

b. Temperature

Higher temperatures promote a greater growth in foliar area and wax thickness. An experiment conducted by Alexander in 1987 has demonstrated that warm temperatures expend the foliar area of plum trees and increase wax production on the leaves' surface. However, foliar area expansion due to high temperatures is faster than the production of wax per unit area. **We therefore conclude that foliar expansion resulting from high temperatures has a positive effect on foliar absorption**.[34]

The effect of temperature on foliar absorption and translocation of mineral elements is another influencing factor. For example, foliar absorption and translocation of potassium within the plant largely depend on temperature. Translocation occurs very slowly at 4 °C, and increases rapidly up to 20 °C. On the other hand, a decrease in the speed of translocation is observed between 20 and 30 °C.[23]

c. Point of deliquescence (POD)

The point of deliquescence is defined by the humidity level at which a solid dissolves by absorbing humidity from the air. When the humidity above the cuticle exceeds the POD of the nutrient, absorption can take place, while humidity below the POD will result in the formation of solid salt residues and the stoppage of cuticular absorption.[31] Therefore, **nutrients used for foliar fertilization should have the lowest possible POD value** (see table 2).

Table 2. Point of deliquescence values for different raw materials (20 °C)[32,33]

Salts	Point of deliquescence
Potassium hydroxide (KOH)	18%
Potassium acetate	22%
Magnesium chloride	34%
Potassium carbonate	43%
Calcium nitrate	53%
Magnesium nitrate	60%
Magnesium acetate	72%
Sodium nitrate	80%
Sulphate of ammonia	82%
Potassium chloride	89%
Calcium acetate	92%
Potassium nitrate	96%
Potassium sulphate	99%

The humidity level also influences foliar absorption of nutrients by increasing the permeability of the cuticle and thus the absorption of the foliar nutrient.[22] Heavy dew is equivalent to light rain and causes leaching. However, a lighter dew is an asset because it increases the permeability of the cuticle.

Foliar fertilizers **should be applied in the morning, in the evening or on cloudy days**, when there is little or no wind and temperatures are not too high. The water applied should dry as slowly as possible so that the nutrients have time to pass through the cuticle. **During the day, in sunny or windy weather, drying out conditions and the percentage of humidity above the cuticle drops quickly**; nutrients can then precipitate on the foliage and no longer be available for absorption. In drying out conditions, the stomata are usually closed to allow the leaf to protect itself against dehydration.[30] Absorption of nutrients by the stomata is then impossible. The spraying of a foliar fertilizer should therefore be carried out in conditions where the air humidity is greater than 60%, the maximum temperature is 25 °C and the wind speed does not exceed 10 km/h.[34,18]

THE PHYSICOCHEMICAL PROPERTIES OF FERTILIZERS/BIOSTIMULANTS 4

a. Solubility of nutrients

Plants absorb nutrients or biostimulants through the roots or the leaves if they are **soluble in water**.[35] When applied to the soil, semi-soluble or insoluble fertilizers will eventually be transformed by biological or chemical actions to be made available for plant roots in the soil solution. When applied on the foliage, semi-soluble or water-insoluble fertilizers **are not quickly absorbed** through the leaves and accumulate on their surface, potentially causing burns.

b. Size of molecules

Many studies have demonstrated that **the absorption rate of nutrients decreases significantly with the increase of their molecular weight**. Inorganic salts are to be preferred because they generally have a lower molecular weight than nutrients in organic form.[15,36] The pores through which nutrients are absorbed generally have a diameter of less than 1 nanometre (nm) (or 1/10,000,000 centimetre). Nutrients usually are molecules of low molecular weight with a diameter between 0.34 nm and 0.44 nm. Amino acids have a diameter between 0.34 nm and 1.12 nm. Larger molecules such as EDTA (1.23 nm) cannot be absorbed by the pores of the foliage.[20]

However, some exceptions apply. Although urea is an organic salt, its absorption rate has been shown to be higher in most studies compared to other sources of nitrogen.[37] It must however be remembered that urea is a molecule of very low dimension (0.26 nm).

c. Electric charge of nutrients

Nutrients usually have a positive charge. As mentioned above, the cuticle and the cell walls have a negative charge. **Nutrients are thus immobilized on the cuticle or on the cell walls of leaves**, once absorbed in the extracellular fluids.

The effectiveness of foliar fertilization depends, among other things, on the mobility of elements in the plant. Phosphorus, potassium and nitrogen are examples of high mobility minerals. This mobility allows nutrients to be distributed quickly throughout the whole plant. For their part, boron, calcium, sulphur, zinc, manganese and iron are low mobility elements in the phloem. To this end, several studies demonstrate that the chelated form of nutrients, in addition to promoting their foliar absorption, increases their mobility in the plant.[38,39,40,3,41,42]

Chelation, also called sequestration or complexation, is a physicochemical process during which a complex is formed, the chelate, between a ligand, called "chelator" (or chelating agent), and a metal cation, then complexed, called "chelated". Chelates (ligands) are inorganic or organic molecules of varying dimensions. The number of bonds between the chelate and the cation, the formation of chelate rings and the size of the chelate determine the strength of the bond between the cation and the chelating agent. **The chelated cation then becomes "neutral", without a positive charge.** [43]

There are several types of chelating and complexing agents, each having their own characteristics and whose performance is linked to the nature of the chelate, the nature of the complexed mineral element and the nature of the plant tissue to be crossed (here the leaf's epidermis) (see figure 1). Unlike adjuvants, chelates—when present in foliar fertilizers—are added by the manufacturer.[43]

The measure of the effectiveness of a chelating/complexing agent is determined by its capacity to maintain the chelated metals in solution. This capacity is variable and depends on the pH of the solution and on the metal to be chelated.

The stability and strength of the bonds of chelating agents is described by the dissociation rate, expressed by the log K value. The higher is the log K value, the stronger is the chelating/complexing agent.[43,44,45] However, it is necessary to note that the strength of the chelating agent must correspond to its use. Thus, a soil application of metals requires a higher binding strength than a foliar application. In the case of a foliar application, the strength of the chelating agent must be moderate in order to allow the release of the metal ion once the foliar penetration has taken place (see table 3).

Figure 1. Form of salts, chelating and complexing agents

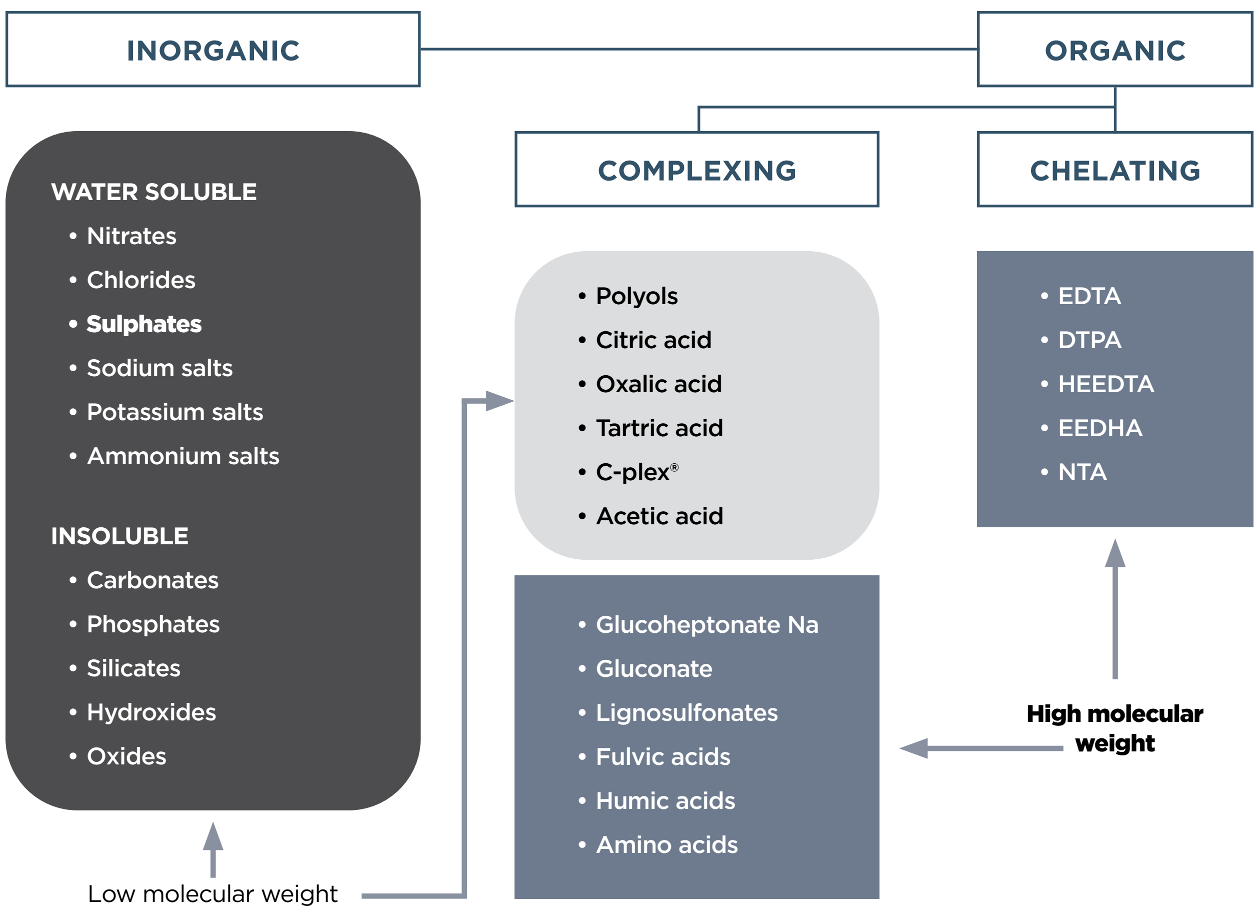
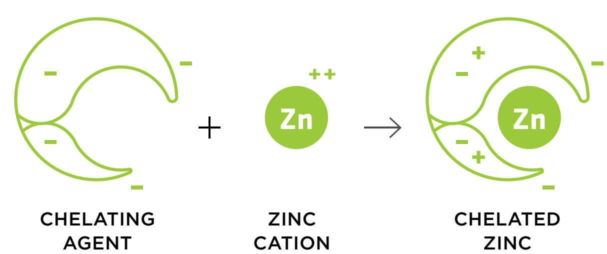


Table 3. Value of dissociation rates for different chelating agents[44,43,45]

Log *K* value of certain chelating/complexing agents							
Chelating agent	**Fe/Fe^{3+}**	**Fe^{2+}**	**Zn^{2+}**	**Cu^{2+}**	**Mn^{2+}**	**Mg^{2+}**	**Ca^{2+}**
EDTA	25.0	14.3	14.9	18.7	13.8	8.8	11.0
EDDHA	33.9	14.3	16.8	23.9	–	8.0	7.2
HEEDTA	19.6	12.2	14.5	17.4	10.7	7.0	8.0
DTPA	28.6	–	18.1	21.0	15.1	9.0	16.5
NTA	15.9	–	10.4	12.6	7.4	–	6.4
Citric acid	3.2	–	4.5	6.1	3.4	2.8	18.0
Fulvic acid	4.8	–	4.9	4.1	5.9	4.2	7.2
Citrate	11.2	4.8	4.9	5.9	3.7	–	4.7
C-plex®	3.0	–	3.9	4.8	3.0	2.5	6.0
Gluconate	37.2	1.0	1.7	36.6	–	0.7	1.2
Polyphosphates	4.1	–	7.5	3.5	5.5	3.2	–
Amino acids	Varies from 2.2 to 8.0 depending on amino acid and cation						
Lignosulfonate	14.0	–	18.0	18.0	18.0	18.0	18.0

Thus, some chelates stand out more than others. For example, one study has tested the effect of iron translocation from the leaf to the roots following a foliar spray of chelated iron carried out in conjunction with five different chelating agents and ten different complexing agents. This study concluded that translocation to the root has occurred only in the case where iron was sprayed with lignosulfonate.[42] However, regarding zinc, a study has demonstrated that the use of chelating agents such as EDTA and lignosulfonate does not increase the foliar absorption capacity of Zn in plants.[46,3,47]

Finally, unexpected properties have been associated with foliar spraying of lignosulfonate. Lignosulfonate would have the effect of triggering an hormonal activity (production of auxin and gibberellin) in corn. This could be explained by the action of the phenolic compounds contained in the complexing agent.[48]



Zinc cation (Zn^{2+}) binds
to a chelating compound by strong bonds

Source: https://adob.com.pl/en/about-chelates/

CONDITIONS OF APPLICATION 5

a. The adjuvants

By "adjuvant", we mean any substance that is added to the mixture to modify and improve the effectiveness of agrochemical products. Adjuvants are used to improve the quality of the mixture, its stability, the quality of the spraying and what the phytosanitary product becomes when it has reached the target.

On plants, adjuvants act as:

- **Adhesives/anti-rebound**. The use of certain adjuvants reduces the rebound effect of the droplets sprayed on the surface of the leaves, which allows for a better coverage by the mixture and therefore, better foliar penetration.[49] These products make the droplets "cling" to the point of impact by an anti-rebound effect. The adhesives fix the active ingredient on the leaves against leaching and volatilization;
- **Surfactant/wetting agent**. Surfactants (surface active agents) form the largest category of adjuvants. The use of surfactants, notably tensio-active agents, can improve wettability on the leaves **by reducing the superficial tension of water.** This reduction in superficial tension between the solution and the foliar surface thus makes it possible to cover a larger surface of contact and exchange[30] and also to increase penetration through the stomatal and cuticular pathways.[50] The function of a wetting agent is to increase the surface of exchange thanks to its lipophilic part and thus to combine hydrophobic and hydrophilic molecules. The hydrophilic/lipophilic ratio can help determine the effectiveness of a surfactant. High values of the hydrophilic/lipophilic ratio usually indicate that a surfactant can improve the foliar absorption of nutrients[21];
- **Humectant/protective**. These products maintain prolonged humidity on the foliar surface (capable of recovering water molecules from the air). The salts absorb the humidity in the air and thus fight against desiccation;
- **Penetrating**. These products improve the penetration of active ingredients through the cuticle. For example, oils promote the penetration of active ingredients by "breaking" the barrier of the plant's cuticular wax layers.

There is no universal adjuvant; it is therefore essential to know each of their functionalities in order to use them wisely.

Adjuvants, except urea, are mostly used in combination with agrochemical products. It is acknowledged that the presence of urea in the fertilizer solution facilitates the penetration of other nutrients into the leaves. The cuticle is 10 to 20 times more permeable to urea than to inorganic ions.[37] Moreover, the addition of urea to the fertilizer solution increases the effectiveness of foliar applications containing P, Mn, S, Mg and Fe in different plant species.[51,52,53] However, the urea must be free of biuret, a product obtained by the condensation of two urea molecules and by the elimination of an ammonia molecule having phytotoxic effects and that can be integrated into the fertilizer during its synthesis.

b. Spraying

The effectiveness of spraying is linked to the best possible distribution of nutrient molecules on the leaf. Effectiveness thus depends on the number of impact points and on the average diameter of the droplets produced.

Nozzles are one of the key elements of spraying. Their role is to divide the pressurized mixture into a multitude of droplets. The mist of drops will have certain characteristics (average diameter, speed and direction of the droplets) on which will depend the effectiveness of the treatment, the extent of the drift, volatilization as well as runoff (losses). Depending on the type of nozzle, the caliber, angle of the spray and working pressure will vary.

Anti-drift nozzles (flat fan tip nozzles, drift control even flat fan nozzles or air-assist fan nozzles) produce ultra coarse size spray droplets (diameter greater than 400 µ). These larger droplets (>400 µ) are less sensitive to drift and volatilization. However, they have many drawbacks: the spreading and the reduction in the number of impacts/cm^2, their behaviour upon impact on the target (rebound or splash phenomenon) as well as their hold on the target (runoff phenomenon).

The penetration of the active ingredient will depend on the dilution, the size of the drops and the resulting drying time (too quick desiccation of small drops). The duration time and the speed of the droplet increase with its size.

Spraying a foliar fertilizer requires coverage which is ideally 80 droplets/cm^2 with a diameter varying between 200 and 300 µ. Controlling the quality of the spray is easily carried out using a sensitive yellow paper which turns blue on contact with water.

CHARACTERISTICS OF AGRO-100 LIQUID NUTRIENTS

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The technologies used by Agro-100 aim to maximize the absorption and mobility of nutrients and biostimulants while respecting as much as possible the principles described in this document.

The choice of raw materials respects the agronomic conditions of solubility, size of molecule, point of deliquescence and chelation described above. Agro-100 liquid nutrients:

- **are solutions and not suspensions** to ensure maximum penetration into the foliage;
- are manufactured with **small-size chelating agents** to ensure the neutrality of the molecules;
- contain **biostimulant technologies** that enhance resistance against abiotic stresses and increase the absorption and mobility of nutrients.

a. The Oligo Prime® technology

Crops have the ability to defend themselves against damage caused by **R**eactive **O**xygen **S**pecies (ROS) created during episodes of abiotic stresses, **such as nutrient deficiencies**, or by ROS generated by herbicides. Defense mechanisms against ROS include enzymatic and non-enzymatic components that serve to balance ROS production and detoxification.

The **OligoPrime® technology** is designed to increase the effectiveness of natural defense mechanisms present in all plants. It is based on four components:

1. **metabolic signals**;
2. **the C-plex® technology**;
3. **fulvic acid**;
4. **chitosan**.

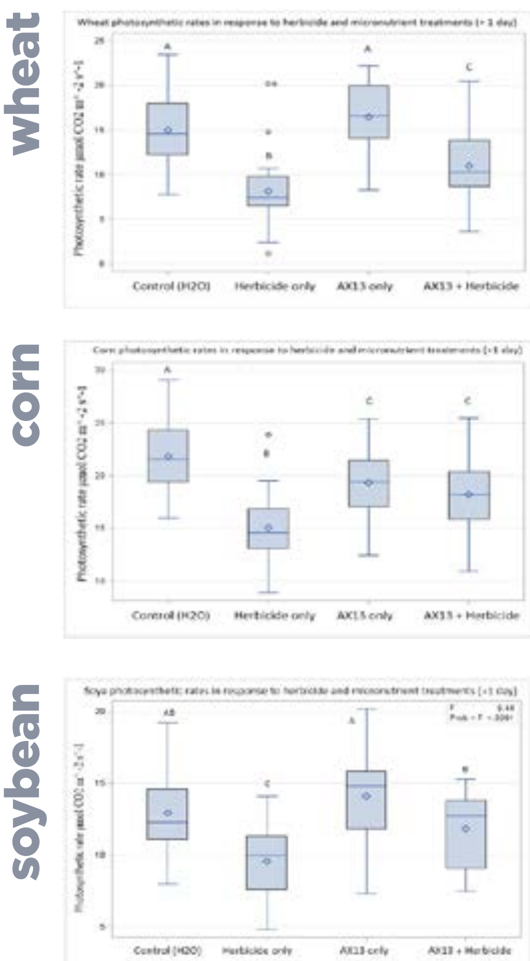
The synergy between these four technologies allows products containing the Oligo Prime® technology to perform better and offer economic returns well above 3:1.

❶ The role of metabolic signals

It is now clear that phytohormone-induced signaling occurs through genome regulation or with an increased production of secondary metabolites.

Secondary metabolites are synthesized in different cellular compartments and their main functions include protection against biotic and abiotic stresses.

Figure 2. Effect of secondary metabolites on the rate of photosynthesis



The addition of secondary metabolites to the Oligo Prime® technology helps to reduce the negative impact on photosynthesis of stresses associated with nutrient deficiencies and herbicides. Thus, the rate of photosynthesis decreases by 50% when the herbicide (wheat: bromoxynil/MCPA, corn: glyphosate, soybean: glyphosate) is used alone, the rate of photosynthesis decreases by 44% for wheat, by 30% for corn and 20% for soybeans when measured one day after application. The addition of secondary metabolites to herbicides helps to reduce the drop on the rate of photosynthesis to 22% for wheat, 16% for corn and 10% for soybeans.[54]

Secondary metabolites included in the Oligo Prime® technology also have an impact on the plant genome and activate the production of 71 defensive proteins and enzymes that play a role in reducing the impact of ROS.

❷ The role of C-plex®

C-plex® is a molecule derived from fulvic acid that has a smaller size and higher cation exchange capacity than fulvic acid. This smaller size is obtained through an exclusive transformation process that yields molecules of a few hundred daltons. This small size allows for quick and easy absorption by the plant and a very high complexing capacity.

❸ The role of fulvic acid

Humic substances are divided into different categories which include humic acids, fulvic acids and humins. Humic acids are larger molecules with molecular weights of up to one hundred thousand daltons, while fulvic acids are typically only a few thousand daltons. As noted above, fulvic acid is considered as the organic fraction of soil that is soluble in both alkali and acid. Fulvic acids have greater total acidity, and a greater adsorption and cation exchange capacity than humic acid. Fulvic acids are responsible for the chelation and mobilization of metal ions, including Fe and Al. Given their small molecular size, fulvic acids can pass through the micropores of biological or artificial membrane systems, unlike humic acids.

❹ The role of chitosan

Chitosan is a natural biopolymer modified from chitins that acts as a biostimulant and an elicitor in agriculture. It is non-toxic, biodegradable and biocompatible, which favours a wide range of application. It improves the physiological response and mitigates the harmful effect of abiotic stresses. Treatment with chitosan stimulates the rate of photosynthesis and the closure of stomata, increases the concentration of antioxidant enzymes and induces the production of organic acids, sugars, amino acids and other metabolites that are required for the control of stomata, the production of metabolic stress signals, and the management of energy under conditions of stress.[55]

Chitosan activates many genes, proteins, and secondary metabolites in plants. It causes the production of signals and increases the concentration of secondary molecules such as hydrogen peroxide and nitric oxide. Preventive treatment with chitosan prior to exposure to abiotic stress increases plant growth, the production of antioxidant enzymes, and of secondary metabolites that promote the production of defensive enzymes, and abscisic acid (ABA). However, plant responses depend on the type of chitosan, concentrations, and the stage of development of the crops.[56]

The addition of chitosan to Oligo Prime® helps to increase the capacity of cells to produce the defensive enzymes required for the inactivation of ROS caused by herbicides.

b. Trial results

i. Research hypotheses

Trials were conducted to confirm the effectiveness of C-plex® and fulvic acid in facilitating the absorption and mobility of nutrients in soybeans. The specific hypotheses verified in this trial are:

- the use of C-plex® and fulvic acid mixed with foliar fertilizers improves the absorption and translocation of the nutrients Ca, Mn and B;
- the presence of saline stress has no effect on the absorption and mobility of nutrients (Ca, Mn, and B);
- there is an interaction between the technologies and the applied stress.

ii. Methodology

The trial was carried out in a greenhouse located in St-Isidore-de-Laprairie during the months of March and April, 2021. 72 pots were sown with soybeans. The cultivar Altitude (Secan) was used.

Treatments:

- **Stress: with and without saline solution**.
  A salt water solution (1% V/V) was used to irrigate half of the pots. The other pots received demineralized water for irrigation.
- **Technologies: with and without the C-plex® (chelating agent) and FulviPro (fulvic acid) technologies**.
  These technologies were added to the foliar fertilizers used for the trial. Twenty-four pots received the technologies mixed with foliar fertilizers containing boron (10% concentrate), manganese (7% concentrate) and calcium (12% concentrate) were used. Twenty-four other pots received foliar fertilizers containing no technologies. The last 24 pots only received water. Foliar fertilizers were applied in a mixture (1% V/V) until dripping.

  During application at stage V3, the bottom leaves were protected with a plastic wrap *(SaranWrap)* so that only the top leaves received the treatments. The plastic wraps were removed immediately following the treatments. The bottom leaves were harvested 24 hours later and sent to the laboratory for tissue analysis.

iii. Results

The results demonstrate that C-plex® and FulviPro technologies improve the absorption and mobility of nutrients towards the leaves. The saline stress caused a difference in the concentration of nutrients only for the calcium. There were no interactions observed in the trials.

Calcium (%)

	Without technologies	With technologies	Control	Average
Salt-free water	2.28	2.49	2.31	2.36[a]
Water with salt	2.15	2.34	1.90	2.13[b]
Average	2.21[a]	**2.42**[b]	2.11[a]	

Different superscripts in each column express significant difference between treatments at p = 0.05

Manganese (ppm)

	Without technologies	With technologies	Control	Average
Salt-free water	462.33	1040.10	331.47	611.30[a]
Water with salt	526.90	873.77	328.47	576.38[a]
Average	494.62[a]	**956.93**[b]	329.97[a]	

Different superscripts in each column express significant difference between treatments at p = 0.001

Boron (ppm)

	Without technologies	With technologies	Control	Average
Salt-free water	445.20	571.20	60.93	359.11[a]
Water with salt	429.83	618.03	61.45	369.77[a]
Average	437.52[b]	**594.62**[a]	61.19[c]	

Different superscripts in each column express significant difference between treatments at p = 0.001

CONCLUSION 7

To conclude, let us remember that foliar fertilization is an important agronomic tool which is not intended to replace basic granular fertilization. Foliar fertilization is complementary to granular fertilization and it is an integral part of a complete fertilization program that aims to promote vigorous and balanced vegetative growth of crops.

The importance of foliar fertilization rests in the significantly positive effect it has on the growth, development and yield of crops. Its role is to give a dynamic boost to plants by allowing small quantities of nutrients to be added in a targeted manner at precise times to support the crop at key vegetative growth stages, particularly when adverse conditions are present.

This flexibility—not to say this precision—of intervention makes it possible to correct or prevent the appearance of mineral deficiencies and to amplify certain physiological characteristics in order to support the plant and thus give it a better chance of achieving and maximizing its full genetic potential of production.

As we have just shown, it is essential to know the factors governing the effectiveness of foliar fertilization in order to maximize the return on investment that these products offer for your production.

Plant crops are under sustained pressure from abiotic stresses (drought, low temperature, salinity, etc.). Agriculture must more than ever be resilient and able to adapt to current agronomic and environmental conditions. The Oligo Prime® technology works with the plant to make it agile enough to withstand the pressure of abiotic stresses. Designed to increase the effectiveness of natural defense mechanisms present in all plants, the Oligo Prime® technology activates plants to perform better and yield optimal results.

Studies show that by supporting vegetative development, foliar fertilization offers an exceptional agronomic response to contemporary growing conditions. In addition to being a preferred and effective vehicle for providing key nutrients at key moments in the plant's development, Agro-100's agroliquid products contain biostimulant technologies that increase resistance to abiotic stresses while promoting absorption and mobility of nutrients essential for plant growth.

Foliar fertilization with Agro-100 agroliquid products offers the flexibility of intervention and nutritional and cultural recovery to correct or prevent the appearance of mineral deficiencies in addition to stimulating the vital and productive activity of the plant and crops. A force of protection, defense and production, foliar fertilization really is an important tool to any complete fertilization program…

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