

Phosphorus, Phosphate,

By Arnold W. Schumann

Phosphite explained

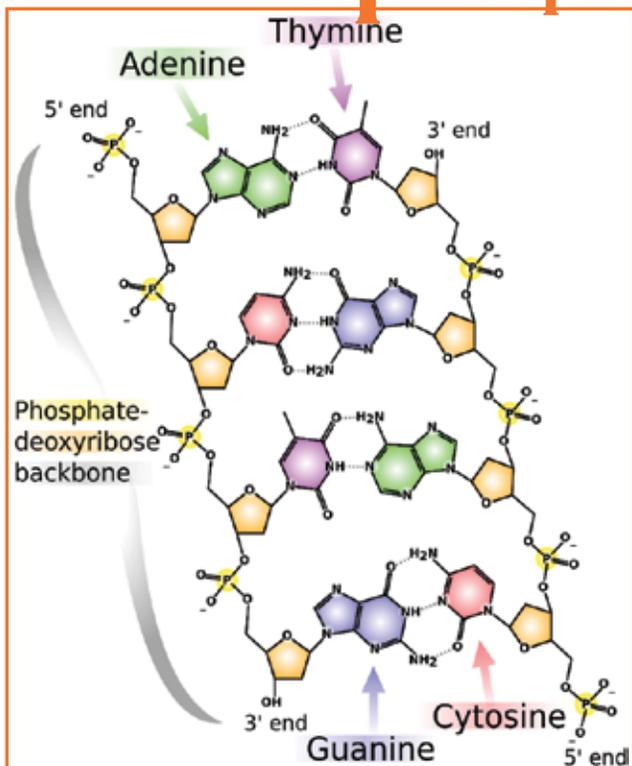


Figure 2. Chemical structure of a portion of the DNA molecule. Phosphorus atoms in the phosphate backbone molecules are highlighted in yellow (Wikipedia, 2012).

Phosphorus is a well-known plant nutrient used in the production of cultivated crops, including citrus. The diversity of phosphorus fertilizer products available for crop production is rapidly increasing and includes a growing list of “phosphite” products used primarily as fungicides/bactericides. The purpose of this article is to review the different forms of phosphorus available in products labeled for citrus production, and to explain the important plant nutritional differences between them.

WHAT IS PHOSPHATE AND WHY IS IT IMPORTANT FOR CITRUS?

Phosphorus (P) is a chemical element in the Periodic Table with atomic number 15. Phosphate is an electrically charged mol-

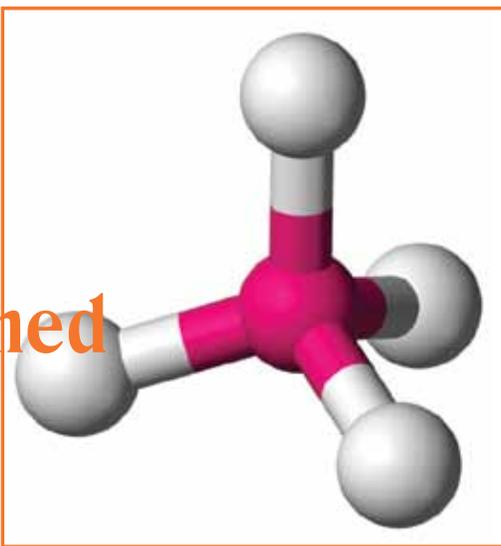


Figure 1 (above). Three-dimensional ball-and-stick model illustrating the molecular structure of the phosphate ion

ecule (ion) consisting of one central phosphorus atom surrounded by four oxygen atoms in a tetrahedral arrangement (Figure 1) and a negative three charge (PO₄³⁻).

Phosphorus is essential for most life. For example, phosphorus is essential in the phosphate-deoxyribose backbone of DNA (deoxyribonucleic acid) as illustrated in Figure 2. In fact, the form of phosphorus in other biochemicals like RNA (ribonucleic acid), ATP (adenosine triphosphate) and phospholipids that are all essential for life is also in the form of *phosphate*. Therefore when we fertilize citrus trees, we apply phosphatic (phosphate-containing) chemical compounds of phosphorus such as mono- or di-ammonium phosphate, and superphosphate, among others.

PHOSPHATE FERTILIZERS AND P₂O₅

Historically, prior to the development of modern lab instrumentation, chemists used a gravimetric (weighing) method after ignition to determine the phosphorus content of phosphate fertilizers in the form of phosphorus oxide (P₂O₅). By convention, the amount (or analysis grade) of phosphorus in fertilizers is still expressed in this oxide form. The percentage P₂O₅ on the fertilizer label is really only 44 percent actual elemental phosphorus; the remaining 56 percent is accounted for by imaginary oxygen.

WHAT IS PHOSPHITE AND HOW DOES IT DIFFER FROM PHOSPHATE?

Phosphite consists of one central phosphorus atom surrounded by only

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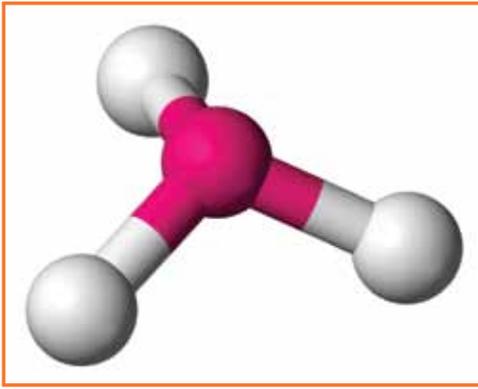


Figure 3. Three-dimensional ball-and-stick model illustrating the molecular structure of the phosphite ion

three oxygen atoms in a trigonal pyramidal arrangement (Figure 3) and a negative three charge (PO_3^{3-}). The phosphorus in phosphite is therefore in a lower oxidation state (+3) than the phosphorus in phosphate (+5). What this means in chemical terms is that the phosphorus atom in phosphite has gained two additional electrons ($2e^-$) compared with the phosphorus atom in phosphate. The transition of phosphorus from a +5 to +3 state associated with the gain of two electrons is called reduction, and phosphite can be described as a more reduced form of phosphorus than phosphate.

At low pH, both oxidized (PO_4^{3-}) and reduced (PO_3^{3-}) forms of phosphorus exist as acids, namely phosphoric acid (H_3PO_4) and phosphorous acid (H_3PO_3), respectively. These strong acids are typically the source materials used for manufacturing concentrated phosphate fertilizers and phosphite fungicides/bactericides, respectively. For example, diammonium phosphate (DAP) fertilizer is manufactured by reacting phosphoric acid with ammonium hydroxide. Similarly, reacting phosphorous acid with potassium hydroxide yields mono- and dipotassium phosphites which are used to formulate some of the commercial phosphite products labeled as fungicides/bactericides or “fertilizers.”

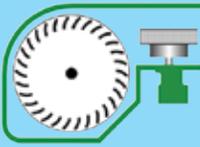
CAN PHOSPHITE SUBSTITUTE FOR PHOSPHATE TO PROVIDE PHOSPHORUS NUTRITION IN CITRUS?

Biologically, the fundamental differences between phosphate and phosphite are vast. The difference in molecular structure between phosphate and phosphite means that phosphite cannot substitute for phosphate in the essential biochemistry of life. For example, in the DNA double helix molecule, the precise three-dimension-

al helical shape is in part determined by the bond angles (109.5 degrees) of the phosphate molecules constituting its phosphate-deoxyribose backbone (Figure 2). Phosphite molecules have bond angles of 107 degrees.

Numerous applied scientific studies with food crops, including citrus, have conclusively shown that phosphite cannot substitute for phosphate as a plant nutrient. If phosphite were a suitable form of phosphorus nutrition (uptake and metabolism), it should improve growth and development of phosphorus-deficient plants. Published studies demonstrated that this was not the case, and phosphite feeding of phosphorus-deficient plants could not improve their condition. Instead, any detrimental effects of phosphite addition were exacerbated when plants were grown in sub-optimal phosphorus nutrition conditions. Furthermore, the stunting caused by moderate phosphite feeding in phosphorus-deficient plants did not resemble phosphorus deficiency, suggesting that phosphite prevented or masked some of the morphological responses of plants to phosphorus deficiency.

Research indicates that phosphite is very easily and rapidly absorbed by plants — sometimes in as little as 15



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minutes — through the leaves. Studies with a range of crops demonstrated that plants which are phosphorus-deficient are more susceptible to growth stunting from even minimal phosphite applications than plants which are phosphorus-sufficient. In some studies, the growth losses incurred from the phosphite feeding were more severe than from the phosphorus deficiency

itself. Interestingly, the total phosphorus concentration in leaf tissue was always increased by the phosphite additions, despite the lack of increases in growth and yield. Co-application of both phosphate and phosphite to phosphorus-deficient plants resulted in growth suppression at low rates, but not at adequate fertilization rates, suggesting a competitive inhibition of phosphate uptake by phosphite. In the same study, favorable elicitation of biochemical responses to stress agents were still measured from the addition of phosphite when phosphate was co-applied to counteract the negative effects on plant nutrition and growth.

In summary, the phosphorus in phosphite products is not a fertilizer unless it transforms to phosphate and can be incorporated into the biochemistry of plants. Scientific evidence to date has shown that phosphites are converted to phosphates too slowly to serve as a plant's main phosphorus source. However, other components present in phosphite compounds used for commercial phosphite products are often plant nutrients such as potassium, calcium or nitrogen, so technically these products are fertilizers in addition to being fungicides/bactericides. To prevent compromised phosphorus nutrition when using phosphite products on citrus, the following advice may be useful:

- Before using phosphite products, ensure that the trees are optimally supplied with phosphate fertilizers according to the amount of phosphorus being removed in the harvested fruit, and by consulting soil phosphorus tests.

- Leaf phosphorus concentrations measured in routine lab analyses may be elevated if phosphite concentrations are increased with foliar applications of phosphite products. Laboratories measure only total phosphorus in the leaf (phosphate + phosphite) which means they cannot distinguish between nutrient and non-nutrient phosphorus. Therefore, the trees could be deficient in phosphate even though the total phosphorus concentration is above the published deficiency level (0.09 percent).

- Co-apply phosphate- and phosphite-phosphorus in the same foliar spray in order to prevent the detrimental effects of phosphite on trees with sub-optimal phosphorus nutrition. Many commercial phosphite products are now conveniently available as blended formulations of both phosphites and phosphates.

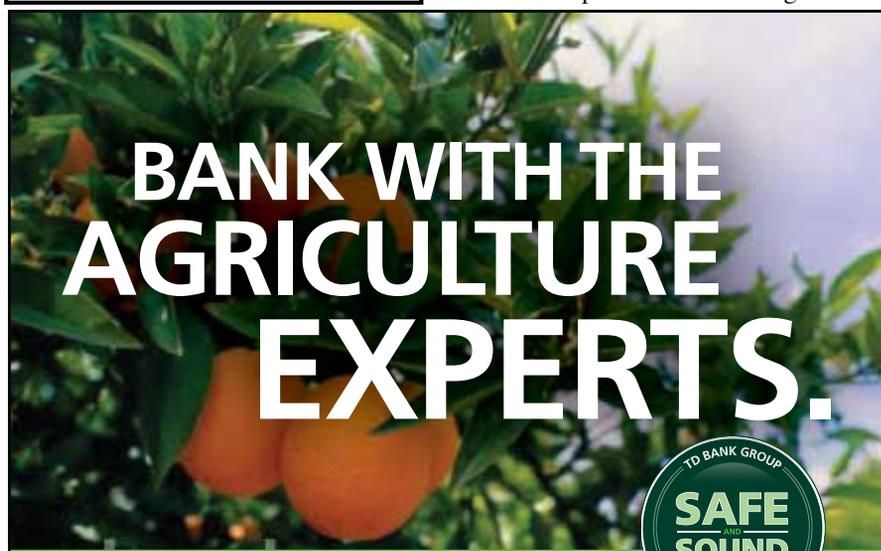
- Don't include the pounds of phosphorus per acre applied as phosphite in the annual total phosphorus fertilization budget.

- Adhere rigorously to the correct rates and other application advice in the label of the phosphite products.

- Remember that plants cannot metabolize phosphite, and its detrimental effect on trees with phosphorus deficiency may be stronger than the deficiency itself.

The author and UF/IFAS do not guarantee or warranty the performance of phosphite described in this review article. The readers are encouraged to reference the listed source publications for a full treatise of this important subject. In particular, refer to the official UF/IFAS EDIS document HS1010

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on the subject of using phosphite and phosphate for plant growth. All chemicals should be used in accordance with directions on the manufacturer's label.

Arnold W. Schumann is an associate professor at the University of Florida-IFAS's Citrus Research and Education Center in Lake Alfred.

Acknowledgements and selected articles for further reading

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What is the current status of HLB in Florida citrus?

By Harold Browning



As Florida's citrus harvest moves into full swing, there are many questions about how the industry is doing in its battle with HLB. These questions eventually point to how much we still don't know about this disease and its ability to affect citrus. Despite the continued, aggressive approach to research across the breadth of possibilities for finding solutions in the short, intermediate, and long term, the questions remain. These questions arise from the efforts of growers and scientists alike who are evaluating field, greenhouse and laboratory trials, and interpreting the data and the general observations that emerge.

There are signs of progress in many areas. Some positive signs are coming from success in new plantings, particularly from trials where high densities of trees are combined with more intensive irrigation/fertilization management. This is combined with incremental gains in managing Asian citrus psyllid (ACP) on new plantings, as well as continued benefit from growers participating in Citrus Health Management Areas. Recent reports at grower meetings and published stories in various outlets point to progress in managing the disease in a variety of ways, using a variety of approaches.

With regard to mature groves, where infection rates continue to grow, the October USDA crop estimate indicates a strong crop load for the year. Factors like summer rains and alternate bearing may help explain the increase in crop size over last year, but nonetheless, it is encouraging news. Included in the estimate for a strong crop season is the possibility that perhaps HLB is not yet fully impacting the industry.

Vital to understanding management of HLB are the combined efforts of researchers and growers to collect observations and data from field trials. Ultimately, all tools for managing citrus in the presence of HLB must be field-tested, and we are learning in the most important laboratory — the grove. Observations in this complicated environment sometimes support our expectations for cause and effect, but in other cases, the results of the trials are unexpected and baffling, causing us to question our original hypotheses. This is the basis for experimental research.

Amidst this ongoing evaluation of strategies, new ideas are emerging. They range from characteristics of irrigation water and their effects on HLB expression, to the implications of HLB infection on onset of other tree stresses, like blight, Phytophthora and root weevils.

Looking at the citrus industry and its fight with HLB, many concerns and tough questions remain:

- Are we tangibly reversing HLB symptom development and disease?
- Are there signs that HLB continues to increase its impact on production? Is the fruit drop being observed this season associated with HLB?
- Is ACP control adequate to protect new plantings from HLB until they reach productive age?
- Will trees survive and produce marketable fruit until resistant trees are available?

These and many more questions remain in the forefront as we begin the next cycle of research projects to support, and as we advance research results to delivery through regulatory and commercialization routes. All of the above elements are, in fact, the drivers for research that is being supported by CRDF, the growers and the research institutions. These questions are central to the projects under way, and those that will be evaluated this winter for funding support.

Harold Browning is Chief Operating Officer of CRDF. The foundation is charged with funding citrus research and getting the results of that research to use in the grove.



Column sponsored by the Citrus Research and Development Foundation