FERTILIZERS: TYPES, REACTIONS, AND RESPONSES

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Fertilizer types

Fertilizer can be categorized in several ways based on physical and chemical properties. Fertilizers may also be broken up into two broad groups -- soil applied or foliar applied. As the terms imply, these categories define the target of the application: either the material is meant to be placed on and incorporated into the soil or it is applied to the plant surface. The nutrients in soil applied fertilizers are intended for uptake by the plant roots while those in foliar applications enter the plant primarily through the leaves, although some material may wash onto the soil and be taken up by the roots. Generally we think of soil applied fertilizers as solids or granular materials. However, liquids may also be used in soil applications. A good example of this is fish hydrolysate fertilizer which is applied at relatively high rates (gallons per acre) and is intended to be washed onto and into the soil and eventually taken up by plant roots.

Soil applied fertilizers are most commonly granular materials. The predominant granulars used in cranberry production are soluble inorganic materials. These manufactured materials may be ammoniated (chemically produced materials in which each particle contains all of the fertilizer minerals and the nitrogen is in the ammonium form) or blended (combinations of particles any one of which may contain only some of the mineral content). Both types may have a variety of sizes of particles. This is not an issue for the ammoniated fertilizer, since each particle is minerally complete. However, in a blended fertilizer, as the particles sort by weight during application and are distributed unequally, the various minerals in those particles are also unequally distributed. Additionally, some blended fertilizers contain filler materials, often lime. Many growers prefer ammoniated fertilizers since this assures the ammonium form of nitrogen (preferred by cranberry plants), no carrier materials, and equal distribution of the fertilizer mineral components. But, cost and availability are increasingly an issue for ammoniated fertilizer.

In addition to untreated granular materials, the soil fertilizer category includes organic fertilizers, liquids, and slow release materials. A primary difference among these materials is the timeline from application until the mineral elements are available for uptake by the roots. The minerals in soluble inorganic fertilizers are immediately available if applied in a liquid formulation and quickly available if applied as granulars (as soon as they dissolve into the soil water). The mineral elements in organic forms only become available as the fertilizer breaks down in the soil, a process that is often mediated by soil microorganisms. Slow release fertilizers are intentionally designed to be slowly available. Depending on the product, the minerals are released to the soil water over a period of one to several months. The release may depend on soil temperature, moisture content, pH, coating thickness, and/or microbial activity. The mineral elements in all of these products are used similarly by the plant once the minerals dissolve or are digested and move into the soil solution. Mycorrhizal associations may also mediate direct uptake on small organic molecules containing nitrogen (for example, amino acids).

Foliar fertilizers are liquid materials designed to be sprayed onto the plant. Once in place, the minerals move directly into the plant through the leaves. By nature, the fertilizers are designed to deliver modest amounts of nutrient. Uptake may be limited by the thickness of the plant cuticle, wet period after application (generally there needs to be moisture present for uptake), concentration of the spray solution, and wash off. Specific elements may be limited in their mobility out of the leaves to the rest of the plant. Foliar fertilizer have advantages in situations where root uptake might be limited. They are also useful for quickly delivering supplemental nutrition. Urea is frequently used in foliar applications to deliver quick supplemental nitrogen.

Fertilizer movement and reactions

As previously stated, granular fertilizers may be distributed unequally depending on product type and delivery system. Once the fertilizer is applied, it must weather, dissolve, or be digested so that the mineral components are dissolved in the soil moisture. Once an element is in solution, it moves through the soil by diffusion (elements move from a concentrated area to an area with lower concentration until all concentration are equal) or through mass flow (dragged along in moving water within the soil).

Elements in the soil water follow three paths -- into the plant roots, away from the target area in water (leaching or runoff) or into a bound form in the soil. Soil binding of minerals varies in strength or permanency. That is, many minerals are loosely bound on exchange complexes in the soil. An example is cation exchange capacity (CEC). CEC is the ability of a soil to loosely hold positively charged particles (cation such as potassium, calcium, and magnesium ions) in such a way that they are retained in the soil but remain available for plant uptake. In cranberry soil, most of the CEC is provided by organic material in the soil since our soils are poor in clay (the common source of CEC in agronomic soils). In acid cranberry soil, strong binding also occurs, particularly binding of phosphorus to iron and aluminum. Strongly bound P is less available to the plant and over time the bond may become virtually permanent.

Plant roots can only take up 'free' minerals so even those bound to the CEC must be released to the soil solution prior to plant uptake.

Plant uptake of fertilizer

In field studies in several growing regions, dissolved, labeled nitrogen was applied to cranberry plants. Uptake was confirmed within 24 hours and continued for about 7 days in Wisconsin. Rate of uptake was temperature dependent, with more rapid uptake at the warmer sites. More N was taken up in WI and NJ in the first 7 days than was taken up in MA after 14 days or OR after 21 days. Examination of weather records suggested that the differences were likely due to temperature.

pH responses and interactions

Ammonium sulfate, one of the most common cranberry N sources, is taken up by plant roots in an active process. As the plant takes in the ammonium ion from the fertilizer, a hydrogen ion (acid) is pumped out of the plant. In this process, the soil is acidified. So it is the uptake process that provides the soil acidification associated with ammonium sulfate. The sulfate is not an acidifier -- only elemental sulfur has that property.

Soil pH plays an important role in the nitrogen cycle in cranberry soils by its impact on two processes: mineralization (the digestion of organic nitrogen by microorganisms to produce ammonium N) and nitrification (the microbial conversion of ammonium to nitrate N). The table below shows nitrogen release from cranberry soil organic matter at three pH levels. As the soil becomes less acid (pH 6.5), more total N is released compared to soil at pH 3.5. However, most of that N is in the nitrate form. An examination of the microbial population in the soils at pH 6.5 vs. 3.5 showed that at the lower pH microbes were suppressed. So at cranberry bog pH, one can expect low microbial activity, slow mineralization (conversion of organic to ammonium N) and little conversion of that ammonium to nitrate. This is good, since nitrate is poorly used by cranberries and readily leaches away from the root zone.

N leached from a sand cranberry soil.

Soil pH	Total N	NH_4-N	NO_3-N
6.5	56.60 a	6.38 a	50.22 a
4.5	10.34 b	3.89 a	6.45 b
3.0	14.07 b	5.46 a	8.61 b

As mentions previously, soil pH also plays a role in the reactions of phosphorus in the soil. As pH moves away from neutral (7.0) in either direction, P becomes more strongly bound to other soil minerals, At low pH P binds to iron and aluminum while at high pH P binds to calcium. Since cranberry soils are strongly acid with large reservoirs of aluminum and iron, large reservoirs of P can build up in cranberry soil. Unfortunately, much of the P is, at best, poorly available to the plant. The only elements that are more available in acid soils are the minor element metals iron, manganese, zinc, and copper.

Salt index and salt injury

All common mineral fertilizers are salts. The 'salt index' was developed as a standard of comparison among fertilizers. The salt index measures the potential soil solution salt concentration that will occur as the fertilizer dissolves in the soil water. If the soil solution becomes to salt laden (concentrated), it becomes difficult for the plant roots to take up water. Such salt effects are not specific to a certain element but rather to the overall concentration in solution.

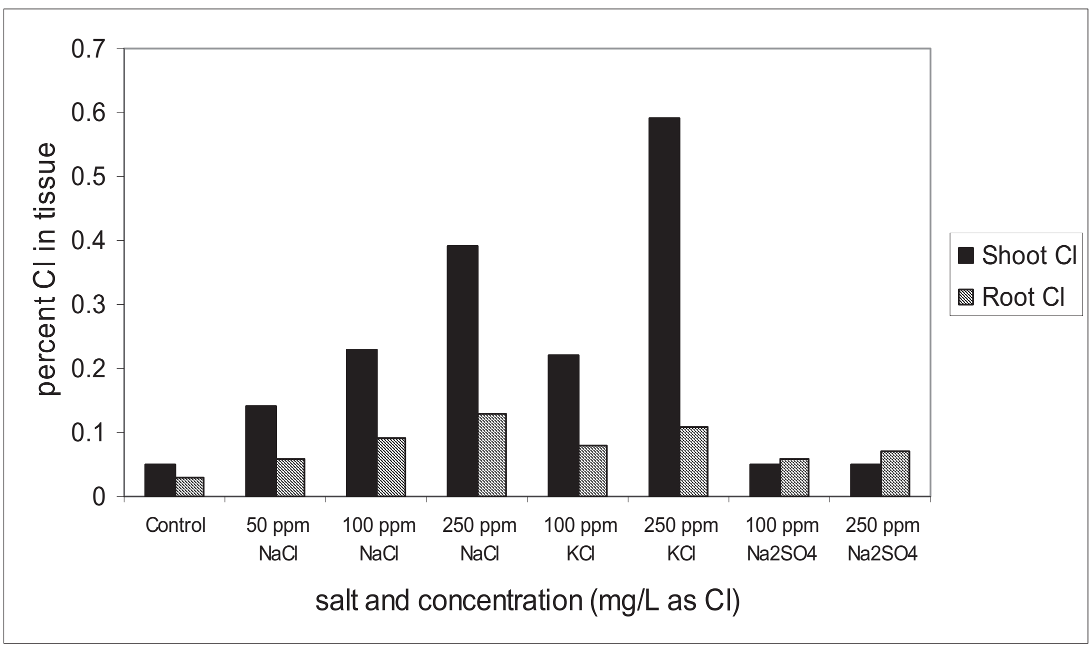
The standard of comparison for the salt index is sodium nitrate whose value is set at 100. Generally other N sources are at or less than 100. Most P sources are between 20 and 30. K sources can be much more variable with most between 40 and 60 with the exception of KCl (muriate of potash, potassium chloride) at 116. Potassium sulfate and SulPoMag are 43.

In addition to generalized salt effects related to salt index, specific salts may present challenges for some plants. In a greenhouse study of lingonberry (a Vaccinium related to cranberry), yield declined and growth was stimulated with increasing concentrations of chloride (Cl). Salt injury to cranberry vines has been observed following east coast hurricanes and in areas that receive highway treatment overspray in the winter. In both instances, the salt in question is sodium chloride (NaCl). Finally, growers have reported that they can 'shut down' cranberry growth with have rates of KCl

(0-0-60). So the question is -- are we looking at a general salt effect or a specific toxicity of Cl (or Na)?

In Massachusetts, we did a study looking at the interaction of K form (KCl, 0-0-60 or K_2SO_4, 0-0-50) and rate with N rate. Plots were set up in a grid pattern so that rows received various K rates and forms while columns received high or moderate N rates. The results showed that K at 100 or 200 lb/A gave higher yield than that in zero K rows. After the first year, yield declined in the high N columns and fruit rot increased. Further, increasing K rates with either source did NOT overcome the deleterious effects of high N. So, we could not shut down growth and restore yield but neither did we observe any damage to the plants with KCl application at these rates.

In order to further investigate the possibility of Cl toxicity in cranberry plants, a cooperative project was initiated by researchers at UMass, University of Wisconsin and Washington State University with funding from the Mass Highway Department. In a greenhouse study in sand culture, cranberries exposed to 250 ppm Cl in irrigation water showed leaf reddening with Cl provided as NaCl *or* KCl. At lower concentrations, runner production was stimulated and at 250 ppm as KCl, many plants died. The figure below shows the Cl concentration in plant tissue after several months of exposure to contaminated irrigation. Not surprisingly, the Cl in the shoots rose as the concentration of Cl in the irrigation water was increased from 50 to 250 ppm.



However, it was notable that when 250 ppm Cl was provided as KCl, more Cl accumulated in the shoots than when that same amount of Cl was provided as NaCl. This is a good indication that KCl (0-0-60) at high rates may not be suitable for cranberry production.

Fertilizer choices for cranberry

Ammonium is the recommended form of N for cranberry production due to its ready uptake by the plants (10 times greater than nitrate), its slow conversion to nitrate in acid soils, and its lower leachability compared to nitrate. Urea, organic fertilizers, and many slow release materials deliver N as ammonium during their breakdown. P is supplied primarily as phosphate (ammonium phosphate or triple super phosphate). The preferred form for K is the sulfate as previously discussed even though this form generally costs 50% more than the chloride.

Most growers use complete fertilizers, those that contain N, P, and K. Since most growers fertilize based on the rate of N to be delivered, choice of NPK ratio is important to determine the P and K that a bog will receive. In the past, many growers used N:P rations as high as 1:4. Current recommendations call for no more than a 1:2 and often a 1:1 is preferred. Custom blends are becoming more available and affordable. This allows a grower to choose a fertilizer based on plant needs and environmental considerations, so that only what you need is what you get. When choosing a cranberry fertilizer, the following should be considerations:

- method of application
- uniformity of material
- cost
- N:P ratio no more than 1:2
- N as ammonium
- K as sulfate