# Salt Index

## The salt indices were estimated by calculation when extrapolated to soil relevant boron calculations:

- *Fertibor*® Borax Pentahydrate: 87.5
- *Optibor*® Boric Acid: 73.3
- *Solubor*®: 82.4

Although salt index has little relevance for micronutrients, this value may nevertheless be requested by customers and regulatory agencies. The salt index is a comparative value with the same mass of sodium nitrate assigned a reference value of 100. Because of the weak electrolyte nature of borax, its salt index is concentration dependent and drops from 87.5 to 55.1 for a 1% solution and to approximately 34.5 for a satured solution. The salt index of boric acid increases only slightly with concentration.

## Background

Salt index is a term specific to the agricultural community. It is a comparative measure of the salt concentrations created in soil solutions by various fertilizers (1). Interest in the salt index relates to the potential for damage to crops and seedlings, such as poor germination, burning or wilting, which might be caused by exposure to high salt concentrations resulting from fertilizer additions. Although not predictive of the exact amount of a fertilizer that could cause crop damage, the salt index allows comparisons between different fertilizer formulations with respect to their potential for salt effects.

The salt index is defined as the ratio of the increase in osmotic pressure of the soil solution produced by a fertilizer compared to that produced by the same mass of sodium nitrate. No standard concentration is included in the definition, with most salt index values found in the literature being determined experimentally from actual soil solutions having a range of fertilizer component concentrations. The general idea is the lower the salt index of a fertilizer the lower is its tendency to cause salt related damage to plants from the application of a same weight of fertilizer. However, this is also mileading in that a larger quantity of a lower salt index fertilizer may be required to achieve the same nutrient application. For example, potassium nitrate has a lower salt index than sodium nitrate, but this is largely a consequence of its higher formula weight. In fact, a greater weight of postassium nitrate must be applied to achieve the same nitrogen application resulting in approximately the same osmotic load on crops making the salt index of questionable value.

It should be noted that the salt index has little relevance to micronutrients since they are applied at far lower concetrations than primary fertilizers and therefore make negligible contributions to soil salinity. In many cases, micronutrients will become toxic to plants at concentrations well below those at which osmotic effects are significant. It is also worth mentioning that it was recently pointed out that the salt index values widely used today are inaccurate or otherwise misleading (2,3). Nevertheless, data on salt index of fertilizer components may be requested by customers or required by regulatory agencies. Most recently, Brazil requested salt index data for *Optibor* TG Boric Acid as a requirement for product registration in that country.

## Discussion

Osmotic pressure, ∏, is a colligative property that can be calculated for various solutes using Equation 1, where *i* is the solute dissociation factor, M is the solute molarity, R is the idea gas constant, and T is the temperature in degrees K. Equation 1 gives osmotic pressure in units of atmospheres if the value of R takes the form 0.082058 $L \cdot atm \cdot mol^{-1} \cdot K^{-1}$. For the present discussion, we will limit T to a value near room temperature, 293 K (20°C), fixing the value of RT at 24.043 L•atm•mol-1, as given by Equation 2.

(1) $\prod = iMRT$

(2) $\prod = iM \times 24.043$

Values for i are determined from the dissociation expressions for sodium nitrate and borax, as given by Equations 3 and 4, giving *i* = 2 for sodium nitrate and *i* = 6 for borax. For boric acid *i* = 1, since it interacts with water only very slightly according to Equation 5 ($K_a = 5.8 \times 10^{-10}$ $mol \cdot L^{-1}$) and the vast majority of boric acid in solution remains nonionized.

(3) $NaNO_3 = Na^+ + NO_3$-

(4) $Na_2B_4O_7 \cdot 5H_2O = 2H_2O = 2\ Na^+ + 2\ B(OH)_4$- $+ 2\ B(OH)_3$

(5) $B(OH)_3 + H_2O = B(O)_4$- $+ H^+$

Equation 2 is reasonably accurate for the strong electrolytes, such as sodium nitrate, at all concentrations, but Equation 3 is only accurate for highly dilute borax solutions. This is because the hydrolysis products B(OH)4- and B(OH)3 strongly associate with formation of polyborates in all but very dilute solutions. Thus, the osmotic pressure of even a moderately concentrated borax solution is difficult to calculate with confidence without empirical information about its osmotic coefficient, also known as the van t'Hoff factor. Fortunately, osmotic coefficients for borax solutions were determined experimentally (4) and can be used to accurately calculate osmotic pressures Equation 6, which includes the osmotic cofficient term. The relatively small osmotic coefficients for sodium nitrate and boric acid are also available and can be used to refine the calculation of salt index (4,5). It can be noted that the osmotic coefficient approaches unity as solution concentration approaces zero. Given that soil boron levels typically fall within the 0.01-5.00 ppm B range (or <0.003% borax equivalent), Equation 2 can be used to calculate osmotic pressure for soil solutions containing agriculturally relevant borax concentrations. Only at higher borax concentrations is Equation 6 required to correct for ion association in the calculation of osmotic pressures.

(6) $\prod = \Phi iM \times 24.043$

## Results

Calculation of salt indices for borax pentahydrate and boric acid involved calculating osmotic pressures at various concentrations for these solutes as well as for sodium nitrate with (Eq. 6) and without (Eq. 2) use of published osmotic coefficients and then taking the ratios of these calculated pressures to determine the final indices. Figure 1 presents a graph of the resulting salt index values for borax pentahydrate and boric acid as a function of concentration with and without application of osmotic coefficient terms to correct for ion association in each case. It should be noted that the uncorrected values, 87.5 for borax pentahydrate and 73.3 for boric acid, are the most appropriate values to use with respect to agriculturally relevant soil concentrations of these solutes.

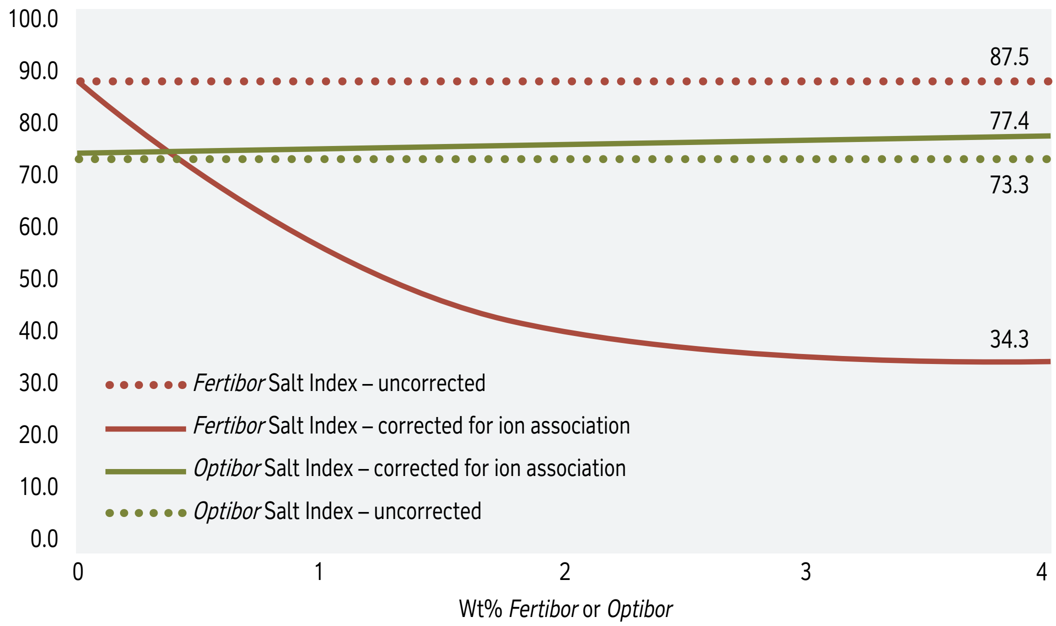


**Figure 1**
Salt index values for borax pentahydrate and boric acid as a function of solution concentration with and without application of the osmotic coefficients to correct for association of chemical species in solution with increasing concentration.

## References

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