Insights

JANUARY, 2000

Demystifying soil analyses

Bottom Line: A good understanding of soil chemistry data is critical to the development of sound fertility and agronomic management programs in turf. But all too often, confusion is created because we are taught to interpret this information as though there is a single "perfect" value for each soil nutrient that we must strive to achieve. In a different approach to understanding soil chemistry data, we have applied a mathematical method known as "fuzzy logic" to help demonstrate that there is no such thing as a perfect level for each nutrient. Instead, there is a very large range of values that can result in high quality turf. This more realistic approach can help you in the interpretation of soil analytical data, and in the design and implementation of more effective and successful fertility programs.

What do earthquake prediction systems, the Space Shuttle docking system, automobile cruise controls and golf course soil chemistry data have in common? At first glance, it's hard to find the connection. But they all share the fact that they can benefit from the application of "fuzzy logic", a mathematical concept first described by computer scientist Lofti Zadeh in 1965. Zadeh felt that conventional evaluation systems, which force extreme judgements such as "yes or no" or "hot or cold", were oversimplifications of the real world. In reality, there are often an infinite number of intermediate values between the two extremes. For example, instead of only having the words "hot" or "cold" to choose from, fuzzy logic would allow us to use "lukewarm" or "somewhat cool" or other in-between values as well.

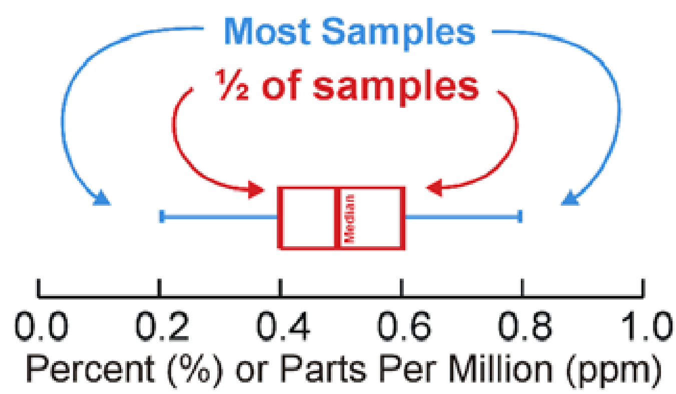
What does all of this have to do with the interpretation of golf course soil chemistry data? We find that very frequently, soil chemistry data is also represented in the conventional way -- as either "good" or "bad" -- as though there were only one, ideal value for each nutrient that we deal with. But in reality, there is no one "perfect" value for each nutrient. Instead, there is a continuous range of numbers – a fairly fuzzy range, in fact – with values that will all result in high quality turf. In the past, we have applied this concept to the analysis of turf tissue nutrient values (PACE Insights, November 1998) and in this issue, we are broadening it to also include analysis of golf course soil chemistry data.

Does fuzzy logic work for all applications? Certainly not! Fuzzy speaking and spelling wouldn't be tolerated by most people, nor would we be very happy with our banks if they used fuzzy techniques for tallying our account balances. But for complex systems such as plant nutrition and growth, it can be a useful tool that helps us to streamline management decisions. For this reason, we have chosen to apply fuzzy logic and a statistical representation known as "box plots" to the interpretation of soil chemistry data, in hopes of providing you with a more realistic look at your test results.

Simplifying with the box plot

Over the past several years, PACE Turf has accumulated a tremendous quantity of data on golf course soil chemistry. This is valuable data, but because of the large size of the data set, hard to represent using conventional methods. Using box plots, we can illustrate these results in a clear and understandable way.

The diagram below is a box plot for a fictional soil nutrient, where the values covered by the red box (in this case, 0.4 – 0.6), represents the range of values seen in the central half of the soil samples tested. In other words, the red box represents the optimum range of values for each nutrient. The vertical red line inside the box represents the median – the value at which half the samples were higher and half were lower. In the diagram, half of the samples had values below 0.5 (the median), and half of the samples had values above 0.5.



The horizontal blue lines extending from the box are called "whiskers" by statisticians, and represent the range that most of the samples fell into. In the diagram below, most of the samples read between 0.2 and 0.8. Soils with values that are encompassed by the "whiskers" (0.2 – 0.4 and 0.6 – 0.8) are probably performing acceptably, but need to be watched.

The PACE Turf soil chemistry data set

Between 1992 and 1998, PACE Turf, in collaboration with over 60 superintendents from California and Illinois, collected over 250 soil samples from greens and fairways that were classified as "good performers" by the superintendents. The samples were subjected to chemical analysis by Brookside Laboratories in New Knoxville, OH, where the majority of nutrients were analyzed using Melich III extraction. The data was then analyzed by PACE. The results for the 24 nutrient measurements evaluated are represented in the box plots on pages 3 - 4.

Using the box plots to evauate your soils

The box plots presented on pages 3 – 4 represent soil chemistry values from a large number of good performing greens and fairways. To see how your soils measure up, compare the values in your soil reports with the range of values that fall within the "box" for each nutrient.

- If your soil test results for a given nutrient fall within the box, you are in very good shape.
- If your soil test results for a given nutrient fall outside the box, but within the range illustrated by the "whiskers" (horizontal lines), your turf may look good, but you'll need to keep an eye on it – you're in a borderline situation.
- If your soil test results for a given nutrient fall outside either end of the "whiskers", it's time to take some action. Your results are atypical and probably represent either a deficiency or excess of that nutrient. Alternatively, your soil type may be of an unusual type that needs special attention and/or different analytical methods. Future issues of PACE Insights will present methods for getting back "inside the box" for key nutrients.

Lessons learned from reviewing the box plots

By presenting soil chemistry results in the form of box plots, it becomes possible to look at a much larger set of data, and to easily compare results among many locations and golf courses. Some of the trends that are revealed when the data is represented this way include:

Location: Although soils, climates and turf varieties differ significantly between Illinois and California, the soil nutrient levels that led to good performing turf were reassuringly similar among all locations. Some notable exceptions include higher sulfur levels in California, probably due to the use of gypsum (calcium sulfate) on a regular basis to decrease sodium levels. And the higher electrical conductivity (dissolved salts) and sodium values in California reflect low rainfall and poor quality irrigation water.

pH: Many textbooks suggest that a pH of 6.2 is necessary for optimum turf growth, and that more basic pHs – those above 7.0 -- can be detrimental. The data we present here contradicts this, with the large majority of good performing greens and fairways demonstrating soil pHs of 7.0 or above. We can therefore conclude that while a pH of 6.2 may be highly beneficial, higher soil pHs can still support high quality turf if other nutrients and agronomic conditions are optimized.

Ammonium: We have long advised that ammonium levels higher than 7 - 10 ppm could cause turf stress and damage. The data presented on page 3 confirms this, where the good performing soil samples all had ammonium levels lower than 10 ppm.

Effect of high soil ammonium levels on bentgrass quality.

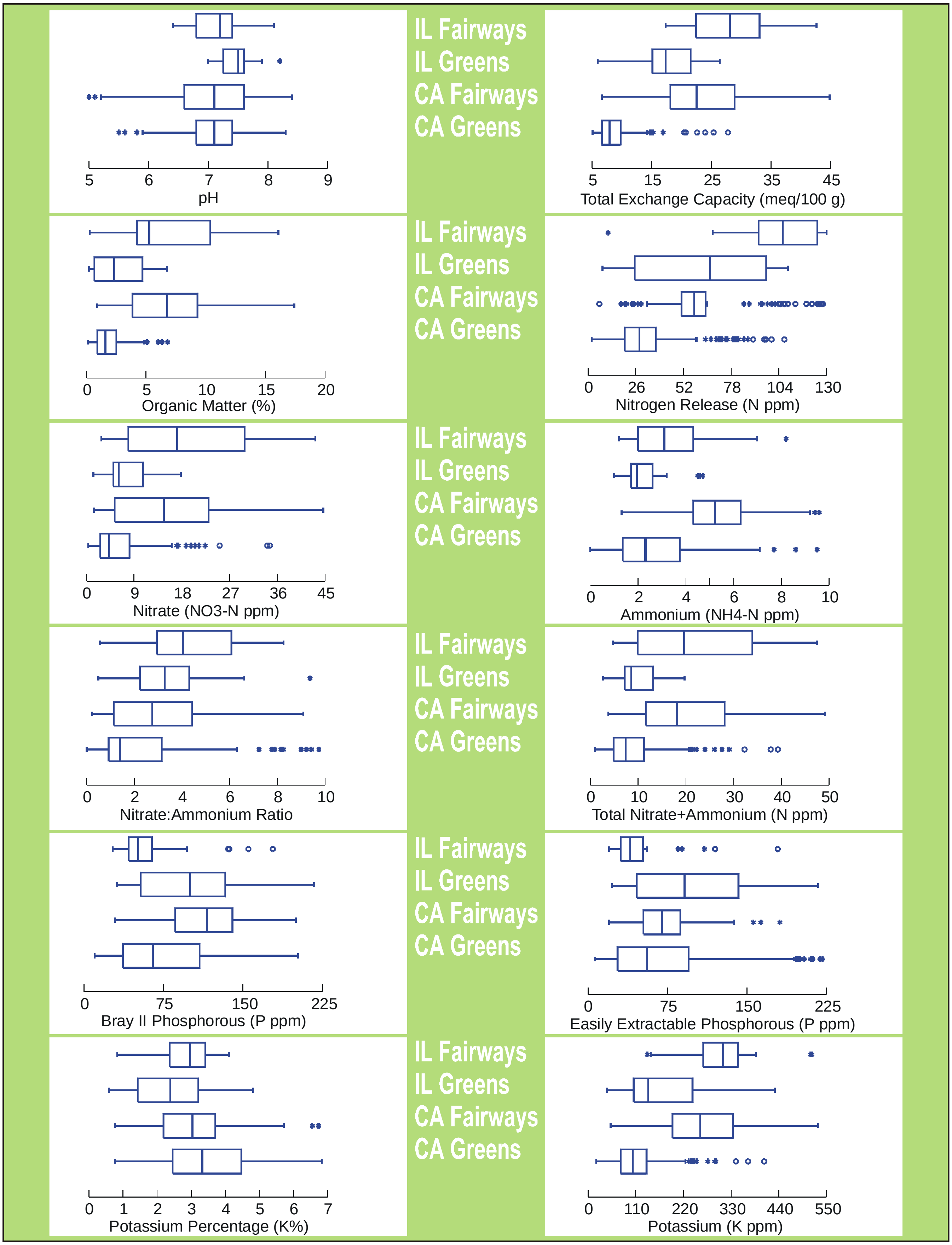
Sulfur: Similarly, it is widely believed that sulfur levels above 50 ppm can be deleterious to turfgrass. However, the high sulfur values that we observed on good performing greens and fairways indicates that high levels of sulfur may not be as detrimental to turf health as previously believed.

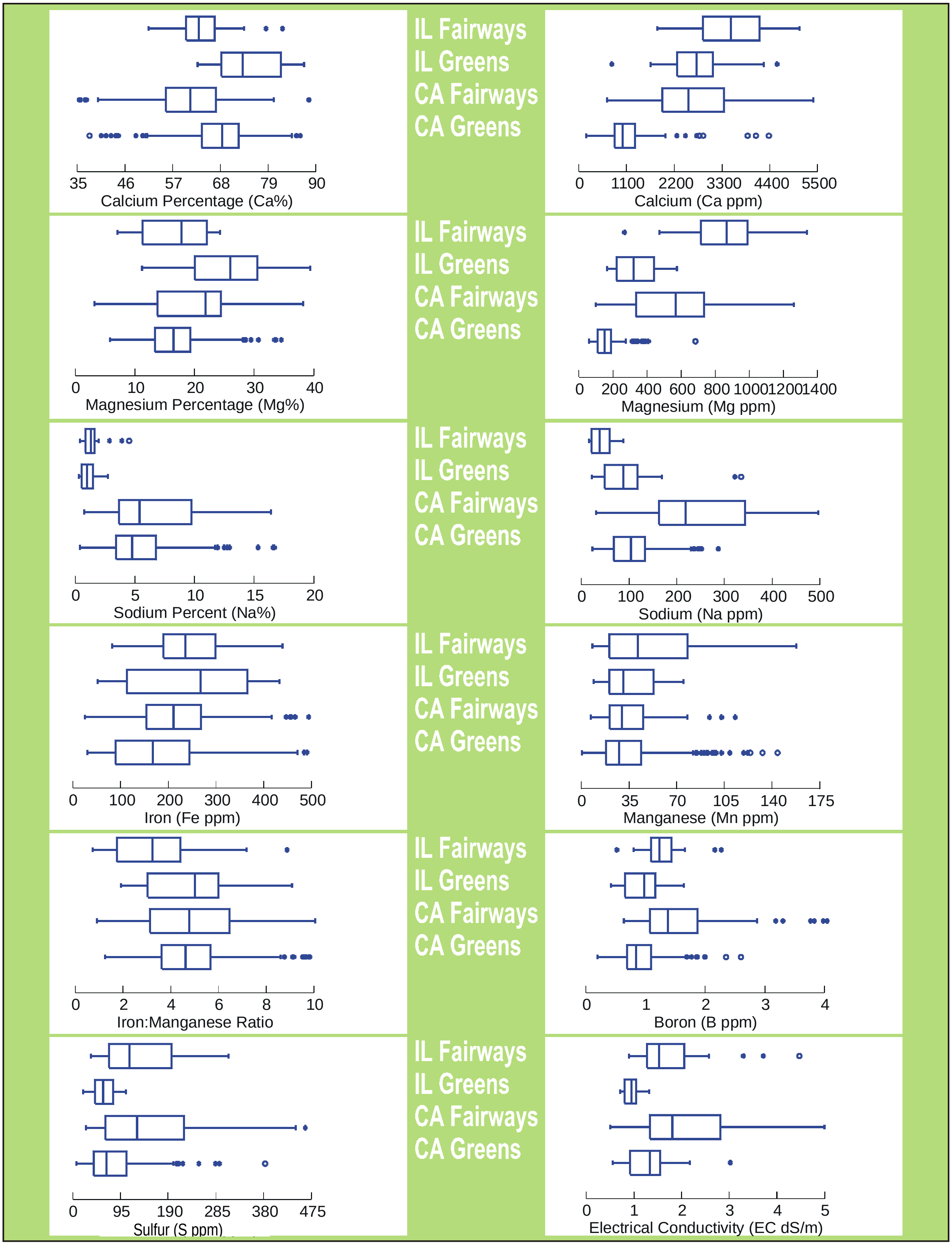
Why is soil chemistry data so fuzzy?

The results shown on pages 3 - 4 indicate that for each soil nutrient, there is a large range of values that will result in high quality turf. In other words, the soil chemistry data is fuzzy. This is mostly because turf quality – the ultimate measurement by which all of our efforts are judged – is itself a fuzzy parameter that is the result of a complex interaction between soil type, weather, irrigation, rainfall, turf variety, management practices, etc. There is no one ideal nutritional recipe for the soil that results in high quality turf. Instead, there are many different combinations and ratios of nutrients that can produce good turf.

Units used in the box plots

The box plots presented on pages 3 – 4 illustrate soil chemistry results for good performing greens and fairways from California and Illinois. Total exchange capacity is reported in milliequivalents per 100 grams of soil (meq/100 g). Electrical conductivity is reported in dS/m (decisiemens per meter), which is equivalent to millimhos/cm. The major cations (Ca, Mg, K, Na) are represented two ways: as parts per million (ppm), a measure of the number of milligrams of the nutrient per kilogram of soil, and as percentages (%), the percent of the total cation exchange capacity represented by each element. Nitrogen release is an estimated annual release of nitrogen from soil organic mater. And finally, organic matter is represented as a percentage on a weight basis.


IL Fairways
IL Greens
CA Fairways
CA Greens
5 6 7 8 9
pH
5 15 25 35 45
Total Exchange Capacity (meq/100 g)
0 5 10 15 20
Organic Matter (%)
0 26 52 78 104 130
Nitrogen Release (N ppm)
0 9 18 27 36 45
Nitrate (NO3-N ppm)
0 2 4 6 8 10
Ammonium (NH4-N ppm)
0 2 4 6 8 10
Nitrate:Ammonium Ratio
0 10 20 30 40 50
Total Nitrate+Ammonium (N ppm)
0 75 150 225
Bray II Phosphorous (P ppm)
0 75 150 225
Easily Extractable Phosphorous (P ppm)
0 1 2 3 4 5 6 7
Potassium Percentage (K%)
0 110 220 330 440 550
Potassium (K ppm)


IL Fairways
IL Greens
CA Fairways
CA Greens
35 46 57 68 79 90
Calcium Percentage (Ca%)
0 1100 2200 3300 4400 5500
Calcium (Ca ppm)
0 10 20 30 40
Magnesium Percentage (Mg%)
0 200 400 600 800 1000 1200 1400
Magnesium (Mg ppm)
0 5 10 15 20
Sodium Percent (Na%)
0 100 200 300 400 500
Sodium (Na ppm)
0 100 200 300 400 500
Iron (Fe ppm)
0 35 70 105 140 175
Manganese (Mn ppm)
0 2 4 6 8 10
Iron:Manganese Ratio
0 1 2 3 4
Boron (B ppm)
0 95 190 285 380 475
Sulfur (S ppm)
0 1 2 3 4 5
Electrical Conductivity (EC dS/m)