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Using Nomograms for Evaluating Plant Morphological and Physiological Data

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ABSTRACT

Simple, graphical techniques are available to plant professionals to evaluate morphological and physiological data. The most commonly used graphs show only one variable at a time. However, plotting two variables into a simple coordinate system and adding diagonal lines to show relationships between those two variables greatly enhances the interpretive possibilities available to the plant practitioner by facilitating simultaneous comparisons of multiple variables. This easy-to-use nomogram is useful for evaluating and comparing plant responses to treatments and environments, plant development over time, and stock quality among species, genotypes, and other factors. This article describes how to construct this type of graph, the kind of data for which this technique is most useful, and how it can be applied to operational and research activities.

Keywords: nomogram, vector analysis, nutrients, morphology, data analysis

Plant professionals, such as nursery growers and reforestation personnel, are increasingly expected to have a greater quantitative understanding of plant physiology and morphology as related to growth projections, economic returns, and plant quality. As a result, intensive data collection has become much more commonplace than ever before, and a variety of tools to interpret that data have been explored.

Most graphical techniques for examining plant data are based on a single measure of data (e.g., a bar graph of height, nutrient concentration, or biomass). However, there is a simple graphical technique that allows for simultaneous comparison of related variables in an integrated graphic format. This technique has been used over the past few decades to examine plant responses to various treatments with the majority of these focused on plant nutrients (Timmer and Miller 1991, Hawkins et al. 1998, Salifu et al. 2006). However, this technique can also be used to examine many other types of plant data and could be useful well beyond a research context. This technique is often referred to as *vector diagrams* or *vector analysis* (Haase and Rose 1995) because vectors can be drawn into the graph to show relative shifts in data. However, the use of vectors is not always required. *Nomogram* is a more general term to describe these graphs. A nomogram is defined as a two-dimensional graphic representation of numerical relations among three interdependent variables; by drawing a straight line through specific points of two variables, the value of a third variable can be determined. Nomograms are considered a graphical calculating device, like a slide rule. Although this technique may sound complicated, it is very simple to use. The objective of this report is to provide a clear description of how to create and interpret nomograms using plant data such that anyone can easily apply this technique to operational or research data.

Types of Data

Any three variables that are mathematically interdependent can be plotted in a nomogram. The three variables must satisfy the linear function $a = f(b, c)$.

Two examples are as follows:

Foliar nutrient content

$$= \text{Nutrient concentration (\%)} \times \text{Foliar biomass (g)} \quad (1)$$

$$\text{Ratio of shoot to root} = \text{Shoot biomass/Root biomass.} \quad (2)$$

Regardless of the type of data used, it is always best to follow the "three Rs" of sample collection: randomization, representation, and replication. By using random sample selection, bias is avoided. This can be accomplished by using a random number generator on the computer or drawing numbers from a deck of cards to designate the plants to be sampled. In addition, samples should be representative of the entire population for which one intends to infer conclusions. For example, if data results are to be applied to a particular tree species growing in three greenhouses, then random samples should be collected from all three greenhouses. Furthermore, it is important to collect more than one sample from each group to be examined (e.g., stock type, treatment, or species). The number of replications depends on available resources, as well as any statistical objectives. More replicate samples collected from each group results in better data quality (accuracy).

Content and Concentration

There is an integral relationship between content and concentration of any plant substance within a particular plant biomass. Content and concentration of plant nutrients are the most common data used in nomograms in the literature. However, this technique can also be used to examine any plant component for which content can be calculated from the biomass and concentration (i.e., concentration × biomass = content). Paunonen et al. (2009) created nomograms showing relative levels of salicylates, acids, flavonoids, and tannins for dark-leaved willow clones (*Salix myrsinifolia* Salisb.). Other examples of using nomograms to examine concentration and content of plant substances are with phenolic compounds as influenced by atmospheric factors (Peltonen et al. 2005), root and needle starch levels as influenced by moisture stress (Khan et al.

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