Use of Vector Diagrams for the Interpretation of Nutrient Response in Conifer Seedlings

Todd Birchler, Diane L. Haase and Robin Rose[1]

Birchler, T.; Haase, D.L.; Rose, R. 1996. Use of Vector Diagrams for the Interpretation of Nutrient Response in Conifer Seedlings. In: Landis, T. D.; South, D. B., tech. coords. National Proceedings, Forest and Conservation Nursery Associations. Gen. Tech. Rep. PNW-GTR-389. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 246-247. Available at: http://www.fcanet.org/proceedings/1996/birchler.pdf

Analysis of seedling nutrient response using vector diagrams enables comparisons of nutrient concentration, nutrient content, and plant growth to be made simultaneously in an integrated graphic format (Haase and Rose 1995). Vector analysis is very useful for examining plant responses to various nursery cultural and silvicultural treatments, and because it is comparative, interpretations may be made independent of predetermined critical levels or ratios. In a nursery setting, vector analysis enables the easy detection of nutrient imbalances, nutrient interactions, and dilution effects.

To construct a vector diagram, all that is needed is the nutrient concentration obtained from laboratory analysis and some measure of unit dry weight of the seedling. The determination of which unit dry weight to use depends on the type of study and the objectives of the study. Commonly used units include the dry weight of a specific number of needles, whole plant dry weight, or shoot dry weight. The nutrient content is then determined by multiplying the nutrient concentration by the unit dry weight.

Absolute numbers may be used, however, relative values enable comparisons to be made between many trials and nutrient elements. To normalize the values, a reference point is determined and set to 100. The other treatments are determined as percentages of the reference point. Determination of the reference point is important and influences the subsequent interpretation. Data from the control treatment is a commonly used reference point.

After normalization, relative nutrient concentration is plotted along the Y-axis and relative nutrient content along the X-axis. The resulting data point will correspond to the relative unit dry weight along the diagonal Z-axis. The vectors are then drawn from the reference point to each subsequent data point (Figure 1).

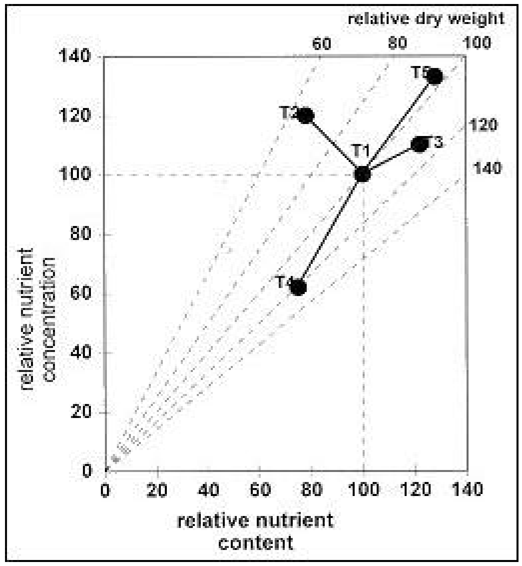

Figure 1. Example of vector diagram showing relative responses of nutrient content, nutrient concentration, and unit dry weight for five treatments.

Interpretation of a vector diagram is based on the direction and magnitude of the vector. Horizontal from the reference point signify an increase or decrease in nutrient content, vertical shifts signify an increase or decrease in nutrient concentration, and shifts on either side of the diagonal Z-axis signify an increase or decrease in unit dry weight. Timmer and Stone (1978) developed interpretive guidelines for the vectors. A nutrient is considered in **sufficient** quantity when there is an increase in nutrient content and unit dry weight without a change in nutrient concentration. If there is an increase in nutrient concentration, nutrient content, and unit dry weight, the nutrient is considered **deficient**.

If there is a decrease in nutrient concentration along with an increase in nutrient content and unit dry weight, **dilution** is the result. **Luxury consumption** occurs when increases in nutrient content and concentration are not accompanied by an increase in unit dry weight. Nutrients are considered to be in **excess** when there is a decline in nutrient content and unit dry weight. A decline in all three parameters may provide evidence of **antagonism** between nutrients.

Vector analysis is useful for illustrating seedling responses to factors such as fertilizer regimes, pH, moisture regimes, seedbed density, stocktype, and provenance. For example, Teng and Timmer (1990) used a single vector diagram to examine nutrient interactions in response to various levels of P. Timmer (1985) used vector diagrams to illustrate micronutrient deficiency and magnesium toxicity in response to lime applications. Vector diagrams were also used to illustrate carbon and nitrogen partitioning between shoots and roots of red pine seedlings grown under various fertilization and moisture regimes (Timmer and Miller 1991).

Vector analysis need not be limited to nutrients. Khan et al. (1996) used vectors to illustrate changes in shoot and root starch levels of containerized Douglas-fir seedlings in response to different soil water contents. Czapowskyj et al. (1980) showed relative differences in ash levels for both red spruce and balsam fir treated with combinations of lime, N, and P.

Vector analysis is a powerful tool for illustrating and interpreting seedling responses to various treatment or conditions. It requires one extra measurement in addition to nutrient concentration: unit dry weight. The information gained, and the ease with which the results may be interpreted, is well worth the effort.

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[1]*Graduate Research Assistant, Associate Director, and Project Leader, Nursery Technology Cooperative, Oregon State University, Department of Forest Science, Corvallis, OR 97331.*

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