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A Computational Approach for Balancing Competing Objectives in Winegrape Production

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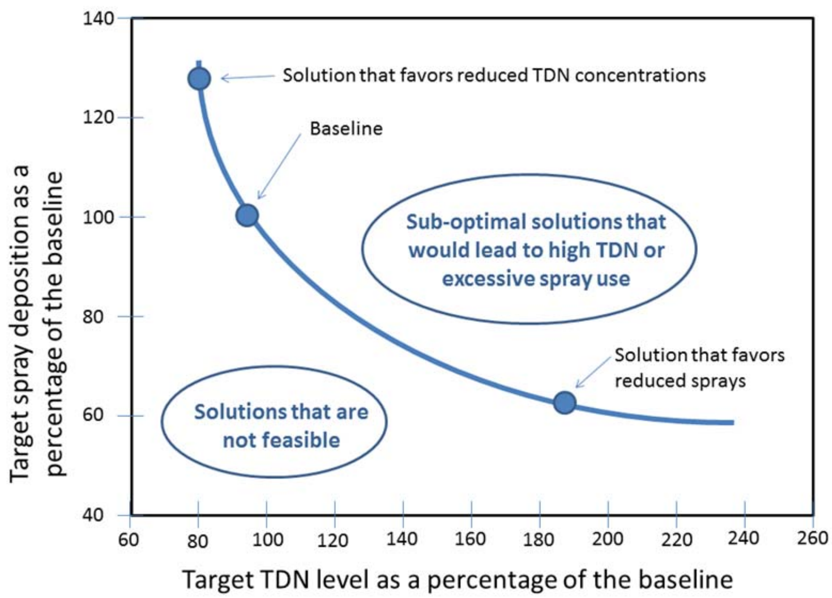
Background. Research often offers targets to improve fruit composition, reduce disease pressure, and optimize vine canopy and architecture, advising a recommended number of leaf layers or a particular ratio of leaf area to fruit weight. However, these targets are unlikely to be optimal for all sites, and growers may want to optimize not one but several factors. In some cases, production goals can be at odds with each other. We have developed a computational framework to balance competing vineyard objectives and use it in a hypothetical scenario in which a Riesling grower wants to both reduce the eventual wine petrol aroma (by decreasing cluster light exposure in the fruit zone) and minimize the amount of fungicide used (by opening up the canopy fruit zone to reduce disease pressure and increase spray penetration).

James Meyers, a postdoctoral associate with Justine Vanden Heuvel, is using computational tools to optimize vineyard management decision making when dozens of objectives must be considered.

Experimental design. We used an Evolutionary Algorithm, a type of solution-finding methodology that hones in on optimal solutions for problems which have more than one objective. The goal was to find a solution that would minimize the concentration of precursors for petrol aroma caused by TDN (1,1,6-trimethyldihydronaphthalene) while maximizing the amount of fungicide spray residue. Cluster exposure (measured as the average percentage of ambient sunlight that is able to reach a fruit clusters in the canopy) and the relative amount of spray residue were variables in the model. Data from studies on the response of TDN to sunlight in the fruit zone and the response of spray residue to cluster exposure were used as input to drive the analysis.

Results. We solved for a cluster exposure from 0% to 50% of ambient sunlight and identified the optimal solutions to the problem of reducing cluster exposure while increasing spray residue (Figure 1).

Figure 1: Results of the optimization. The blue line indicates all of the optimal, valid solutions.



The light exposure values that would result in the optimal levels of TDN and spray were calculated. To achieve the maximum possible reduction in TDN (80%) would require shaded fruit (only 20% of ambient light reaching the clusters) and that the spray program be adjusted to increase spray residue by approximately 31% using methods such as altering the droplet size or tank concentration. To achieve a 30% reduction in spray material using canopy management would lead to an 88% increase in TDN concentration.

Conclusions

- This method provides computational support to optimize decision making by vineyard managers in situations where they have competing objectives.
- This model can be expanded to optimize other measurable objectives, such as reduced fertilizer use, reduced water use, or increased phenolic content.
- Knowing the optimal target can prevent excessive use of inputs, failure to achieve objectives, or setting unattainable objectives.

The bottom line: The use of computational methods can increase the utility and commercial impact of research data and align vineyard management practices with overall objectives.

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