PVCURVE: A Computer Spreadsheet Template for Evaluating Pressure-volume Curves

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Pressure-volume (PV) analysis is often considered to give the most accurate estimate of symplastic osmotic potential (Tyree and Jarvis, 1982). Additional information about tissue water relations can also be computed from PV curves: estimates of bulk cell wall elasticity, symplastic water volume, and turgor potential at various states of tissue water content. The generation of PV curves is a time-consuming procedure, however, and involves considerable computation. Computer programs of varying sophistication that attempt to model the PV relation have been described before (Schulte and Hinckley, 1985). This article describes a computer spreadsheet template for traditional evaluation of a PV curve through linear regression of the zero turgor segment. The template allows real-time plotting of the inverse of water loss relation derived with "expressed sap" or "bench-top drying" protocols, provides estimates of most commonly calculated PV characteristics, and permits instant graphic visualization of changes in water potential components with changes in water potential, total tissue water, and symplastic water content. An acquaintance with spreadsheet software and a thorough understanding of pressure-volume theory on the part of the user is assumed.

The template is organized into six discrete portions, each occupying roughly one screen of the spreadsheet and accessed with a key-stroke. The first portion identifies the sample and lists water relations information at each level of tissue hydration in the PV curve. Once balance pressures, incremental sample fresh weights, final sample dry weight, and clingfilm weight (if used) are entered into appropriate cells, a macro allows quick calculation of total water loss, inverse balance

pressure, relative water content, relative osmotic (or symplastic) water content, volume of symplastic water, water potential, turgor potential, and osmotic potential at each stage of tissue hydration. The inverse balance pressure/tissue water loss relation is automatically plotted, allowing the user to view the PV curve as it develops and to select points (3 to 12) in the zero turgor, linear segment of the plot for linear regression. This first portion of the template records the regression information: number of points regressed, regression and correlation coefficient, slope, and x and y intercepts. Each new regression replaces the previous one; in this way, several regressions may be performed within seconds and the best-fit line selected (based on the predetermined criteria of the investigator).

The second portion lists most of the characteristics commonly calculated in PV analysis (Table 1). Routine decisions regarding which PV characteristics can be meaningfully derived from a particular PV curve are still the responsibility of the investigator; drawbacks of PV analysis (Cheung et al., 1976; Tyree and Richter, 1981a, 1981b) are not eliminated or reduced by the program. The template's chief utility is in hastening calculations

and graphics. The remaining portions of the template show a legend of macros (which simplify spreadsheet movements and computations), macro definitions, regression calculations, and a table of those points used in the most recent regression. One macro allows selection of graphs that portray total water potential and each water potential component as a function of relative tissue water content or relative osmotic water content. Finally, a macro is given that extracts PV information for each curve and organizes it for insertion into a summary template.

Templates have been written for IBM-compatible machines with Quattro (Borland, Seotts Valley, Calif.) for PV analysis using either a pressure chamber or psychrometer. (The psychrometer template contains a calibration subtemplate and converts WV readings into water potential values.) Templates may be obtained by sending \$3.00 to me to cover diskette, mailer, and postage.

Literature Cited

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Table 1. An example of the summary screen within the PVCURVE template: characteristics computed from a PV curve constructed from a rose root sample using a pressure chamber.

Total sample water =	0.7237 g	Scroll down to see all information.
Fresh weight @ full turgor =	0.9060 g	
Water potential @ full turgor =	-0.05 MPa	Press Home to return to start of spreadsheet.
Osmotic potential @ full turgor =	-0.54 MPa	
Turgor potential @ full turgor =	0.49 MPa	
Water content @ full turgor =	79.9 %	
Water potential @ turgor loss (calc) =	-0.82 MPa	
Water potential @ turgor loss (meas) =	-0.83 MPa	
Turgid/dry weight ratio =	5.0	
Relative dry weight =	25.2	
RWC @ turgor loss =	67.0 %	
ROWC @ turgor loss =	65.7 %	
Lowest RWC plotted =	21.9 %	
Symplastic water percentage =	96.1 %	
Apoplasmic water percentage =	3.9 %	
N (total $\mu\text{osmol/sample}$) =	152.2 μosmol	
N/g symplastic water =	218.9 $\mu\text{osmol/g}$ or (mosmol/kg)	
N/g total water =	210.4 $\mu\text{osmol/g}$	
N/g sample fresh wt =	168.0 $\mu\text{osmol/g}$	
N/g sample dry wt =	835.1 $\mu\text{osmol/g}$	

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