MacroMixer: A Spreadsheet Program to Aid Mixing Macronutrients for Solution Culture

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Abstract MacroMixer, a microcomputer spreadsheet program, offers 15 commonly used nutrient sources for quick formulation of a macronutrient mix in solution culture. The program displays the total concentration of each macro-element and the contribution of each source when the user specifies the desired volume of the mix and the amount of source considered. This program, used with trial and error, eases computational complexity, as sources may contain more than one controlled macro-element.

In solution culture experiments, determining the quantity of nutrient sources to dispense in a solution mix is time-consuming. When a source contains more than one controlled element [e.g., Ca and N in $\text{Ca}(\text{NO}_3)_2$], a change made to control one element (Ca) requires an adjustment to the other element (N). Additional adjustments may be necessary for the types of ions, volatility, pH, and cost (Resh, 1989). Since a complex computation can be simplified by using a spreadsheet (Ozminowski et al., 1991), MacroMixer, a microcomputer spreadsheet program, was developed to ease the computational chore of mixing macronutrients.

Determining a solution mix with MacroMixer is a two-step process (Fig. 1). In the first step, the user specifies the final volume of the mix at the beginning, although it can be changed later. Next, the user specifies the desired concentration (in milligrams per liter) for the primary controlled element in each source in the respective spreadsheet cell. The program computes the weight (volume for liquids) of source required in the mix. For efficiency, we recommend starting with a source that contains two controlled elements. The concentration of the second controlled element in the source will be adjusted later.

In the second step, the weight (or volume) of each source computed in the first step serves as a starting value. The program computes all available elemental concentrations from each source. Totals of all elements in the final solution mix are also computed. The deficit or excess in the second controlled element can be adjusted by adding or reducing a source that

contains only the second controlled element. This step can be repeated easily for refining the mix, as an adjustment made to one source is reflected instantly on the source's elemental contributions and also on the totals from all sources. This two-step process allows quick formulation of a solution mix.

The program accommodates a maximum of seven sources and seven elements in a

standard computer display (80 columns $\times$ 25 lines), while each numeric value holds five significant digits, including one decimal. However, users can increase the limits for more sources and elements. Fifteen sources are incorporated presently in the program. The spreadsheet format hides computational constants and formulae for a clear view of solution composition. The constants (atomic weight, formula weight, purity, and density) are stored in a separate screen, while formulae are stored as cell formats. Thus, users are encouraged to exercise trial and error to achieve the most desirable solution mix.

To demonstrate MacroMixer's use, we duplicated the macronutrients in Hoagland's solution 1 (Hoagland and Arnon, 1950) by entering the recommended sources and elemental concentrations (Fig. 2) in the program. The macro-element composition in the solution mix and the weight of each element delivered by 100 ml of mix are displayed. The contributions of two sources of N and K can be observed readily. Modifications can be made to the final volume, the solution's concentration, and source by entering numbers in the appropriate cells.

We used only four mineral salts for demonstrating Hoagland's solution 1. However, additional sources, including ammonium nitrate, ammonium phosphate, urea, phosphoric acid,

Fig. 1. The diagram of MacroMixer spreadsheet program that incorporates a two-step process to achieve a desirable solution mix for macronutrients. This diagram's arrangement closely resembles that of the program on a computer monitor.

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Final volume →	20 l							
Appl per pot →	100 ml	N	P	K	Ca	Mg	S	(Na)
Amount needed		Desired concentration in mg/l						
HNO ₃	0.00 ml	0.0						
NaNO ₃	0.00 g	0.0						
NH ₄ H ₂ PO ₄	0.00 g		0.0					
KH ₂ PO ₄	2.78 g		31.0					
KNO ₃	10.11 g			195.5				
Ca(NO ₃) ₂ ·4H ₂ O	23.86 g				200.4			
MgSO ₄ ·7H ₂ O	9.86 g					48.6		
Amount dispensed		Elements present in mg/l						
HNO ₃	0.00 ml	0.0						
NaNO ₃	0.00 g	0.0						0.0
NH ₄ H ₂ PO ₄	0.00 g	0.0	0.0					
KH ₂ PO ₄	2.78 g		31.0	39.1				
KNO ₃	10.11 g			195.5				
Ca(NO ₃) ₂ ·4H ₂ O	23.86 g	140.0			200.4			
MgSO ₄ ·7H ₂ O	9.86 g					48.6	64.1	
Element total	mg/l	>210.0	31.0	234.6	200.4	48.6	64.1	0.0
Delivery	mg/pot	→ 21.0	3.1	23.5	20.0	4.9	6.4	0.0

Fig. 2. The macronutrient composition for Hoagland's solution 1 (Hoagland and Arnon, 1950) as an example of a MacroMixer application. The program displays the amount of each recommended compound needed to make 20 liters of solution mix (A), the element concentrations from each source (B), the total of each element (C), and the weight of each element delivered in 100 ml of solution mix (D).

ammonium sulfate, potassium sulfate, potassium chloride, and magnesium nitrate, are incorporated in the program for general use.

MacroMixer requires a microcomputer that runs Lotus 1-2-3 (Lotus Development Corp., Cambridge, Mass.) or compatible spreadsheet programs. A minimum configuration for a DOS computer to run Lotus 1-2-3 is 256K RAM and a floppy disk drive. Instructions for program use are included on the program diskette. Researchers can obtain MacroMixer by sending a self-addressed diskette mailer with a formatted diskette to O.K. or R.A.C.

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