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MACRONUT: Calculation Software for Custom-mixed Nursery Fertilizers

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ADDITIONAL INDEX WORDS. container nursery, nutrient ratios, nutrient solutions

SUMMARY. MACRONUT, a software program for microcomputers, calculates mixing rates of 17 commonly used nutrient sources of six mineral macronutrients for custom-mixed fertilizers. The software alleviates the need for the cumbersome calculations required to develop or adjust custom

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mixed fertilizers. The software can be used by field professionals and as an instructional tool for teaching horticultural students how to develop custom fertilizers for container nursery crops.

M any container nurseries using liquid-based fertility programs use custom-mixed fertilizers (nutrient solutions). Custom-mixed liquid fertilizers offer several advantages over commercial liquid fertilizers, including reduced costs and the ability to design nutrient

Fig. 1. Equations used to calculate mixing rates for compounds recognized by MACRONUT. X is the target amount of the nutrient in parts per million set by the user; Y is the milligrams required to mix of the source compound to achieve the target amount of the nutrient; and, Z is the amount, in parts per million, of the associated nutrient provided by the compound is applicable. Target amounts of nitrogen are reported either as NH_4 or NO_3, as MACRONUT allows the user to prioritize between these two forms of nitrogen.

Screen A: Target Levels Input Screen.

```
What is the ppm target level of total Nitrogen in the applied solution? 150
<Enter>
What is the percentage of total Nitrogen derived from NO3  compounds? 50
<Enter>
What is the ppm target level of Phosphorus in the applied solution? 75
<Enter>
What is the ppm target level of Potassium in the applied solution? 75
<Enter>
What is the ppm target level of Magnesium in the applied solution? 40
<Enter>
What is the ppm target level of Sulfur in the applied solution? 52 <Enter>
What is the ppm target level of Calcium in the applied solution? 0 <Enter>
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Because several of the compounds may supply more than one of the macro-
nutrients, deriving a formulation that exactly meets the ppm target levels
may not be possible.  Therefore a 5% tolerance is incorporated to allow for
formulation using specified criteria.


Press enter to continue...? <Enter>
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Screen B: Output Target Levels, Nutrient Sources and Mixing Rates.

Nutrient	ppm in Applied Solution	Target ppm
Magnesium	40	40
Sulfur	52	52
Potassium	75	75
Phosphorus	75	75
Ammonium	75	75
Nitrate	75	75
Nitrogen	150	150

```
The following table lists the compounds and amounts to use to develop the
stock solution to achieve the desired concentration in the applied
solution.
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Source	Grams/Liter	Grams/Gallon
Magnesium Sulfate	40.00	151.41
Potassium Carbonate	13.39	50.70
Phosphoric Acid	23.44	88.72
Ammonium Nitrate	44.12	167.00

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Would you like a printed copy  y/n?
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Table 1. Sources of mineral macronutrients recognized as nutrient sources by MACRONUT. MACRONUT was written for use with technical grades of these compounds. Analyses given are N–P$_2$O$_5$–K$_2$O–Ca–Mg–S.

Compound name	Source for					
	N	P	K	Mg	S	Ca
Ammonium nitrate (NH$_4$NO$_3$) [34–0–0]	X					
Ammonium sulfate ((NH$_4$)$_2$SO$_4$) [21–0–0–24S]	X				X	
Calcium nitrate(Ca(NO$_3$)$_2$) [15–0–0–17Ca]	X					X
Diammonium phosphate ((NH$_4$)$_2$HPO$_4$) [21–54–0]	X	X				
Dipotassium phosphate (K$_2$HPO$_4$) [0–40–54]		X	X			
Magnesium sulfate (MgSO$_4$) [0–0–0–13S–10Mg]				X	X	
Monoammonium phosphate (NH$_4$H$_2$PO$_4$) [11–48–0]	X	X				
Monopotassium phosphate (KH$_2$PO$_4$) [0–52–34]		X	X			
Nitric acid (HNO$_3$(70% w:w))	X					
Phosphoric acid (H$_3$PO$_4$(85% w:w))		X				
Potassium carbonate (K$_2$CO$_3$) [0–0–68]			X			
Potassium chloride (KCl) [0–0–63]			X			
Potassium nitrate (KNO$_3$) [13–0–45]	X		X			
Potassium sulfate (K$_2$SO$_4$) [0–0–53–18S]			X		X	
Sodium nitrate (NaNO$_3$) [16–0–0]	X					
Sulfuric acid (H$_2$SO$_4$(93% w:w))					X	
Urea (CO(NH$_2$)$_2$) [45–0–0]	X					

ratios to optimize specific crop production. However, several limitations exist to using custom fertilizers. First, availability and costs of raw materials can fluctuate significantly. This can significantly affect the cost efficiency and reliability of using custom-mixed fertilizers. Second, making slight changes in the fertilizer, either in rates applied or in sources of nutrients, requires several cumbersome calculations to be performed. MACRONUT (Harrington and Glass, 1996) alleviates these obstacles to using custom-mixed liquid fertilizers supplying six mineral macronutrients (Fig. 1).

The MACRONUT program is designed to help container nurseries, researchers, and students calculate custom-formulated, water-soluble fertilizers. The MACRONUT program uses 17 commonly available compounds traditionally used to supply mineral macronutrients in liquid fertilizer formulations. MACRONUT is designed to allow the user to set the ratios of nitrogen, phosphorous, potassium, magnesium, calcium, and sulfur in the fertilizer solution. The MACRONUT program also allows the user to prioritize the different sources of these mineral macronutrients when multiple sources are available. MACRONUT outputs the amount of the nutrient sources necessary to mix a concentrated stock solution and the nutrient levels of the applied solution. A 5% tolerance has been designed into the program due to chemical constraints. Some ratios will not be achievable;

however, MACRONUT will calculate a stock solution within 5% of the targeted applied rate or it will inform the user that the target ratios set are not achievable.

MACRONUT does not supply any information regarding chemical incompatibility or solubility of nutrient sources. A table in the MACRONUT manual highlights certain problem chemicals and their interactions. The program allows the user to set priorities for the nutrient sources and relies on user knowledge of this information. For instance, chemical incompatibility can be a significant problem when using calcium nitrate in a nutrient solution (see Landis et al., 1989, or other nursery fertilization texts for further information).

Running MACRONUT

An IBM compatible computer with DOS version 2.1 or greater is required to run the program. The user is required to supply the injection ratio of the injector or siphon and a list of available chemicals. Table 1 lists the chemicals MACRONUT will recognize as source chemicals. MACRONUT was written to use the technical grade of the source compounds. Fertilizer grades of these compounds often contain high percentages of impurities, which may compromise the accuracy of the fertilizer solution (Landis et al., 1989). The manual associated with the software also contains this table and the information required to run the program. Briefly,

all user inputs into MACRONUT are either alphabetic (without case sensitivity) or numeric as an integer. All concentrations are expressed as parts per million.

After starting the program, the user is asked to set the nitrogen level (of the applied solution) in parts per million. Next, the user is asked to set the percentage of nitrogen to be derived from nitrate (NO$_3$). The user is then asked to set the target levels of phosphorous, potassium, magnesium, sulfur, and calcium in the applied solution.

In the following step, the user provides information on the compounds available for making the nutrient solution. MACRONUT requests the user to respond yes (y) or no (n) to the availability of each of the 17 possible source compounds. Two error traps are included in the program at this point. The first error trap involves setting a target magnesium level but not listing magnesium sulfate as an available compound. Magnesium sulfate is the only recognized source of magnesium in the program. MACRONUT allows the user to correct this problem in one of two ways. The user can reset the target magnesium level to 0 or can make magnesium sulfate available. A second error trap involves the ratio of magnesium to sulfur in the desired application solution. If the sulfur level is set too low relative to magnesium, the program cannot generate the desired ratio. This is also because magnesium sulfate is the only source

of magnesium the program recognizes.

Following this, the user is asked to rank the compounds he has selected for each mineral nutrient. Several compounds, such as potassium nitrate, contain more than one mineral nutrient. If selected in the previous step, potassium nitrate will appear in the nitrogen and potassium priority lists. After this step, the program calculates an optimum formulation for the targeted solution.

After calculating the targeted solution, if possible, the user is prompted to enter an injection ratio or siphon rate. The value requested is the number of parts of water to one part of fertilizer. For example, if the injector rate is 1:150, the number 150 is entered. If no injector is used, the value 1 is entered to achieve the applied solution formulation. MACRONUT will generate the closest formulation possible using the inputs provided. If

MACRONUT cannot formulate a solution with the information provided, it will respond with the following message: "No solution is possible with current criteria."

The output of the program provides the calculated applied solution

Fig. 2. Target levels input screen and output target levels, nutrient sources, and mixing rates screen generated by MACRONUT.

Ammonium nitrate [NH_4NO_3]
X ppm NH_4/0.17= Y mg·L^{-1} NH_4NO_3

Y mg·L^{-1} NH_4NO_3 × 0.17 = Z ppm NO_3

Ammonium sulfate [$(NH_4)_2SO_4$]
X ppm NH_4/0.21 = Y mg·L^{-1} $(NH_4)_2SO_4$

Y mg·L^{-1} $(NH_4)_2SO_4$ × 0.24 = Z ppm S

Calcium nitrate [$Ca(NO_3)_2$]
X ppm Ca/0.17 = Y mg·L^{-1} $Ca(NO_3)_2$

Y mg·L^{-1} $Ca(NO_3)_2$ × 0.15 = Z ppm NO_3

Diammonium phosphate [$(NH_4)_2HPO_4$]
X ppm NH_4/0.21 = Y mg·L^{-1} $(NH_4)_2HPO_4$

Y mg·L^{-1} $(NH_4)_2HPO_4$ × 0.24 = Z ppm P

Dipotassium phosphate [K_2HPO_4]
X ppm K/0.45 = Y mg·L^{-1} K_2HPO_4

Y mg·L^{-1} K_2HPO_4 × 0.18 = Z ppm P

Magnesium sulfate [$MgSO_4$]
X ppm Mg/0.10 = Y mg·L^{-1} $MgSO_4$

Y mg·L^{-1} $MgSO_4$ × 0.13 = Z ppm S

Monoammonium phosphate [$NH_4H_2PO_4$]
X ppm NH_4 /0.11 = Y mg·L^{-1} $NH_4H_2PO_4$

Y mg·L^{-1} $NH_4H_2PO_4$ × 0.21 = Z ppm P

Monopotassium phosphate [KH_2PO_4]
X ppm K/0.28 = Y mg·L^{-1} KH_2PO_4

Y mg·L^{-1} KH_2PO_4 × 0.23 = Z ppm P

Nitric acid [(70%) HNO_3]
X ppm NO_3/0.22= Y mg·L^{-1} (70%) HNO_3

Phosphoric acid [(85%) H_3PO_4]
X ppm P/0.32 = Y mg·L^{-1} (85%) H_3PO_4

Potassium carbonate [K_2CO_3]
X ppm K/0.56 = Y mg·L^{-1} K_2CO_3

Potassium chloride [KCl]
X ppm K/0.52 = Y mg·L^{-1} KCl

Potassium nitrate [KNO_3]
X ppm K/0.37 = Y mg·L^{-1} KNO_3

Y mg·L^{-1} KNO_3 × 0.13 = Z ppm NO_3

Potassium sulfate [K_2SO_4]
X ppm K/0.44 = Y mg·L^{-1} K_2SO_4

Y mg·L^{-1} K_2SO_4 × 0.18 = Z ppm S

Sodium nitrate [$NaNO_3$]
X ppm NO_3 0.16 = Y mg·L^{-1} $NaNO_3$

Sulfuric acid [H_2SO_4]
X ppm S/0.33 = Y mg·L^{-1} H_2SO_4

Urea [$CO(NH_2)_2$]
X ppm NH_2/0.45= Y mg·L^{-1} $CO(NH_2)_2$

Screen A: target levels input screen.
Screen B: output target levels, nutrient sources, and mixing rates.

for the desired fertilizer in parts per million for each mineral nutrient (Fig. 2). The nitrogen level is further partitioned into ammonium and nitrate fractions. Using this information and the injection ratio input, MACRO-NUT calculates the number of grams per liter or grams per gallon required for each compound to formulate the concentrated stock solution.

As an example, a solution of 150 ppm nitrogen, 75 ppm phosphorus, 75 ppm potassium, 40 ppm magnesium, 52 ppm sulfur, and 0 ppm calcium is desired. Fifty percent of the nitrogen should be derived from NO_3. Compounds available for this solution are ammonium nitrate, magnesium sulfate, mono-ammonium phosphate, phosphoric acid, potassium carbonate, potassium chloride, urea, and sulfuric acid. Ranking for the nitrogen sources is ammonium nitrate 1, urea 2, and mono-ammonium phosphate 3. Ranking for the phosphorus compounds is phosphoric acid 1 and monoammonium phosphate 2. Ranking for the potassium sources is potassium carbonate 1 and potassium chloride 2. Ranking for the sulfur sources is magnesium sulfate 1 and sulfuric acid 2. Lastly, the injection rate is set at 1:100. The output for the applied solution is illustrated in Fig. 2.

The MACRONUT program and manual are available free of charge. The program can be downloaded from the New Mexico State University–Mora Research Center home page on the Internet (http://taipan.nmsu.edu/aght/mora/mora.html). Once at this site, go to the nursery research hyperlink. The nursery research page contains the information required to download the software and its corresponding manual. A second option for obtaining the MA-CRONUT program and manual is to send a stamped, self-addressed disk mailer and a 3 1/2-inch formatted (IBM) diskette to the Mora Research Center, P.O. Box 359, Mora, NM 87732.

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A Rapid Nondestructive Technique to Predict Leaf Nitrogen Status of Grapefruit Tree with Various Nitrogen Fertilization Practices

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ADDITIONAL INDEX WORDS. citrus, SPAD, dry fertilizer, fertigation, slow-release fertilizer

SUMMARY. The objective of this study was to evaluate the use of a leaf chlorophyll meter (SPAD-502) to predict nitrogen status and yield response of grapefruit trees. The study included two irrigation treatments, three sources, and four rates of fertilizer [dry soluble granular fertilizer broadcast or through fertigation with N rates either 50, 100, 150 lb/acre/yr (56, 112, or 168 kg·ha^{-1}·yr^{-1})], and controlled-release fertilizer with N rates either 25, 50, 100 lb/acre. Irrigation treatments did not affect SPAD readings and leaf N concentrations. Correlations between SPAD readings and leaf N were greater for the spring flush ($r^2 = 0.61$) than for

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the summer flush ($r^2 = 0.49$). High correlations of SPAD meter readings with either fruit yields or leaf N suggests that SPAD meter reading is an acceptable index of N status and fruit production of the trees. SPAD readings can be made rapidly without destructive sampling of the leaves. This study demonstrates that the SPAD meter can be used to evaluate the tree N status and improve a N fertilization program for grapefruit trees.

Nitrogen fertilizer applied to citrus trees grown in deep sandy soils in excess of that required for annual tree growth and fruit production is subject to either surface runoff or leaching below the rootzone (Calvert, 1975). Soil and leaf analyses can be used as guidelines to adjust the N fertilizer program for citrus trees (Tucker et al., 1995). However, these analyses are costly, time consuming, and require trained technical personnel and a well-equipped laboratory. Leaf chlorophyll content is closely correlated to leaf N content (Wolfe et al., 1988; Wood et al., 1992a). Chlorophyll meters (SPAD-501 or SPAD-502, Minolta Corp., Ramsey, N.J.) are calibrated to estimate the chlorophyll content in the leaves rapidly and nondestructively. Studies on corn (Dwyer et al., 1991; Piekielek and Fox, 1992; Schepers et al., 1992; Wood et al., 1992a), cotton (Wood et al., 1992b), rice (Peng et al., 1995; Turner and Jund, 1991), peppermint (Westcott and Wraith, 1995), and wheat (Follett et al., 1992; Fox et al., 1994; Reeves et al., 1993) have shown that the SPAD meter can be used as an aid to predict N status of the crop and thus can be used as the basis to develop a precise N fertilization program. The photosynthetic rate of soybean leaves was correlated with SPAD meter reading at R4 (dough stage) and R5 (dent stage) growth states of 16 genotypes (Ma et al., 1995). Blackmer and Schepers (1995) reported a significant linear correlation between SPAD meter readings of corn leaves, measured at either R4 or R5 growth stages, and grain yield. The SPAD meter was also used as a tool for diagnosing iron chlorosis in citrus rootstocks (Sudahono et al., 1994).

The objective of this study was to evaluate the relationships between SPAD meter readings of grapefruit tree leaves, concentrations of leaf N, N fertilization rates, and fruit yields.