DIVISÃO 3 - USO E MANEJO DO SOLO

Comissão 3.1 - Fertilidade do solo e nutrição de plantas

FERTILIZER RECOMMENDATION SYSTEM FOR MELON BASED ON NUTRITIONAL BALANCE

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ABSTRACT

Melon is one of the most demanding cucurbits regarding fertilization, requiring knowledge of soils, crop nutritional requirements, time of application, and nutrient use efficiency for proper fertilization. Developing support systems for decision-making for fertilization that considers these variables in nutrient requirement and supply is necessary. The objective of this study was parameterization of a fertilizer recommendation system for melon (Ferticalc-melon) based on nutritional balance. To estimate fertilizer recommendation, the system considers the requirement subsystem (REQ), which includes the demand for nutrients by the plant, and the supply subsystem (SUP), which corresponds to the supply of nutrients through the soil and irrigation water. After determining the REQtotal and SUPtotal, the system calculates the nutrient balances for N, P, K, Ca, Mg, and S, recommending fertilizer application if the balance is negative (SUP < REQ), but not if the balance is positive or zero (SUP ≥ REQ). Simulations were made for different melon types (Yellow, Cantaloupe, Galia and Piel-de-sapo), with expected yield of 45 t ha^{-1}. The system estimated that Galia type was the least demanding in P, while Piel-de-sapo was the most demanding. Cantaloupe was the least demanding for N and Ca, while the Yellow type required less K, Mg, and S. As compared to other fertilizer recommendation methods adopted in Brazil, the Ferticalc system was

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more dynamic and flexible. Although the system has shown satisfactory results, it needs to be evaluated under field conditions to improve its recommendations.

Keywords: *Cucumis melo* L., nutrient demand, nutrient supply, modeling.

RESUMO: *SISTEMA DE RECOMENDAÇÃO DE FERTILIZANTES PARA O MELOEIRO COM BASE NO BALANÇO NUTRICIONAL*

O meloeiro é uma das cucurbitáceas mais exigentes em relação à adubação, requerendo conhecimento sobre solos, exigência nutricional da cultura, época de aplicação e eficiência no uso de nutrientes para uma adubação adequada, assim como sendo necessário o desenvolvimento de sistemas de apoio à decisão para adubação que considere essas variáveis no requerimento e suprimento de nutrientes. O objetivo deste estudo foi a parametrização de um sistema de recomendação de adubação para o meloeiro (Ferticalc-Melão), com base no balanço nutricional. Para estimar a recomendação de adubação, o sistema considera: o subsistema requerimento (REQ), que inclui a demanda de nutriente pela planta; e o subsistema suprimento (SUP), que corresponde ao suprimento de nutrientes pelo solo e pela água de irrigação. Após a determinação do REQtotal e SUPtotal, o sistema calcula o balanço de nutrientes para N, P, K, Ca, Mg e S, recomendando adubar, se o balanço for negativo (SUP < REQ), ou não adubar, para o caso de o balanço ser positivo ou zero (SUP ≥ REQ). Foram feitas simulações para diferentes tipos de melão (Amarelo, Cantaloupe, Gália e Pele-de-sapo), com produtividade estimada de 45 t ha^{-1}. O sistema estimou que o Gália foi o menos exigente em P, enquanto o Pele-de-sapo, o mais exigente. Cantaloupe foi o que menos demandou N e Ca, enquanto o tipo Amarelo requereu menos K, Mg e S. Em comparação com outros métodos de recomendação de adubação adotados no Brasil, o sistema Ferticalc foi mais dinâmico e flexível em suas recomendações. Embora o sistema tenha apresentado resultados satisfatórios, esse precisa ser avaliado no campo para o aprimoramento das suas recomendações.

Palavras-chave: Cucumis melo L., demanda de nutriente, suprimento de nutriente, modelagem.

INTRODUCTION

Melon (*Cucumis melo* L.) is a leading fresh fruit in Brazilian exports. Its importance increases when taking into account that the main producing areas of the country are located in the semiarid region of northeastern Brazil, promoting economic development by generating employment and income in one of the poorest regions of the country.

Among the cucurbits, the melon crop is the most demanding in relation to fertilization, which requires knowledge of soil, plant nutrient requirements, and fertilizer efficiency, considering the time and mode of application, as well as the amount and source of each nutrient (Faria and Fontes, 2002).

Currently, fertilizer recommendations for melon in Brazil are mostly based on the use of recommendation tables and soil analysis, or fertilization trials performed by medium and large growers (Crisóstomo et al., 2002). However, their use has some limitations, such as geographic restriction, low flexibility, high cost, and the fact that recommendations do not vary according to expected yields or according to nutrient content and buffer capacity of the soil, showing no prospects for future developments.

The use of “nutrient balance systems” as a form of fertilizer recommendation in Brazil began with the cultivation of eucalyptus (Barros et al., 1995) and was improved by Tomé Junior and Novais (2000) as an alternative to recommendation tables. These systems already include various crops, such as banana (Oliveira et al., 2005), soybean (Santos et al., 2008), pineapple (Silva et al., 2009), and coconut (Rosa et al., 2011).

Thus, the aim of this study was to parameterize a fertilizer recommendation system for melon (Ferticalc-melon) based on crop nutrient requirements and nutrient supply through the soil and irrigation water as an alternative to current forms of fertilizer recommendation for this crop.

MATERIAL AND METHODS

System development

The Ferticalc-melon model is divided into two subsystems: the requirement subsystem (REQ) and supply subsystem (SUP). The REQ represents nutrient demand by the plant to achieve a given yield, considering its efficiency in taking up the nutrients applied, as well as a rate that meets the criteria of “sustainability” for potassium, whereas the SUP corresponds to the supply of nutrients by the soil and irrigation water.

Requirement subsystem

The REQ subsystem was determined as shown in figure 1. Initially, the expected yield was established considering the genetic potential of the melon types. The yield values used were 15.0, 22.5, 30.0, 37.5, and 45.0 t ha^{-1} for Yellow, Cantaloupe, Galia, and Piel-de-sapo types, with populations of 12,500, 16,666, 13,513, and 13,513 plants per hectare, respectively.

After establishing the expected yield (YIELD), it was converted into fruit dry matter (FDM), considering that FDM corresponds to 6 % of fresh fruit weight on average (Equation 1). From this, the system estimated the amount of nutrients in the fruits (A_NutFru) necessary to obtain the projected yield through division between FDM and the coefficient of biological utilization in the fruit (CBU_Fru) in kg kg^{-1} of each nutrient (Equation 2).

$$FDM = YIELD \times 0.06 \qquad \text{Eq. 1}$$

$$A\_NutFru = \frac{FDM}{CBU\_Fru} \qquad \text{Eq. 2}$$

where FDM, YIELD, A_NutFru, are in kg ha^{-1}; and CBU_Fru is an efficiency ratio that indicates the ability of the plant to convert the nutrient taken up into fruit dry matter in kg kg^{-1}.

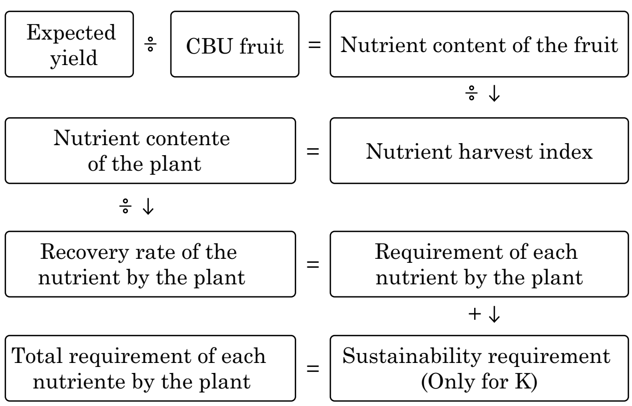

Figure 1. Flowchart used by generic Ferticalc-melon to estimate nutrient application for melon.

The average values of CBU_Fru were obtained from the literature as shown in table 1. After determining the A_NutFru, the nutrient content of the plant (NutCPl) was estimated in kg ha^{-1} by dividing the A_NutFru by the nutrient harvest index (NutHI), which is expressed in kg kg^{-1}. The nutrient harvest index refers to the ratio between the nutrient accumulated in the organ exported (fruit) and the nutrient accumulated in the whole plant. In this case, all organs were considered, except for the roots, due to lack of data. The values used in the present version of Ferticalc-melon are also shown in table 1.

To determine the nutrient requirements of the plant, it is necessary to consider the recovery rate of the nutrient for the plant (RRNutPl) since the plant

Table 1. Coefficient of biological utilization in fruit (CBU_Fru) and the nutrient harvest index (NutHI) for different melon types used in Ferticalc-melon

	CBU_Fru(1)						NutHI(1)					
	N(2)	P(3)	K(4)	Ca(5)	Mg(6)	S(7)	N(2)	P(3)	K(4)	Ca(5)	Mg(6)	S(7)
	kg kg^{-1}											
Yellow	47	198	36	60	929	199	0.64	0.76	0.72	0.41	0.25	0.72
Cantaloupe	95	216	24	206	286	337	0.48	0.49	0.70	0.21	0.25	0.30
Galia	72	502	34	96	112	331	0.34	0.42	0.65	0.29	0.44	0.43
Piel-de-sapo	59	102	18	35	284	297	0.48	0.53	0.54	0.23	0.32	0.42
ȳ	66	189	30	96	485	297	0.45	0.61	0.66	0.29	0.36	0.42
CI	5	30	2	39	132	50	0.03	0.05	0.04	0.05	0.04	0.13
LI	61	160	28	57	353	247	0.42	0.55	0.62	0.25	0.32	0.29
LS	72	219	32	135	617	347	0.48	0.66	0.70	0.34	0.40	0.55
Min.	34	90	10	30	112	108	0.15	0.34	0.38	0.10	0.13	0.14
Max.	161	502	78	351	1304	498	0.76	0.88	1.29	0.46	0.58	1.38
No.	84	44	87	20	35	20	84	44	87	20	35	20
SD	25.25	100.51	9.55	89.09	399.62	114.68	0.14	0.18	0.18	0.11	0.13	0.29
CV (%)	38.08	53.10	31.74	92.77	82.39	38.63	31.12	29.78	26.80	37.17	34.95	68.72

ȳ: average, CI: confidence interval (0.05), LI: lower limit of the confidence interval, LS: upper limit of the confidence interval, Min: minimum value, Max: maximum value, No.: number of observed data, SD: standard deviation, and CV: coefficient of variation. (1) Mean values obtained from studies: (2, 3, 4, 6, 7) Prata (1999); (2, 3, 4, 5, 6) Silva Junior (2005); (2, 3, 4, 5, 6) Duarte (2002); (2, 4) Temóteo (2006); (2, 3, 4) Damasceno (2011); (2, 3, 4, 5, 6) Gurgel et al. (2010); (2, 3, 4, 5) Gurgel et al. (2008); (2, 4) Paula (2007); (3, 6, 7) Kano (2002); (2) Belfort et al. (1986); (3, 4, 5, 6, 7) Lima (2001); (4) Mota (1999).

does not take up 100 % of the nutrient applied via fertilizer, due to factors such as losses and reactions with the soil (Santos et al., 2008). The recovery rate was determined according to equation 3:

$$\text{RRNutPl} = \frac{(\text{NACF - NACNF})}{\text{ANA}} \times 100 \qquad \text{Eq. 3}$$

where NACF and NACNF correspond to the nutrient absorbed by the crop fertilized and not fertilized, respectively, both in kg ha^{-1}, while ANA refers to the amount of nutrient applied in kg ha^{-1}.

Because of the difficulty in obtaining experimentally derived RRNutPl for melon, in the first version of the model we used values obtained for crops previously included in the Ferticalc system (Table 2). It should be noted that the values displayed are used as minimum values, given that, in practice, it is expected that RRNutPl values for melon are probably higher, due to the fact that most melon crops in Brazil are fertigated, which increases the efficiency of plant nutrient uptake.

For the nutrient P, the RRNutPl values used by Ferticalc-melon (Table 2) consider the soil buffering capacity, based on the study carried out by Muniz (1983) for soybean and adapted by Santos et al. (2008), with application of a soluble source of phosphate. However, it is necessary to make corrections for in-furrow fertilizer applications (RRNutPl_Ps) since the equation (Table 2) corresponds to P broadcast application. Based on this, we used the correction factor (CF) calculated by using the remaining phosphorus (P-rem) based on Santos et al. (2008) and then determined the RRNutPl_Ps corrected for the furrow, according to equations 4 and 5:

$$\text{CF} = 4.2 - 0.04 \times \text{P-rem} \qquad \text{Eq. 4}$$

$$\text{RRNutP1\_Ps} = \text{RRNutP1\_P} \times \text{CF} \qquad \text{Eq. 5}$$

where P-rem is in mg L^{-1}, and RRNutPl_Ps and RRNutPl_P are in %.

The total requirement of each nutrient by the plant (TRNutPl) to achieve the expected yield was obtained using the relationship between the NutCPl and the RRNutPl (Equation 6), considering that 80 % of the roots are in the 0-20 cm layer (ELNA), which is the effective layer of nutrient availability. For potassium, the TRNutPl used an extra rate, called the sustainability requirement (Sus_ReqK), which is the total amount of K exported by the crop (TAK_NutFru), i.e., 100 % of the K content in the fruit, corrected for the recovery rate for K in the plant (CRR_Pl_K), according to equation 7.

$$\text{TRNutPl} = \frac{\text{NutCPl}}{\text{RRNutPl}} \times \text{ELNA} \qquad \text{Eq. 6}$$

$$\text{Sus\_ReqK} = \frac{\text{TAK\_NutFru}}{\text{CRR\_Pl\_K}} \qquad \text{Eq. 7}$$

where TRNutPl, NutCPl, Sus_ReqK, and TAK_NutFru are in kg ha^{-1}; and RRNutPl, ELNA, and CRR_Pl_K are expressed in %.

The sustainability rate seeks to prevent nutrient depletion in the soil over time and ensure a minimum yield in subsequent crops (Cantarutti et al., 2007). The total requirement of plant K (TRNutPl_K) is obtained as follows.

$$\text{TRNutP1\_K} = (\text{TRNutP1} + \text{Sus\_ReqK}) \times \text{ELNA} \qquad \text{Eq. 8}$$

where TRNutPl_K is expressed in kg ha^{-1}.

Supply subsystem

The SUP subsystem refers to the nutrients provided by soil and irrigation water. For crops covered by the system previously, SUP accounts for the nutrient supply from liming (pineapple and soybean), crop residues or organic waste (pineapple, banana, and soybean), and organic matter (pineapple). These supplies may vary

Table 2. Recovery rate of the nutrient by the plant (RRNutPl) for melons in percentage of different nutrients adopted by Ferticalc-melon[(1)]

Nutrient	Equation/rate	R^2	Source
Nitrogen	$\text{RRNutPl}_{\text{-N}} = 60$ %	-	Oliveira (2002)
Phosphorus	$\text{RRNutPl}_{\text{-P}} = (4.508^{***}e^{0.0347\text{P-rem}})$	0.837	Santos et al. (2008)
Potassium	$\text{RRNutPl}_{\text{-K}} = 65$ %	-	Oliveira (2002)[(2)]
Calcium	$\text{RRNutPl}_{\text{-Ca}} = 80$ %	-	Oliveira et al. (2005)
Magnesium	$\text{RRNutPl}_{\text{-Mg}} = 80$ %	-	Oliveira et al. (2005)
Sulfur	$\text{RRNutPl}_{\text{-S}} = 45$ %	-	Oliveira et al. (2005)

***: significant at 0.1 %; [(1)] The values shown above are drawn from studies on other crops due to the lack of specific information for the melon crop. The RRNutPl values for melon are probably greater than those presented because the current use of fertigation facilitates the uptake of nutrients by the crop and increases efficiency in the use of fertilizers. Therefore, these values are considered as minimum values to be adopted; [(2)] approximate value.

depending on the crop and are suitable for some crops and not for others. Furthermore, there is a possibility of other manners of supplying nutrients, e.g., melon, in which supplying of nutrients may be by irrigation water.

The supply of nutrients from the soil (SUPsoil) was obtained from the nutrient contents present in the soil analysis as follows:

$$\text{SUPsoil} = \frac{\text{NC\_SA}}{\text{RRSExt}} \times \text{CSL} \qquad \text{Eq. 9}$$

where NC_SA, RRSExt, and CSL are the nutrient content from soil analysis (mg dm^{-3}), the recovery rate of the soil extractor (%) as in table 3, and the contribution of the soil layer in the supply of nutrients (dm), respectively. The SUPsoil is expressed in kg ha^{-1}, for N, the value is zero.

With respect to RRSExt, the Ferticalc-melon system considers the following extractors in chemical soil analyses (Table 3): Mehlich-1 or Resin for P and K, KCl for Ca and Mg, and $Ca(H_2PO_4)_2$ in HOAc for S. For P, extracted by Mehlich-1 and Resin, the system takes into account the buffer capacity factor. For the other nutrients, we use fixed rates because they are not greatly influenced by buffering capacity.

To determine the amount of nutrient supplied by the soil, chemical and physical analysis of two melon-producing regions were considered, with values adapted from Lima (2001), Dantas (2007), Diniz et al. (2007), and Costa et al. (2011) (Table 4). The first soil sample corresponds to an Inceptisol Ustept with higher pH, representative of melon-producing areas of the Apodi Plateau in the States of Ceará and Rio Grande do Norte, Brazil (SA-I). The second soil sample was an Entisol Psamment with lower pH, characteristic of areas of the Lower Basin of the Vale do São Francisco in the States of Bahia and Pernambuco, Brazil (SA-II).

To determine the nutrient amounts supplied by irrigation water (SUPwater), the system considers K, Ca, and Mg using equation 10 (Paula, 2007). Another important nutrient that could be considered as supplied by irrigation water would be the NO_3^--N ion; however, for the first version of the system, it will not be considered because its quantification is not common in chemical analyses of water for irrigation purposes.

Table 4. Chemical and physical soil analysis used for fertilization recommendations by the Ferticalc-melon system

Attribute	SA-I	SA-II
$pH(H_2O)$ (1:1)	7.09	5.10
P (mg dm^{-3})(1)	2.06	1.17
P-rem (mg L^{-1})(2)	38.69	40.58
S (mg dm^{-3})(3)	10.30	2.34
K^+ ($cmol_c$ dm^{-3})(1)	0.55	0.07
Ca^{2+} ($cmol_c$ dm^{-3})(4)	4.73	0.10
Mg^{2+} ($cmol_c$ dm^{-3})(4)	1.45	0.10
Na^+ ($cmol_c$ dm^{-3})(4)	0.16	0.04
Al^{3+} ($cmol_c$ dm^{-3})(4)	0.00	1.06
H+Al ($cmol_c$ dm^{-3})(5)	0.67	4.83
SB ($cmol_c$ dm^{-3})	6.88	0.31
t ($cmol_c$ dm^{-3})	6.88	1.37
T ($cmol_c$ dm^{-3})	7.55	5.14
V (%)	91.10	6.09
m (%)	0.00	77.37
B (mg dm^{-3})(6)	0.11	-
Cu (mg dm^{-3})(1)	2.60	0.13
Fe (mg dm^{-3})(1)	5.08	13.44
Mn (mg dm^{-3})(1)	81.00	7.44
Zn (mg dm^{-3})(1)	2.50	1.09
Sand (%)	69.80	91.00
Silt (%)	14.70	6.00
Clay (%)	15.50	3.00

Values adapted from Lima (2001), Dantas (2007), Diniz et al. (2007), and Costa et al. (2011); SA-I and SA-II: soil analysis for example with hypothetical values for Inceptisol Ustept and Entisol Psamment, respectively. Extractor: (1) Mehlich-1; (2) Value estimated by the equation: P-rem = 52.44-0.9646** clay + 0.005** $clay^2$ R^2 = 0.75 (Freire, 2001), and clay (%); (3) $Ca(H_2PO_4)_2$; (4) 1 mol L^{-1} KCl; (5) Acetate of Ca 0.5 mol L^{-1}, pH 7.0; and (6) Hot water.

Table 3. Recovery rate of the nutrient by extractors adopted by Ferticalc-melon

Nutrient	Extractor	Equation/rate	R^2	Source
Phosphorus	Mehlich-1	$RRSExt_{\_P}$ = (0.0672821 + 0.0121615**P-rem) × 100	0.681	Possamai (2003)
Phosphorus	Resin	$RRSExt_{\_P}$ = [0.419***(P-rem)$^{0.128099}$] × 100	0.694	Possamai (2003)
Potassium	Mehlich-1	$RRSExt_{\_K}$ = 70 %	-	Prezotti (2001)(1)
Potassium	Resin	$RRSExt_{\_K}$ = 75 %	-	Oliveira et al. (2005)(1)
Calcium	KCl	$RRSExt_{\_Ca}$ = 70 %	-	Prezotti (2001)(1)
Magnesium	KCl	$RRSExt_{\_Mg}$ = 70 %	-	Prezotti (2001)(1)
Sulfur	$Ca(H_2PO_4)_2$	$RRSExt_{\_S}$ = 40 %	-	Rosa (2002)(1)

** and ***: significant at 1 and 0.1 %, respectively; (1) approximate value.

$$SUPwater = \frac{DWA\_CNW \times AW}{100} \quad \text{Eq. 10}$$

where DWA, CNW, and AW represent the depth of water applied to the crop (mm), the content of nutrient or ions in the irrigation water ($mmol_c\ L^{-1}$), and the atomic weight of each element or ion contained in the water, respectively.

The SUPwater represents the supply of K, Ca, and Mg nutrients in kg ha^{-1}, while for other macro and micronutrients, the value equals zero. Equation 11 was used to calculate DWA (Paula, 2007):

$$DWA = AWD \times LLC \quad \text{Eq. 11}$$

where AWD and LLC refer to the average water depth applied daily to the crop (mm d^{-1}) and the crop cycle (day), respectively.

For the first version of Ferticalc-melon, the user will choose to use or not the amount of nutrients present in the irrigation water (Table 5). If the user chooses to use it, the system will initially assume an average DWA of 400 mm, typically used in melon-producing regions of the Northeast of Brazil. In the future, Ferticalc-melon versions will be more dynamic because the system will indicate the exact amount of water to be applied daily through irrigation, based on the evapotranspiration of the previous day. Thus, by the end of the cycle, the amount of nutrient applied through irrigation water will be calculated more precisely.

After determination of the SUP and REQ subsystems, the results are used in the Nutritional Balance (NB), in kg ha^{-1}, as in equation 12. If the balance is positive or zero (SUP ≥ REQ), the application of fertilizers is not recommend; if it is negative (SUP < REQ), fertilizer application is recommended. For P and K nutrients, the recommendations were converted to P_2O_5 and K_2O, using the factors 2.29 and 1.20, respectively.

$$NB = SUP - REQ \quad \text{Eq. 12}$$

Having established the total amount of nutrients required for a given yield and melon type, the system recommends pre-planting rates for N, P, and K, and the partitioning of these and Ca, Mg, and S to be applied in topdressing, based on the nutrient uptake pattern of the crop.

Application system

The Ferticalc-melon proposes specific application of fertilizer in pre-planting and topdressing for each melon type. Based on field experiments, we created a database tabulated on spreadsheets in Excel®, with information about the pre-planting and topdressing of fertilization used in melon varieties and their yields, stratified for each melon type, with yield greater than or equal to 30 t ha^{-1}. Then we

Table 6. Ferticalc-melon recommendations for relative application of nutrients in pre-planting and topdressing based on total recommendations

Melon/Type	Application	N	P	K
		%		
	Montag (1999)			
Melon	Pre-planting	15	100	15
	Topdressing	85	0	85
	Crisóstomo et al. (2002)			
Melon	Pre-planting	10	80	10
	Topdressing	90	20	90
	Ferticalc-melon[1]			
Yellow[2]	Pre-planting	8	50	2
	Topdressing	92	50	98
Cantaloupe[3]	Pre-planting	25	65	25
	Topdressing	75	35	75
Galia[4]	Pre-planting	11	32	13
	Topdressing	89	68	87
Piel-de-sapo[5]	Pre-planting	24	56	14
	Topdressing	76	44	86

[1] Distribution suggested by the system based on fertilizers used in field experiments with total fruit yield ≥30 t ha^{-1}; [2] Data base for the Yellow type used to suggest the distribution in Ferticalc-melon: Araújo Junior (2008), Oliveira (2010), Fernandes (2010), Pereira (2010), and Tomaz (2008); [3] Data base for the Cantaloupe type used to suggest the distribution in Ferticalc-melon: Araújo Junior (2008), Dantas (2007), Pereira (2010), Gerhardt (2007), Prata (1999), Duarte (2002), and Damasceno (2011); [4] Data base for the Galia type used to suggest the distribution in Ferticalc-melon: Pereira (2010), Gerhardt (2007), and Santos Junior (2007); ([5] Data base for the Piel-de-sapo type used to suggest the distribution in Ferticalc-melon: Pereira (2010), Rodrigues (2008), Dantas (2008), and Temóteo (2006).

Table 5. Water chemical analysis used for fertilizer recommendation by Ferticalc-melon system

Water source	EC	pH(H_2O)	SAR	Ca^{2+}	Mg^{2+}	K^+	Na^+	Cl^-	HCO_3^-	CO_3^{2-}	SO_4^{2-}[1]
	dS m^{-1}						$mmol_c\ L^{-1}$				
I[2]	3.90	6.90	6.33	15.2	2.80	0.15	19.00	25.20	4.80	0.20	Pres.
II[3]	0.08	-	0.14	0.60	0.10	0.04	0.08	0.16	0.70	0.00	-
III[4]	1.64	6.72	1.52	8.72	2.97	0.25	3.69	6.97	7.41	-	-

EC: Electrical Conductivity; SAR: Sodium Adsorption Ratio. [1] Qualitative analysis; [2] Groundwater analysis from the Apodi Plateau (Nogueira, 2010); [3] Surface water analysis from the São Francisco River (Cordeiro, 2001); [4] Average of groundwater analyses from various municipalities of the Apodi Plateau (Medeiros et al., 2003).

verified the total amount of N, P, and K applied to pre-planting and topdressing, and the arithmetic average was obtained for each type (Table 6).

The choice of which pattern of fertilizer distribution between pre-planting and topdressing is made by the user, according to that which best fits the site conditions. Pre-planting fertilization (Table 6) should be applied in a single rate in the furrow before sowing or transplanting, while topdressing should be divided throughout the crop cycle.

According to Fontes and Lima (1993), the nutrient uptake pattern by the plant is an indispensable tool for fertilizer management in crops because it shows the amount of nutrient taken up throughout the crop cycle. Thus, based on nutrient uptake patterns by melon from experiments carried out by Prata (1999), Silva Junior (2005), and Damasceno (2011), the Ferticalc-melon system proposes topdressing distribution of N, P, K, Ca, Mg, and S to be distributed via fertigation according to tables 7 and 8.

Due to the lack of specific data for nutrients Ca, Mg, and S in the studies of Montag (1999) and Crisóstomo et al. (2002), the system uses only the nutrient uptake pattern presented by Prata (1999) to generate recommendations for distribution of nutrients throughout the cycle for each melon type (Table 8).

RESULTS

Simulations for fertilizer recommendation

The recommendations generated by Ferticalc-melon considers a total fruit yield of 45 t ha^{-1} for all melon types, and soil with 44 mg L^{-1} P-rem, with fertilizer application being distributed in pre-planting and topdressing according to tables 6, 7 and 8.

Under the same conditions, the system simulates different recommendations for the melon types,

Table 7. Ferticalc-melon recommendations for relative distribution of nitrogen, phosphorus and potassium nutrients in topdressing (fertigation)[1]

<table>
<tr><th rowspan="2">Source</th><th rowspan="2">Melon/Type</th><th colspan="11">Days after sowing or transplanting[2]</th></tr>
<tr><th>5</th><th>10</th><th>15</th><th>20</th><th>25</th><th>30</th><th>35</th><th>40</th><th>45</th><th>50</th><th>>50</th></tr>
<tr><td></td><td></td><td colspan="11">N (%)</td></tr>
<tr><td>Montag (1999)[3]</td><td>Melon</td><td colspan="5">24</td><td colspan="3">19</td><td colspan="3">57</td></tr>
<tr><td>Crisóstomo et al. (2002)[4]</td><td>Melon</td><td colspan="4">22</td><td colspan="5">56</td><td colspan="2">22</td></tr>
<tr><td>Ferticalc-melon</td><td>Yellow</td><td colspan="3">1</td><td colspan="3">60</td><td colspan="3">34</td><td colspan="2">5</td></tr>
<tr><td></td><td>Cantaloupe</td><td colspan="3">7</td><td colspan="3">20</td><td>18</td><td>21</td><td colspan="2">19</td><td>15</td></tr>
<tr><td></td><td>Galia[7]</td><td colspan="3">9</td><td colspan="3">17</td><td colspan="3">33</td><td colspan="2">35</td></tr>
<tr><td></td><td>Piel-de-sapo[8]</td><td colspan="4">5</td><td colspan="2">8</td><td colspan="2">15</td><td colspan="2">33</td><td>25</td></tr>
<tr><td></td><td></td><td colspan="11">P(5) (%)</td></tr>
<tr><td>Montag (1999)</td><td>Melon</td><td colspan="11">0</td></tr>
<tr><td>Crisóstomo et al. (2002)</td><td>Melon</td><td colspan="4">0</td><td colspan="5">100</td><td colspan="2">0</td></tr>
<tr><td>Ferticalc-melon</td><td>Yellow</td><td colspan="3">5</td><td colspan="3">52</td><td colspan="3">32</td><td colspan="2">11</td></tr>
<tr><td></td><td>Cantaloupe</td><td colspan="3">6</td><td colspan="3">18</td><td>21</td><td>27</td><td colspan="2">26</td><td>2</td></tr>
<tr><td></td><td>Galia</td><td colspan="3">4</td><td colspan="3">46</td><td colspan="3">32</td><td colspan="2">18</td></tr>
<tr><td></td><td>Piel-de-sapo[8]</td><td colspan="4">6</td><td colspan="2">12</td><td colspan="2">21</td><td colspan="2">30</td><td>27</td></tr>
<tr><td></td><td></td><td colspan="11">K (%)</td></tr>
<tr><td>Montag (1999)</td><td>Melon</td><td colspan="5">18</td><td colspan="3">21</td><td colspan="3">61</td></tr>
<tr><td>Crisóstomo et al. (2002)[6]</td><td>Melon</td><td colspan="4">11</td><td colspan="5">22</td><td colspan="2">45</td></tr>
<tr><td>Ferticalc-melon</td><td>Yellow</td><td colspan="3">3</td><td colspan="3">28</td><td colspan="3">58</td><td colspan="2">11</td></tr>
<tr><td></td><td>Cantaloupe</td><td colspan="3">6</td><td colspan="3">15</td><td>17</td><td>23</td><td colspan="2">24</td><td>15</td></tr>
<tr><td></td><td>Galia[7]</td><td colspan="3">4</td><td colspan="3">12</td><td colspan="3">30</td><td colspan="2">38</td></tr>
<tr><td></td><td>Piel-de-sapo[8]</td><td colspan="4">5</td><td colspan="2">10</td><td colspan="2">25</td><td colspan="2">39</td><td>12</td></tr>
</table>

[1] Distribution of total recommended in topdressing (fertigation) for each nutrient; such recommendations should be parceled preferably on a daily basis, depending on the amount specified for each period; [2] Recommendations based on the rate of nutrient uptake by the Yellow, Cantaloupe, Galia, and piel-de-sapo type adapted from Prata (1999), Damasceno (2011), and Silva Junior (2005), respectively; [3] Considers a yield range of 30-50 t ha^{-1}, at 75 or 85 days after sowing or transplanting, respectively; [4] N application after 55 days is not recommended; [5] P application by topdressing assumes use of sources such as MAP, phosphoric acid, and others; [6] Recommended up 22 % of the total topdressing for K after 55 days; [7] Recommendation up the application of 6 and 16 % after 60 days for N and K, respectively; [8] Recommendation up the application of 14, 4, and 9 % from 55 to 69 days for N, P, and K, respectively.

Table 8. Ferticalc-melon recommendations for relative distribution of Ca, Mg, and S nutrients in topdressing (fertigation)(1)

Type	Days after sowing or transplanting(2)										
	5	10	15	20	25	30	35	40	45	50	>50
					Ca (%)(3)						
Yellow		2			18			55		25	
Cantaloupe		2			30			55		13	
Galia		4			26			55		15	
Piel-de-sapo		2			8			39		49	
					Mg(%)(3)						
Yellow		4			8			58		30	
Cantaloupe		1			15			71		13	
Galia		3			15			66		16	
Piel-de-sapo		2			6			38		54	
					S (%)(3)						
Yellow		8			25			66		1	
Cantaloupe		1			9			33		57	
Galia		1			25			50		24	
Piel-de-sapo		2			13			24		61	

(1) Distribution of total recommended in topdressing (fertigation) for each nutrient; such recommendations should be parceled preferably on a daily basis depending on the amount specified for each period; (2) Recommendations are based on the rate of nutrient uptake by the melon crop adapted from Prata (1999); (3) Recommendations of topdressing for Ca, Mg, and S after 45 days should be performed up to 60 days after sowing or transplanting.

showing that the nutritional requirement varies with the genetic material used (Table 9). The system recommends 121, 79, 149, and 128 kg ha^{-1} of N to obtain a yield of 45 t ha^{-1} for Yellow, Cantaloupe, Galia, and Piel-de-sapo types, respectively.

With respect to P, the system simulated rates of 50, 77, 31, and 166 kg ha^{-1} and 56, 83, 38, and 172 kg ha^{-1} of P_2O_5 for Yellow, Cantaloupe, Galia, and Piel-de-sapo types in SA-I and SA-II soils, respectively (Table 9).

For K, considering that the nutrient supply by the soil and irrigation water was greater than the crop requirement in SA-I, the system simulated only for the SA-II soil (Table 9). The recommendations were 168, 301, 195, and 527 kg ha^{-1} of K_2O by considering the supply by irrigation water, and 175, 309, 202, and 535 kg ha^{-1} of K_2O, without considering that supply for Yellow, Cantaloupe, Galia, and Piel-de-sapo types, respectively.

The system did not recommend Ca and Mg fertilization for the SA-I soil given the high levels of those nutrients in the soil and irrigation water, but it recommended fertilization for SA-II soil. For Ca, the system recommended 6 and 232 kg ha^{-1} for Yellow and Piel-de-sapo types, respectively, considering the supply from the irrigation water. That shows that Piel-de-sapo has a greater Ca requirement than the other types, which is shown by its low CBU (Table 1). Without considering the supply of nutrients by irrigation water, the recommendations were 54, 5, 38, and 280 kg ha^{-1} of Ca for Yellow, Cantaloupe, Galia, and Piel-de-sapo types, respectively.

For Mg, under consideration of the supply from irrigation water, the system recommended fertilization only for the Galia type, with 15 kg ha^{-1}. Without considering the Mg supply by irrigation water, the rate increased to 20 kg ha^{-1}. For the Cantaloupe type, the system recommended the application of 3 kg ha^{-1} of Mg only when not considering supply from irrigation water.

Recommendations for S application were only for SA-II soil, with values of 65, 105, 67, and 80 kg ha^{-1} of SO_4 for Yellow, Cantaloupe, Galia, and Piel-de-sapo types, respectively.

In addition to recommending the required amount of each nutrient, the system proposes the distribution of the amount to be applied between pre-planting and topdressing (Table 9). For distribution in topdressing by fertigation, the example of recommendations for the Yellow type was used (Table 10).

The practice of fertigation is extremely important because it keeps the soil fertility at adequate levels throughout the crop cycle. The continuous supply of fertilizer meets the needs of the plant and maximizes nutrient absorption, with gains in yield and quality (Mohammad and Zuraiqi, 2002). To achieve that, it is recommended that the total amount suggested be divided into daily fertigations, providing the plants with small amounts of readily absorbable nutrients, avoiding waste and applications higher than plant demand.

Comparison of Ferticalc-melon with other recommendation methods

The recommendations generated by the system were compared with current forms of recommendation for melon (Table 11). The Table shows the recommendations for the states of Ceará (UFC, 1993) and Pernambuco (Cavalcanti et al., 1998), the recommendations from Embrapa (Crisóstomo et al., 2002), and the average fertilization used for each melon type by different growers of the Apodi Plateau (GAP), as reported during a survey in the cities of Quixeré, CE, and Baraúna and Mossoró, RN, in the Northeast Region of Brazil in the years 2011 and 2012.

In the case of N, the system made recommendations similar to Crisóstomo et al. (2002) for the Yellow and Piel-de-sapo types, but showed considerable differences for Cantaloupe and Galia. This is because the system is dynamic, recommending different rates of a determined nutrient for different melon types, considering the same expected yield. This flexibility is not possible with fertilizer recommendation tables.

Table 9. Ferticalc-melon recommendations for total nutrient application and distribution in pre-planting and topdressing (fertigation) considering a yield of 45 t ha^{-1}

Soil analysis	Recommendation				Pre-planting				Topdressing			
	Yell.	Cant.	Gali.	Piel	Yell.	Cant.	Gali.	Piel	Yell.	Cant.	Gali.	Piel
	kg ha^{-1}											
	N											
SA-I/with(1)	121	79	149	128	10	20	16	31	111	59	132	97
SA-I/without(2)	121	79	149	128	10	20	16	31	111	59	132	97
SA-II/with	121	79	149	128	10	20	16	31	111	59	132	97
SA-II/without	121	79	149	128	10	20	16	31	111	59	132	97
	P_2O_5											
SA-I/with(1)	50	77	31	166	25	50	10	93	25	27	21	73
SA-I/without(2)	50	77	31	166	25	50	10	93	25	27	21	73
SA-II/with	56	83	38	172	28	54	12	97	28	29	26	76
SA-II/without	56	83	38	172	28	54	12	97	28	29	26	76
	K_2O											
SA-I/with(1)	0	0	0	0	0	0	0	0	0	0	0	0
SA-I/without(2)	0	0	0	0	0	0	0	0	0	0	0	0
SA-II/with	168	301	195	527	3	75	25	74	164	226	169	453
SA-II/without	175	309	202	535	4	77	26	75	172	232	176	460
	Ca											
SA-I/with(1)	0	0	0	0	-	-	-	-	0	0	0	0
SA-I/without(2)	0	0	0	0	-	-	-	-	0	0	0	0
SA-II/with	6	0	0	232	-	-	-	-	6	0	0	232
SA-II/without	54	5	38	280	-	-	-	-	54	5	38	280
	Mg											
SA-I/with(1)	0	0	0	0	-	-	-	-	0	0	0	0
SA-I/without(2)	0	0	0	0	-	-	-	-	0	0	0	0
SA-II/with	0	0	15	0	-	-	-	-	0	0	15	0
SA-II/without	0	3	20	0	-	-	-	-	0	3	20	0
	SO_4											
SA-I/with(1)	0	0	0	0	-	-	-	-	0	0	0	0
SA-I/without(2)	0	0	0	0	-	-	-	-	0	0	0	0
SA-II/with	65	105	67	80	-	-	-	-	65	105	67	80
SA-II/without	65	105	67	80	-	-	-	-	65	105	67	80

(1) Considering water analysis; (2) Ignoring water analysis. Yell.: Yellow; Cant.: Cantaloupe; Gali.: Galia; Piel: Piel-de-sapo.

The recommendations for P_2O_5 suggested by the system were lower than those generated by other methods for Yellow, Cantaloupe, and Galia types (Table 11). For the Piel-de-sapo type, the P_2O_5 rate was less than that recommended by Crisóstomo et al. (2002) and the average rate applied by GAP.

The system recommended the application of K_2O only to the SA-II soil, as in Examples 3 and 4 (Table 11), showing similarities to the tables for the states of Ceará and Pernambuco for the Yellow type and to the recommendation of Crisóstomo et al. (2002) for the Cantaloupe type. In Examples 1 and 2, the system did not recommend fertilization with K_2O, while the other methods recommended high K_2O rates.

For Ca, Mg, and SO_4, the results were compared only with the amounts used by GAP due to the absence of recommendations from other methods. The system does not recommend use of Ca for SA-I soil, given the high content both in the soil and in irrigation water. Even so, GAP still recommends application at 11, 83, and 49 kg ha^{-1} of Ca for Yellow, Cantaloupe, and Galia, respectively.

For the SA-II soil, in example 3 (Table 11), the system recommended 6 and 232 kg ha^{-1} of Ca for Yellow and Piel-de-sapo, respectively. In

Table 10. Ferticalc-melon recommendations for nutrient distribution in topdressing (fertigation) for Yellow type considering a yield of 45 t ha^{-1}

	Days after sowing or transplanting					
Soil analysis	Yellow	0-15	16-30	31-45	46-60	>60
	kg ha^{-1}					
	N					
SA-I/with(1)	111	1	67	38	5	-
SA-I/without(2)	111	1	67	38	5	-
SA-II/with	111	1	67	38	5	-
SA-II/without	111	1	67	38	5	-
	P_2O_5					
SA-I/with(1)	25	1	13	8	3	-
SA-I/without(2)	25	1	13	8	3	-
SA-II/with	28	1	15	9	3	-
SA-II/without	28	1	15	9	3	-
	K_2O					
SA-I/with(1)	0	0	0	0	0	-
SA-I/without(2)	0	0	0	0	0	-
SA-II/with	164	5	46	95	18	-
SA-II/without	172	5	48	100	19	-
	Ca					
SA-I/with(1)	0	0	0	0	0	-
SA-I/without(2)	0	0	0	0	0	-
SA-II/with	6	0	1	3	2	-
SA-II/without	54	1	9	30	14	-
	Mg					
SA-I/with(1)	0	0	0	0	0	-
SA-I/without(2)	0	0	0	0	0	-
SA-II/with	0	0	0	0	0	-
SA-II/without	0	0	0	0	0	-
	SO_4					
SA-I/with(1)	0	0	0	0	0	-
SA-I/without(2)	0	0	0	0	0	-
SA-II/with	65	5	16	43	1	-
SA-II/without	65	5	16	43	1	-

(1) Considering water analysis; (2) Ignoring water analysis.

example 4, the demand increased to 54, 5, 38, and 280 kg ha^{-1} of Ca for Yellow, Cantaloupe, Galia, and Piel-de-sapo, respectively.

For Mg, only 3 kg ha^{-1} was recommended for Cantaloupe in SA-II in example 4, and 15 and 20 kg ha^{-1} for Galia in examples 3 and 4, respectively. However GAP recommends application of 7, 20, 17, and 3 kg ha^{-1} for Yellow, Cantaloupe, Galia, and Piel-de-sapo, respectively.

Since S content is low in the SA-II soil, the Ferticalc-melon recommended 65, 105, 67, and 80 kg ha^{-1} of SO_4 . However for SA-I soil, for which the system does not recommend S fertilization, GAP are applying an average of 23, 46, 45, and 92 kg ha^{-1} of SO_4 for Yellow, Cantaloupe, Galia, and Piel-de-sapo, respectively.

DISCUSSION

Requirement subsystem

In determination of TRNutPl, the RRNutPl and Sus_ReqK are two fundamental indexes to be obtained, especially RRNutPl for melon for which, due to the absence of specific data, values of other crops were adjusted for the first version of Ferticalc-melon. Therefore, research with melon is of utmost importance for specific data on RRNutPl of macronutrients, addressing mainly P and S, thereby providing subsidies for future versions of the system.

In regard to Sus_ReqK, the sustainability requirement was used only for K. Although subject to leaching losses, K may accumulate in the soil, becoming available for subsequent crops. In addition required in large quantities by the melon crop.

For the other nutrients, we chose not to use a sustainability rate, for several reasons. In the case of N, due to its dynamics in the soil, it is not possible to ensure that rates above plant requirements will be available for subsequent crops. Climatic factors and soil properties may influence the loss of nitrogen, in addition to the fact that under tropical conditions, nitrogen fertilization has low efficiency (Baligar and Bennett, 1986; Sommer and Hutchings, 2001; Martines et al., 2010).

Typical tropical soils are naturally low in P, with high phosphate fixation capacity. Phosphorus applications to soil above the P required by the plant are unviable, due to the difficulty of the soil in providing this nutrient to subsequent crops, reducing the efficiency of phosphate fertilizers (Nziguheba et al., 2002; Simpson et al., 2011). The Ca and Mg nutrients are applied in liming.

As for S, the sustainability rate could be used, however, information on S is still incipient, and absence of this information does not compromise the system since the crop will receive the required amount of this nutrient from other fertilizers containing S commonly used in the cultivation of melon.

Supply subsystem

The Ferticalc system, more precisely the SUP subsystem, generally use liming, crop residues, and organic matter as a nutrient supply in crops, previously contemplated by the system. However, they will not be used in Ferticalc-melon because this system uses liming as an indirect supply of Ca and Mg to neutralize toxic Al, and increase

Table 11. Comparison of Ferticalc-melon nutrient recommendations with other methods currently used for fertilizer recommendation, considering a yield of 45 t ha^{-1}

Ex.	Yellow					Cantaloupe					Gália					Piel-de-sapo				
	FERT	CE	PE	CT	GAP	FERT	CE	PE	CT	GAP	FERT	CE	PE	CT	GAP	FERT	CE	PE	CT	GAP
	kg ha^{-1}																			
N																				
1	121	90	90	120	130	79	-	-	120	253	149	-	-	120	216	128	-	-	120	110
2	121	90	90	120	130	79	-	-	120	253	149	-	-	120	216	128	-	-	120	110
3	121	90	90	120	-	79	-	-	120	-	149	-	-	120	-	128	-	-	120	-
4	121	90	90	120	-	79	-	-	120	-	149	-	-	120	-	128	-	-	120	-
P_2O_5																				
1	50	160	160	240	183	77	-	-	240	332	31	-	-	240	256	166	-	-	240	272
2	50	160	160	240	183	77	-	-	240	332	31	-	-	240	256	166	-	-	240	272
3	56	160	160	240	-	83	-	-	240	-	38	-	-	240	-	172	-	-	240	-
4	56	160	160	240	-	83	-	-	240	-	38	-	-	240	-	172	-	-	240	-
K_2O																				
1	0	90	40	300	236	0	-	-	300	356	0	-	-	300	387	0	-	-	300	360
2	0	90	40	300	236	0	-	-	300	356	0	-	-	300	387	0	-	-	300	360
3	168	180	160	300	-	301	-	-	300	-	195	-	-	300	-	527	-	-	300	-
4	175	180	160	300	-	309	-	-	300	-	202	-	-	300	-	535	-	-	300	-
Ca																				
1	0	-	-	-	11	0	-	-	-	83	0	-	-	-	49	0	-	-	-	-
2	0	-	-	-	11	0	-	-	-	83	0	-	-	-	49	0	-	-	-	-
3	6	-	-	-	-	0	-	-	-	-	0	-	-	-	-	232	-	-	-	-
4	54	-	-	-	-	5	-	-	-	-	38	-	-	-	-	280	-	-	-	-
Mg																				
1	0	-	-	-	7	0	-	-	-	20	0	-	-	-	17	0	-	-	-	3
2	0	-	-	-	7	0	-	-	-	20	0	-	-	-	17	0	-	-	-	3
3	0	-	-	-	-	0	-	-	-	-	15	-	-	-	-	0	-	-	-	-
4	0	-	-	-	-	3	-	-	-	-	20	-	-	-	-	0	-	-	-	-
SO_4																				
1	0	-	-	-	23	0	-	-	-	46	0	-	-	-	45	0	-	-	-	92
2	0	-	-	-	23	0	-	-	-	46	0	-	-	-	45	0	-	-	-	92
3	65	-	-	-	-	105	-	-	-	-	67	-	-	-	-	80	-	-	-	-
4	65	-	-	-	-	105	-	-	-	-	67	-	-	-	-	80	-	-	-	-

1: Example based on SA-I and accounting for the nutrient supply by irrigation water; 2: Example based on SA-I without including nutrient supply from irrigation water; 3: Example based on SA-II and accounting for the nutrient supply by irrigation water; 4: Example based on SA-II without including nutrient supply from irrigation water; FERT: Recommendations for fertilizing by Ferticalc-melon; CE: Recommendations for fertilizing and liming for the state of Ceará, Brazil (UFC, 1993); PE: Recommendations for fertilizing for the State of Pernambuco, Brazil, 2nd approximation (Cavalcanti et al., 1998); CT: technical circular from Embrapa (Crisóstomo et al., 2002); GAP: Average obtained from the fertilization used by growers of the Apodi Plateau Region.

nutrient availability and base saturation, improving the chemical characteristics of the soil. The crop residues of melon are generally removed to avoid phytosanitary problems after harvest of melon fruit (Seebold et al., 2009). Crops in general have low efficiency in the use of N from organic matter, due to the lack of synchronization between its release and plant demand, especially in short cycle crops (Kramer et al., 2002). Its supply was considered relatively small compared to that required by the crop in soils of the Brazilian Northeast (Tiessen et al., 2001).

Simulations in fertilizer recommendation

Assessing the effects of N and K on fruit yield and quality in Yellow melon, Coelho et al. (2001) obtained fruit yields of 35.8, 40.8, 51.2, and 55.0 t ha^{-1} at application rates of 0, 60, 120, and 180 kg ha^{-1} of N, respectively, with the authors recommending the rate of 120 kg ha^{-1}. For K_2O, no response was observed. The response for both N and K as obtained by these authors was similar to that estimated by Ferticalc-melon, which recommended 121 kg ha^{-1} of N and non-application of K_2O.

For the Piel-de-sapo melon type, Dutra (2005) evaluated the effect of N and K rates, obtaining a fruit yield of 37.4 t ha^{-1} with 149 kg ha^{-1} of N. The author did not observe response to K rates. Note that this study was conducted under soil conditions similar to the SA-I soil, for which the system does not recommend K_2O application.

Studying increasing K_2O rates (0, 60, 120, 180, and 240 kg ha^{-1}) for the Yellow and Cantaloupe types, Bardiviesso (2011) obtained a maximum yield of 45.7 t ha^{-1} with a rate of 137 kg ha^{-1} for the Yellow type and 39.4 t ha^{-1} for the Cantaloupe. The optimum rate obtained by the author was similar to that estimated by the Ferticalc-melon system for the Yellow type, considering the SA-II soil with fertigation.

By comparing the K_2O rates with other methods, using the Yellow type as an example, it may be observed that the system recommends fertilization only in examples 3 and 4, with applications of 168 and 175 kg ha^{-1}, respectively (Table 11). These recommendations are similar to the recommendations for the States of Ceará (180 kg ha^{-1}) and Pernambuco (160 kg ha^{-1}) and unlike the rates recommended by Crisóstomo et al. (2002), which, in addition to presenting high K_2O rates (300 kg ha^{-1}), does not make any distinction between Examples 1, 2, 3, and 4, while the GAP recommends 236 kg ha^{-1} of K_2O for examples 1 and 2.

According to the Ferticalc-melon system, the rates found in Crisóstomo et al. (2002) and GAP are unnecessary. It is important to note that Crisóstomo et al. (2002), for example, recommend the same K_2O rate for all melon types under four different situations. However, the tables, even with some drawbacks, make different recommendations for SA-I and SA-II, showing how different these soils are.

From this, one can see that the system is a good alternative for melon growers as a tool to assist them by providing more precise and scientifically established fertilizer recommendations, taking characteristics such as melon type and yield, nutrient supply by soil and irrigation water, and the effect of the buffering capacity of the soil into account.

As previously described, the P_2O_5 recommendations were generally lower for most melon types evaluated when compared with other methods, with the exception of the Piel-de-sapo type. This may indicate that the system needs adjustments in P recommendation in particular, or, otherwise, that P_2O_5 rates currently in use might be above crop demands. Therefore, it is important to perform calibration and validation in the field for the rates recommended by Ferticalc-melon in order to assist in possible adjustments, thus contributing to improvement of the system.

Analyzing the system recommendations for Ca, Mg and SO_4 nutrients, a big difference may be observed in recommendations for different melon types, particularly Ca recommendations (Table 11). This shows that there is a great variation in demand for this nutrient by different genetic materials, and the system is sensitive to this. This sensitivity is related to the continuous variations of the recommendations generated by the Ferticalc-melon system depending on expected yield, nutrient contents in the plant, and the soil buffer capacity for nutrients. These variations do not occur, for example, with recommendation tables that establish fixed rates of nutrients depending on the nutrient content in the soil, but that do not take expected yield into account (Silva et al., 2009).

CONCLUSIONS

The Ferticalc-melon system is a useful tool for fertilizer recommendation for the melon crop, with the advantage that recommendations vary depending on the melon type, expected yield, and nutrient content in the soil and irrigation water, as well as taking the buffering capacity of the soil into account.

The system which has been developed has great prospects for optimizing fertilizer use in the melon crop. However, it requires more specific crop data to improve it, and it is important to perform field validation under different situations so as to generate more precise and specific recommendations for different scenarios.

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