Article

Concentration and extraction of macronutrients in four strawberry varieties

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Abstract

Strawberry (*Fragaria x ananassa*) nutrition is a fundamental factor in achieving high yields and fruit quality. For this, fertilizer sources, timing and concentrations must be considered. The plant is adapted to subtropical and temperate conditions but is sensitive to ionic fluctuations in the nutrient solution and to the nutrient content in soil and substrate. The analysis of nutrient absorption dynamics is one of the most used strategies to infer the needs at each phenological stage. For this the need arises to formulate an algorithm that allows to know the amount of nutrient that the plant requires in each phenological stage. The objective was to determine, through regression models, the nutritional demand during the crop cycle of the strawberry varieties Albion, Festival, Jacona and Zamorana. The hypothesis was that the concentration and absorption of nutrients is differential in each variety and phenological stage of the plant, in addition the absorption of nutrients can be described by multiple linear regression models. The study was conducted using a completely random sampling for the collection of plant material under field cultivation conditions. Nutrient concentration was determined by chemical analysis. The nutritional extraction was obtained and related to each phenological stage. The reference values for the concentration and nutritional extraction were obtained for N, P, K, Ca, Mg and S, using mathematical models that determine the nutritional needs of the plants at each stage of their development.

Keywords: *Fragaria x ananassa*, nutritional concentration, nutrient extractions, regression models.

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Introduction

Strawberry (*Fragaria x ananassa*) is one of the most popular strawberries in the world. In Mexico it occupies an area of 8 976 ha and the average yield is 40.3 t ha^{-1}. The total annual production is 361 928 t, where the main producing states in order of importance are: Michoacán, Baja California, Baja California Sur, Mexico, Oaxaca, Morelos and Jalisco (SIAP, 2017). The crop generates economic benefits for society through the generation of jobs, since in each crop cycle it represents 1 158 wages ha^{-1} in nursery, commercial plantation and industrialization (Vega, 2007).

In addition, it invests in a large number of inputs for agriculture such as cover plastics, irrigation systems and agrochemicals, benefiting branch companies in the producing regions, also introduces foreign exchange for its export and encourages contract farming (Lundy, 2007; Vega, 2007). These benefits are achieved thanks to the high technification of the crop which increases the yield, cleanliness, quality and health of the fruit, generates precocity in the plant, controls weeds, allows fertigation, in order to improve irrigation efficiency and the fertilizer absorption applied. Fertilization is one of the key aspects to achieve the main objectives in strawberry production, which is to increase the quality and quantity of fruits per unit area (Jamali *et al*., 2013). In the valley of Zamora, Michoacán, there are three production systems grouped according to their technological level: the traditional, intermediate and advanced. In this same region, the use of improved technologies began in 1991 with the introduction of plastic padding, whose main advantage was to control weeds and allow fertigation.

In 1998, the use of tunnels with plastic cover to protect the crop from late rains and low temperatures began. Subsequently, in 2002, semi-hydroponic cultivation began, first in soil and then in coconut fiber substrate, trying to reduce soil disinfection costs (Vega, 2007). Under the previous context, the nutrition of the plant constitutes a fundamental factor to achieve high yields, in this process the fertilizer sources, the opportunity and the concentrations applied must be considered.

When this is done by fertigation, either in soil or in substrate, the amount of nutrients should consider: the needs of the plant, the state of development, the variety (since the latter can present differential nutritional requirements), the contribution of nutrients that the soil or substrate can make, the source of fertilizer in some nutrients and the efficiency of use of the fertilizer, which changes in soil or substrate (Martínez-Bolaños *et al*., 2008).

When the fertigation strategy is used to supplement nutrients to the plant, nutrient solutions already defined are usually applied, in terms of their ionic relationships and concentrations, being the responsibility of the technician or farmer to decide the application opportunity based on their experience; however, in this type of systems, producers and technicians face nutritional problems of the plant that can occur as chlorosis, yellowing and growth deficit, which is reflected in yield losses (Favela *et al*., 2006; Petrovic and Yoshida, 2013). Nutrient solutions contain ions available for the absorption of plants, most have mechanisms to absorb them, however, the concentration of each ion has differential effects on physiological processes, depending largely on the species and the environmental conditions of development (Tagliavini *et al*., 2004; Cárdenas-Navarro *et al*., 2006).

The strawberry plant is adapted to sub-tropical and temperate conditions, but it is very sensitive to ionic fluctuations in nutrient solution and nutrient content in both soil and substrate, so it is necessary to look for strategies that ensure a supply optimum mineral nutrition according to the requirements of the plant and keeping the availability of nutrients in the substrate in optimal conditions (Tagliavini *et al*., 2004; Yadav *et al*., 2016).

One of the most used strategies to infer the needs of the plant at each stage of its development is the analysis of nutrient absorption dynamics, which relates the difference in nutritional content in each organ or in the entire plant and the accumulation of biomass between two phenological stages, considering the availability of each element in the soil or in the substrate, to elucidate the actual nutrient needs for the plant (Daugaard, 2001; Wojcik and Lewandowski, 2003). The above, with the objective of making an optimal dosage of the fertilizer and in this way, rationing resources and reducing the leaching of fertilizer residues to deeper horizons of the soil, aquifers, bodies of water or even the atmosphere (Tagliavini *et al.*, 2005).

This type of analysis is also called the nutrient absorption curve, which determines the amount of nutrients a plant consumes; through its life cycle and allows continuous monitoring of the plant's response to the nutrient conditions of the substrate, to achieve a balance in physiological functions and development of its maximum genetic potential (Molina *et al*., 1993; Orona-Castillo *et al*., 2004; Mattar and Pizarro, 2007).

Once the nutritional demand has been identified, the need arises to formulate an algorithm that allows the amount of nutrient that the plant requires at each phenological stage to be interpolated, especially at times when no sampling has been carried out. To that end, mathematical models are created and designed. For this reason, the objective of this research was to determine, through regression models, the nutritional demand during the crop cycle of the Albion, Festival, Jacona and Zamorana strawberry varieties.

Materials and methods

Crop establishment

This research was carried out on a plot with commercial strawberry cultivation in the area of Zamora, Michoacán, Mexico (19° 59’ 57” north latitude 102° 20’ 9” west longitude and altitude 1 570 m). The cultivation was carried out in a plastic macro tunnel, in coconut fiber substrate and with fertirriego, in a highly technified system, where Albion, Festival, Jacona and Zamorana varieties were evaluated. The plants were developed in containers of 1 m x 0.3 m x 0.1 m (pens), where 10 double row plants distributed in three bobbins were placed, each row had five plants at a separation of 0.2 m.

The crop was fertilized with Steiner's nutrient solution, applied in irrigation, which varied its concentration and electrical conductivity according to the phenological stage of the crop (Steiner, 1984; Hernández *et al*., 2006) (Table 1). Weed, pest and disease control were carried out according to the technical management scheme carried out by the producers in the study area. Irrigation was dosed with constant monitoring of substrate moisture.

Table 1. Composition of the nutrient solution applied at each phenological stage in strawberry plants grown in coconut fiber substrate in Zamora, Michoacán.

DDT†	Phenological stage	CE	NO_3^-	$H_2PO_4^-$	SO_4^{2-}	K^+	Ca^{2+}	Mg^{2+}
		(dS m^{-1})	(meq L^{-1})					
0-60	Vegetative	0.5	3	0.3	1.8	1.8	2.3	1
>60-90	Flowering	1	6	0.5	3.5	3.5	4.5	2
>90-120	Fruit ripening	1.3	7.5	0.6	4.4	4.4	5.6	2.5
>120-165	Fruit harvest	1.5	9	0.8	5.3	5.3	6.8	3

†= Days after transplant.

Obtaining the samples

The plant material was obtained by completely random sampling every 15 days after transplantation (DDT) and for 165 days, with a total of 11 samples. In each sampling four plants were selected per variety and each one was considered as a subsample.

Variables

The variables evaluated were a) production of aerial biomass (formed by leaves, petioles, flowers, fruits and crown of the plant); and b) concentration and extraction of N, P, K, Ca, Mg and S. In parallel, the phenology of the plants of each variety was recorded (Enz and Dachler, 1998; Woldb and Hutchisona, 2003; Meier *et al*., 2009). The plants were dried in an oven with forced ventilation at 70 °C for 72 h and weighed to estimate biomass production. Subsequently, the dried tissue was ground with a Wiley mill and stored in paper envelopes to continue the chemical analysis.

The determination of N was performed using the Semimicro-Kjeldahl method (Alcantar and Sandoval, 1999), while P, K, Ca, Mg and S were determined by wet digestion with a mixture of perchloric and nitric acids in relation to 2:1 (Alcantar and Sandoval, 1999). The quantification of P, Ca and Mg was performed with an atomic absorption spectrophotometer with plasma coupled induction (Liberty Series II model, Variant Germany brand). The K was quantified by a flamometer (Corning 400-Flame photometer) and the S by a spectrophotometer (Thermo Genesys 10 series). Nutritional extraction was estimated from the product of aerial biomass and nutrient concentrations.

Statistic analysis

The statistical analysis of the production of aerial biomass plus crown, concentration and nutritional extraction was carried out by means of regression analysis considering the phenological stage, according to the method described by Volke (2008), where a model with a few variables is specified from the graphic relationships between the response variables and the study factors, where variables are attached to the model based on the graphic relationship between the residuals and the factors not yet included in the model, which showed some response trend, until the model with the lower mean square of error (CME) and higher coefficient of determination (R^2) (Montoya-García *et al*., 2018).

For each variety and nutrient, a regression model was generated in relation to the phenological stage of the crop cycle. The regression models were obtained with SAS® version 9.0 and the graphs of the nutritional concentration were generated with the values estimated by the models.

Results and discussion

Phenological stages of the crop

The phenological stages that were identified during the study and related to the nutritional concentration were: 1) 4 to 5 leaves (15 DDT); 2) appearance of primary flowers (30 DDT); 3) stolon emission (45 DDT); 4) foliage increase (60 DDT); 5) flowering (75 DDT); 6) white fruits (90 DDT); 7) fruit development (105 DDT); and 8) fruiting (120 to 165 DDT). The phenological development of the Jacona and Zamorana varieties occurred with a delay of 15 days in relation to the Albion and Festival varieties, which resulted in a 15-day longer development cycle for the former. Due to the above, Albion and Festival bore fruit early compared to Jacona and Zamorana.

Production of aerial biomass

The regression models that described the dynamics in the accumulation of dry matter in the strawberry varieties studied were the following:

Albion

$PBA = 1.69+2.05x10^{-4}T^3–4.72x10^{-6}T^4+3.88x10\text{-}8T^5–1.07x10^{-10}T^6$

(Pr F=0.0001, CME=5.123, CV=18.72%, R^2=0.973)

Festival

$PBF = 1.29+ 0.012T^2 – 1.696x10^{-4}T^3+1.18x10^{-8}T^5–4.810x10^{-11}\ T^6$

(Pr F =0.0001, CME=10.626. CV=16.69%, R^2=0.973)

Jacona

$PBJ =1.27+1.20x10^{-2}T^2–2.091x10^{-4}T^3+1.243x10^{-6}T^4–1.255x10^{-11}T^6$

(Pr F = 0.0001, CME = 21.201, CV=0 19.56%, R^2 = 0.946)

Zamorana

$PBZ = 1.23+9.95x10^{-3}T^2–1.82T^3+1.15x10^{-6}\ T^4–1.25x10^{-11}T^6$

(Pr F =0.0001, CME=8.115, CV=13.58%, R^2 = 0.981).

Where: PB= production of aerial biomass plus crown (g $plant^{-1}$, dry base), in each strawberry variety; T= days from transplant up to 165 days; Pr F= probability of F; CME= mean square of the error; CV= coefficient of variation; R^2= multiple determination coefficient.

These models had the best fit for the production of biomass accumulated in each variety during the crop cycle (Pr F ≤ 0.0001, R^2 > 0.9). Albion had lower production of aerial biomass compared to Festival, Jacona and Zamorana, this response may be due to Albion being characterized by slow development compared to other varieties, has a smaller size and is susceptible to pests such as the red spider, although It has a high phenotypic plasticity (Shaw and Larson, 2005; Costa *et al*., 2017; Esteca *et al*., 2017).

Biomass production presented three stages of greater accumulation: the first, from 15 to 30 DDT, where a rapid development of the leaf area was observed; the second from 90 to 120 DDT, which was characterized by rapid vegetative development and the third from 150 to 165 DDT, where maximum development was achieved, showing signs of aging and leaf loss.

The greatest increases in biomass occurred from 90 to 135 DDT in all varieties, mainly due to the development of the reproductive organs (Figure 1). The above coincided with the results of Molina *et al*. (1993) and Tagliavini *et al*. (2005) who observed that the growth of the Chandler variety was very low during the first nine weeks (63 days); while between 113 and 168 the highest biomass production is presented, which coincides with the peak of fruiting.

After 155 days, biomass accumulation fell due to defoliation and the demand for energy that fruiting requires. This behavior occurs in each fruiting event, where the fruit is of lower quality in each successive fruiting (Avitia-García *et al*., 2014) (Figure 1).

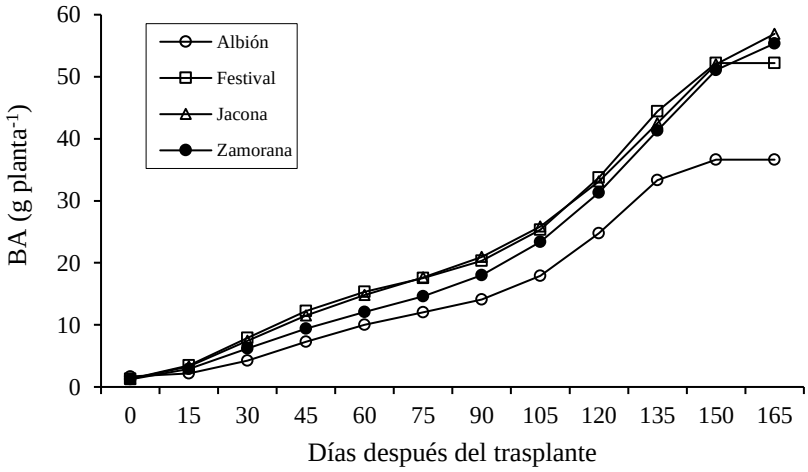

Figure 1. Accumulated production of aerial biomass for four strawberry varieties grown in coconut fiber with a hydroponic system estimated using regression models. BA= accumulated aerial biomass.

Nutrient concentration in aerial part plus crown

The regression models with the best fit to quantify the nutritional concentration in each of the strawberry varieties according to their phenological stage were the following:

Nitrogen

$CN=1.72-0.16V_2-0.29V_3-0.179V_4-7.75x10^{-3}T+1.041748x10^{-5}T^3-1.9x10^{-7}T^4 + 1.23x10^{-9}T^5 2.73x10^{-12}T^6$

(Pr F= 0.0001, CME= 0.0046, CV= 4.158%, R^2= 0.856)

Phosphorus

Albion, Festival, Zamorana

$CP= 0.41+2.39x10^{-6}T^3–4.56x10^{-8}T^4+3.20x10^{-10}T^5–7.82x10^{-13}T^6+0.37P_{15}$

(Pr F= 0.0001, CME= 0.00103, CV= 5.25%, R^2= 0.948)

Jacona

$CP= 0.45+2.41x10^{-7}T^3–1.33x10^{-9}T^4+0.239P_{15}$

(Pr F= 0.0282, CME= 0.00312, CV= 10.24%, R^2= 0.7029)

Potassium

$CK= 2.74-0.29V_2-0.27V_3-0.26V_4+0.25T^{0.5}-0.024T+4.88x10^{-5}T^2+1.86K_{150}$

(Pr F= 0.0001, CME= 0.06782, CV= 8.09%, R^2= 0.831)

Calcium

$CCa=1.05+0.02V_2-0.026V_3+9.43x10^{-4}V_4-4.3x10^{-2}T+2.33x10^{-3}T-3.95x10^5T^3+2.68x10^7T^4-6.32x10^{-10}T^5 + 0.629\ Ca_{l5}$

(Pr F= 0.0001, CME= 0.01228, CV= 10.34%, R^2= 0.68)

Magnesium

$CMg= 0.69-0.01V_2-0.13V_3-0.079V_4–3.99x10^{-4}T-3.71x10^{-3}V_2T+2.32\ x10^{-5}V_2T^2-2.92x10^{-3}\ V_4T+1.92V_4T^2$

(Pr F= 0.0218, CME = 0.00922, CV = 17.17%, R2 = 0.385)

Sulfur

$s=0.38+2.75x10^{-2}V_2-8.35x10^{-2}V_3-9.995x10^{-2}V_4-2.71x10^{-3}T+1.37x10^{-5}T^2-2.75x10^{-3}\ V_2T+1.9206x10^{-5}V_2T^2+5.711x10^{-4}V_3T +7.34x10^{-4}V_4T$

(Pr F = 0.0001, CME = 0.00173, CV = 15.6%, R^2 = 0.634)

Where: CN, CP, CK, CCa, CMg and Cs are the concentrations of N, P, K, Ca, Mg and S (percentage on dry basis); V_2, V_3 and V_4 are auxiliary variables for the Festival, Jacona and Zamorana varieties; T= days from transplant up to 165 days; P_{15}, K_{150} and Ca_{15} are auxiliary variables for the periods of 15 and 150 days in which all varieties showed higher concentrations than the observed trend. Pr F= probability of F, CME= mean square of the error, CV= coefficient of variation, R^2= multiple determination coefficient. All regression coefficients were significant (Pr F≤ 0.01)

The values of nutritional concentration in the biomass plus crown estimated with the models are presented in Figures 2 and 3. In Figure 2A, the nutritional concentration of N in the four varieties studied is observed, the concentrations were positioned in the range of 1.3 to 1.95%, losses compared to those reported by Cárdenas-Navarro *et al.* (2006), where the concentration varied from 1.5 to 2.9%, in a trial of various ammonium/nitrate ratios.

However, Castro *et al*. (2005) applied marginal concentrations of N where they found that the plants expressed nitrogen deficiency at the concentration of 1.1% in leaf tissue, at the end of the crop cycle. Molina *et al*. (1993), found that throughout the 30-week (210-day) cycle the concentration was from 1.40 to 2.86%, variations in the upper end may be due to the dosage of N in each particular experiment. Nitrogen is an element whose dosage should be done carefully since its excess can decrease the quality of the fruit, decreasing firmness, the content of ascorbic acid and increasing the content of poly phenols (Castro *et al*., 2005; Agulheiro-Santos, 2009).

Figure 2B shows the phosphorus concentrations (P) for the four strawberry varieties, which ranged from 0.41 to 0.78%, values that coincide with those found in the Aromas, Seascape, Chandler, Diamante and Pájaro varieties, which presented deficiencies of this nutrient at concentrations below 0.15% (Muramoto, 2003). However, the Chandler variety showed much lower concentrations during its cultivation cycle, which ranged from 0.16 to 0.44% (Molina *et al*., 1993), although concentrations as low as 0.19 to 0.35% have been reported (Daugaard, 2001).

The phenological stages where the plant increased the concentration of P was in fruit development and fruiting, which indicates the importance of ensuring the availability of phosphorus in these critical stages, since deficient plants can develop flowers and small fruits in comparison with non-deficient plants (Nestby *et al*., 2004).

Potassium (K) concentrations ranged from 2.46 to 3.42% in the four varieties, which is higher than reported by Molina *et al*. (1993), in the Chandler variety that had concentrations between 1.33% to 2.52%. While Daugaard (2001), he found concentrations of between 1.5% and 1.8% throughout the crop cycle in an average of eight strawberry varieties (Figure 2C). In the present investigation, the differences in concentration of K between the initial and final stages were of the order of 1% in each variety. The phenological stages where the highest concentration of this nutrient was observed coincide with the appearance of the first flowers on days 30 and 45, although, the concentrations of K in the plant tissue constituted 1 to 5% of the dry matter, which It is considered sufficient to be greater than 1.5% (Favela *et al*., 2006; Mattar and Pizarro, 2007).

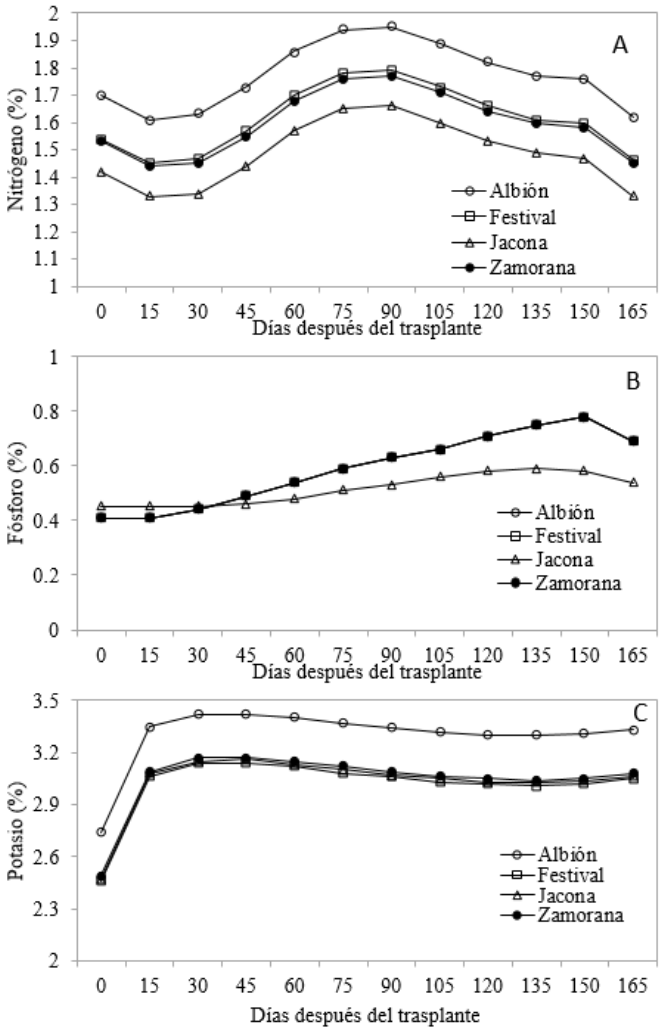

Figure 2. Concentration of macronutrients in aerial biomass plus crown as a function of time for four strawberry varieties. A) nitrogen; B) phosphorus; and C) potassium.

The calcium concentration (Ca) ranged from 0.76 to 1.27% (Figure 3A), coinciding with the values reported by Molina *et al*. (1993), where concentrations ranged from 0.47 to 1.9% and from Daugaard (2001), whose concentrations ranged from 0.9 to 1.9%; the optimal concentration can be between 0.7 and 1.2% (Nestby *et al*., 2004) and deficiency symptoms can be observed at concentrations below 0.5% (Mattar and Pizarro, 2007).

The magnesium (Mg) concentrations were homogeneous throughout the crop cycle since they ranged from 0.46 to 0.68%, sufficient levels for the plant (Favela *et al*., 2006), the highest concentrations were presented at the beginning and end of the crop cycle; in other studies (Daugaard, 2001; Molina *et al*., 1993), concentrations ranging from 0.19 to 0.65% have been found, whose values coincide with those found in this work (Figure 3B). Sulfur concentrations ranged from 0.18 to 0.41%, the concentration of this element in plant tissue was constant throughout the crop cycle (Figure 3C). Deficiency symptoms occur only at concentrations lower than 0.01%, optimal leaf concentrations range between 0.15 and 0.5% (Olivia *et al*., 2017).

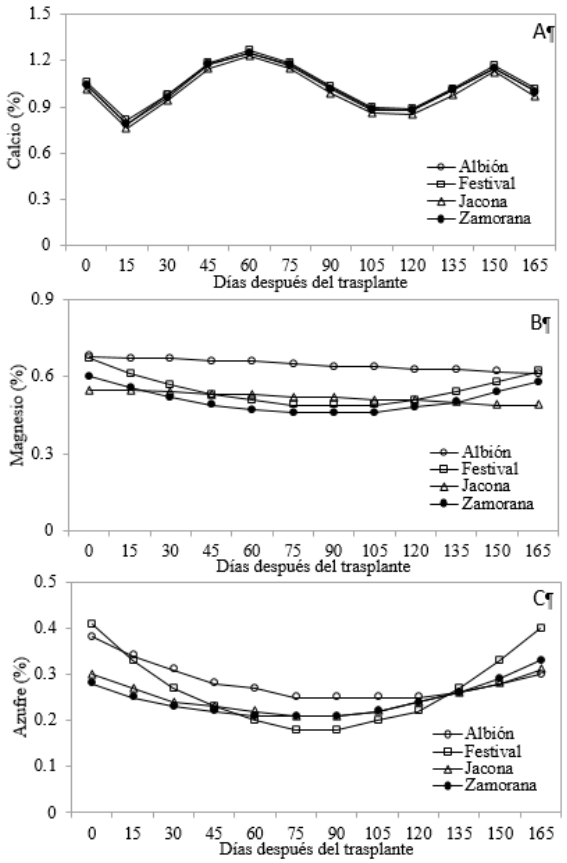

Figure 3. Concentration of macronutrients in aerial biomass plus crown as a function of time for four strawberry varieties. A) calcium; B) magnesium; and C) sulfur.

The concentrations of all the elements in the four varieties were within the permissible limits and therefore no deficiency symptoms were observed in any of the varieties evaluated. For this reason, the average values of the nutritional concentration of the four varieties can be used as referents, as long as the quantification methodology is homologous.

Nutritional extraction

Six models were developed for each strawberry variety, one for each nutrient analyzed (N, P, K, Ca, Mg, S), resulting in 24 models that predict the extraction of the elements as a function of time. The latter can be related to the phenological stage of the crop, only by substituting the parameters to obtain the extraction of nutrients expressed in kilograms per hectare. Models to estimate nutrient extraction based on the product of the concentration of each element and the content of aerial biomass in N, P, K, Ca, Mg and S in each strawberry variety were expressed in units of mass (g) in 50 000 strawberry plants since this is an average population density in the growing areas, however, each equation can be adjusted according to the desired population density (Table 2 and 3).

Table 2. Nutritional extraction equations for the Albion and Festival varieties.

Ex†	Model¶	CME	CV	R^2	Pr F
	Albión				
N	$1.8x10^{-1}T^3-5.7x10^{-3}T^4+6.6x10^{-5}T^5-3.2x10^{-7}T^6+5.5x10^{-10}T^7$	2413.6	1.6	0.9	**
P	$3.4x10^{-1}T^2+2.7x10^{-2}T^3-9.1x10^{-4}T^4+8.9x10^{-6}T^5-2.8x10^{-8}T^6$	175.8	1	0.9	**
K	$6.5T^2-4.3x10^{-3}T^4+6.6x10^{-5}T^5-3.6x10^{-7}T^6+6.4x10^{-10}T^7$	5112.3	1.2	0.9	**
Ca	$1.4x10^{-1}T^3-4.2x10^{-3}T^4+4.6x10^{-5}T^5-2.1x10^{-7}T^6+2.9x10^{-10}T^7$	37839	9.6	0.9	**
Mg	$7.6x10^{-1}T^2+2.8x10^{-2}T^3-1.4x10^{-3}T^4+1.9x10^{-5}T^5-1.1x10^{-7}T6+1.9x10^{-10}T^7$	1204	3.2	0.9	**
S	$4.9x10^{-1}T^2-3.1x10^{-4}T^4+5.1x10^{-6}T^5-2.8x10^{-8}+4.9x10^{-11}T^7$	687.3	5.4	0.9	**
	Festival				
N	$41.9T+6.7T^2-0.2T^3+1.9x10^{-3}T^4-5.9x10^{-6}T^5$	1513.9	1	0.9	**
P	$3.3T^2-0.10T^3+1.5x10^{-3}T^4-1.2x10^{-5}T^5+5.7x10^{-8}T^6$	79.1	0.4	0.9	**
K	$45.7T+25.8T^2-1.03T^3+1.6x10^{-2}T^4-1.2x10^{-4}T^5+4.8x10^{-7}T^6-7.9x10^{-10}T^7$	3517.4	0.8	0.9	**
Ca	$4.3T^2-2.9x10^{-3}T^4+4.4x10^{-5}T^5-2.33x10^{-7}T^6+4.1x10^{-10}T^7$	40823	6.8	0.9	**
Mg	$5.7T^2-0.24T^3+4.1x10^{-3}T^4-3.5x10^{-5}T^5+1.6x10^{-7}T^6-2.8x10^{-10}T^7$	416	1.4	0.9	**

†= nutritional extraction in g in 50 000 plants; ¶T= days from transplant. All regression coefficients were significant (Pr F≤ 0.01).

These regression models allowed estimating nutrient requirements for the plant based on the phenological stage in each variety. However, for its implementation, it should be taken into account that each model does not consider the efficiency of fertilizer use since it depends on the cultivation system used (soil, drip, hydroponics, substrate).

Therefore, the dosages should be adjusted according to the agronomic or recovery efficiency of the fertilizer as suggested by Stewart (2007). This same author mentions that the efficiency of recovery of nutrients are as follows: N from 50 to 70%, P from 10 to 25%, K from 50 to 60%, the latter two have potential for accumulation in the soil, by this factor should also be considered when establishing a fertilization program.

Table 3. Nutritional extraction equations for the Jacona and Zamorana varieties.

Ex†	Model¶	CME	CV	R^2	Pr F
	Jacona				
N	$56.5T+3.6T^2-0.11T^3+1.01x10^{-3}T4-2.9x10^{-7}T5$	1800.6	1.1	0.9	**
P	$21.5T+1.4T^2-5.6x10^{-2}T^3+6.8x10^{-4}T^4-3.14x10^{-6}T^5+4.5x10^{-9}T^6$	733.2	2	0.9	**
K	$106.9T+17.9T^2-0.8T^3+1.2x10^{-2}T4-8.9x10^{-5}T^5+3.4x10^{-7}T^6-5.3x10^{-10}T^7$	8782	1.2	0.9	**
Ca	$3.8T^2-2.4x10^{-3}T4+3.5x10^{-5}T^5-1.8x10^{-7}T^6+ 3.1x10^{-10}T^7$	19289	4.8	0.9	**
Mg	$10.5T+3.6T^2-0.15T^3+2.2x10^{-3}T^4-1.69x10^{-5}T^5+6.4x10^{-8}T^6-9.9x10^{-11}T^7$	519.6	1.8	0.9	**
S	$7.8T+1.5T^2-6.7x10^{-2}T^3+1.2x10^{-3}T^4-9.6x10^{-6}T^5+4.05x10^{-8}T^6-7.01x10^{-11}T^7$	199.3	1.7	0.9	**
	Zamorana				
N	$21.9T+6.7T^2 -0.3T^3+3.9x10^{-3}T^4-3.2x10^{-5}T^5+1.4x10^{-7}T^6-2.6x10^{-10}T^7$	979	0.8	0.9	**
P	$2.8T^2-0.10T^3+1.6x10^{-3}T^4-1.4x10^{-5}T^5+ 7.04x10^{-8}T^6-1.5x10^{-10}T^7$	39.6	0.3	0.9	**
K	$105.1T+13.5T^2-0.61T^3+9.7x10^{-3}T^4-7.3x10^{-5}T^5 +2.8x10^{-7}T^6-4.3x10^{-10}T^7$	5516.7	1	0.9	**
Ca	$4.21T^2-7.8x10^{-2}T^3+6.12x10^{-6}T^5-2.6x10^{-8}T^6$	16645	4.5	0.9	**
Mg	$12.4T+2.6T^2-0.12T^3+1.96x10^{-3}T^4-1.6x10^{-5}T^5+6.6x10^{-8}T^6-1.13x10^{-10}T^7$	540.1	1.6	0.9	**
S	$6.2T+1.1T^2-5.1x10^{-2}T^3+8.9x10^{-4}T^4-7.5x10^{-6}T^5+3.24x10^{-8}T^6-5.8x10^{-11}T^7$	125.2	1.4	0.9	**

†= nutritional extraction in g in 50 000 plants; ¶T= days from transplant. All regression coefficients were significant (Pr F≤ 0.01).

Conclusions

The dynamics of the accumulation of aerial biomass was different between varieties, being Jacona Zamorana and Festival those that accumulated greater biomass. The models obtained by multiple linear regression allowed describing the dynamics of the concentration and nutritional extraction of N, P, K, Ca, Mg and S in the strawberry varieties Albion, Festival, Jacona and Zamorana. Nutrient concentrations were presented in the following order K> N> Ca> Mg> P> S.

The models for nutrient concentration can be used as a benchmark in the foliar nutritional diagnosis for strawberry cultivation considering the variety. Similarly, nutritional extraction models can be used as a support tool in making fertilization decisions in semi-hydroponic or hydroponic systems of strawberry cultivation.

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