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Absorption curves - mineral-extraction under an aeroponic system for white chrysanthemum (*Dendranthema grandiflorum* (Ramat.) Kitam. cv. Atlantis White)

Curvas de absorción-extracción mineral bajo un sistema aeropónico para crisantemo blanco (*Dendranthema grandiflorum* (Ramat.) Kitam. cv. Atlantis White)

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Abstract

The aim of this study focused on the construction of the absorption and extraction curves under an aeroponic system for *White chrysanthemum* cv. Atlantis White, and therefore, propose the periods of maximum and minimum nutrient accumulation from aboveground, root and total biomass. Vegetative cycle of the plant, measured from the day after transplantation (dat) to aeroponic system, and the first day of court lasted 49 days. Evaluations were carried out each week on plants, in absolute competition. For the average aboveground biomass, three replicates were recorded. To obtain total root biomass only one sample, was measured. Therefore, total biomass in average, had achieved 130.9313 g.plant^{-1}, where 72.26% (94.163 g) corresponded to the aboveground biomass and 27.74% (36.3183 g) to root biomass. From nutrient contents reported in tissue analysis and biomass, nutrients absorbed-extracted were calculated. Overall, two plant stages development in nutrient absorption were observed as follows: the first, at day 21 dat; and second, from day 22 to day 49 dat. In this study, the reported elements (N, P, K, Ca, Mg and S), its accumulation during the first stage did not exceeded 29%, except for S, which reached 30.19%. Consequently, the mostly close to 70% nutrients were absorbed in the second stage of development, which coincided with the plant reproductive stage.

Key words: macronutrients, nutrient balance (plants), nutritional status, ornamental species, plant development stage, plant nutrition, plant soil relations.

Resumen

El objetivo de este estudio se centró en la construcción de las curvas de absorción-extracción bajo un sistema aeropónico para crisantemo blanco cv. Atlantis White y así plantear los periodos de máxima y mínima acumulación de nutrientes de las biomasas aérea, radical y total. El ciclo vegetativo de la planta, medido desde el día de trasplante (ddt) al sistema aeropónico y el día de inicio de corte, duró 49 días. Las evaluaciones se realizaron cada semana sobre plantas en competencia absoluta. Para el promedio de la biomasa aérea se tomaron tres repeticiones, para la biomasa radical se tomó una sola muestra. La biomasa total promedio alcanzada fue de 130.9313 g planta^{-1}, de la cual el 72.26% (94.163 g) correspondió a la parte aérea y el 27.74% (36.3183 g) a la radical. A partir de contenidos de nutrientes reportados en los análisis de tejidos y las biomasas se calculan los nutrientes absorbidos-extraídos. En términos generales, se observan dos etapas en la absorción de nutrientes, una primera hasta el día 21 ddt y la segunda desde el día 22 hasta el día 49 ddt. Para los elementos reportados en este estudio (N, P, K, Ca, Mg y S); su acumulación durante la primera etapa no supero el 29%, excepto el S que llegó hasta el 30.19 %. En consecuencia, la mayor cantidad de nutrientes, cerca al 70%, fueron absorbidas en la segunda etapa de desarrollo, coincidente con la fase reproductiva de la planta.

Palabras clave: Balance de nutrientes (plantas), especies ornamentales, estatus nutricional, etapa de desarrollo vegetal, nutrición vegetal, macronutrientes, relaciones planta-suelo.

Introduction

Chrysanthemum (*Dendranthema grandiflorum* (Ramat.) Kitam.) is one of the most worldwide cultivated ornamental species, this activity is reported as an outstanding line in British, Canadian and Dutch economy, standing out Colombia as the American country where this activity takes a modernization process of more than 25 years, where the Antioquia department, manage the production of chrysanthemums (ASOCOLFLORES, 2015).

In Colombia, the flower industry generates about 182174 direct jobs and approximately 1000000 indirect jobs, becoming a line of social and dynamic stabilization of the Colombian economy. According to reports by the year 2012, had recorded 7900 hectares engaged in flower production, these exports generated about USD$ 1270 million. In St. Valentine's Day, is expected to export some 500 million stems (Manrique, Zuleta, Agudelo, Burgos, Jerez, Mejia, Pereira & Palacio, 2014).

From the total flower production in the country, 95% is exported, from this percentage: 75.7% comes out exported to the United States, 5% for Russia and to other countries such as Japan, United Kingdom and Canada, among others. In total, Colombia sells flowers to about 89 countries, this makes Colombian floriculture the first line of non-traditional agricultural exports and also represents 75% of the mobilized air cargo. Chrysanthemum figures with carnations and roses as the flowers of greater international demand (ASOCOLFLORES, 2015).

The floriculture technician condition, suggests a highly calibrated and validated processes. However, with respect to fertilization rates, there are no implementation plans supported in absorption studies that reflect the amounts required per plant and even less, times of greatest and lowest nutrient absorption-extraction mineral curves.

In general terms, the fertilization agronomical assessment is based on the results of soil analysis and subsequently, recommendations are based primarily on soil element levels, regardless the nutrient contents in plant tissues. Consequently, this generates problems associated with unsupported dosages in an inappropriate timing, which cause deficiencies, toxicities, little homogeneity and phytosanitary crop problems associated with poor plant nutrition.

In addition, the extraction-absorption curve, measures the accumulation element over time, and have allowed the proper moment of maximum and minimum nutrient uptake. These curves are established for different authors (Bertsch & Gonzalez, 1989; Bertsch, Hernández, Arguedas & Acosta, 2003; Bertsch, 2005), which is an instrument that provides closest information about the quantity of plant uptake nutrients and accurate amounts that must be replaced throughout fertilizers.

Absorption curve-extraction can be in soil environment under alternative systems or hydroponics. A modification of the latter, is aeroponics, which promotes the study of the plant root zone to keep it suspended without any substrate, but is mainly limited to transient species of medium-sized to small (Putra & Yuliando,2015).

Therefore, this study was aimed to the construction of the absorption-extraction curves in different phenological stages of chrysanthemum (*Dendranthema grandiflorum* (Ramat.) Kitam. cv. Atlantis White) under an aeroponic system without soil, in order to determine more precisely the periods of maximum and minimum nutrient accumulation from aboveground, root and total biomass, according to plant demand

Material and methods

Study area

The study was carried out at the Universidad Catolica del Oriente, Colombia, located in the municipality of Nuestra Señora de Arma Rionegro- Antioquia, Colombia at 2100 m.a.s.l., with an average annual temperature of 18°C, relative humidity of 87% and an average annual rainfall ranging from 1800 - 2500mm.

Nutrient solution management-aeroponic system

Three aeroponic beds of 9m long, 1m x 80cm, equipped with two irrigation lines of 16mm and GREEN MIST™ nebulizers, with a capacity of 20 gallons per hour, were built at a distance of 70 cm apart. To resemble dark soil, side and bottom is covered with a black plastic (size 6) also allows the return of nutrient solution excess after spraying. Top of the beds expanded polyethylene sheets that fulfills the function of sustaining productive units with holes of 4 cm in diameter, where seedlings are placed. Growing density used in total 27m^2 (2057), which was based on a previous study carried out by Prieto, Escobar & Posada (1986).

Irrigation system was programmed to automatically sprinkle in two cycles, one ranged from 08:00 to 17: 30 hours every 7 minutes for 30 seconds and second, ranged from 17:31 to 07:59 every 3 hours for 30 seconds (Idris & Sani, 2012 method); an embedded system consisted of a PIC16F886 microcontroller and Real Time Clock (RTC) DS1307 and a serial converter for communication with the computer for adjusting cycles and relays as interface module coupling to energize the electromagnetic contactor controlling a motor pump 1.5HP, responsible for promoting Hoagland solution (Hoagland & Arnon, 1950) from a 1000 liter plastic tank through irrigation system above mentioned, a closed hydraulic cycle, which have allowed the remaining solution of each irrigation cycle will return to the tank for reuse later.

During the first three days, water without nutrients was applied to remove substrate from rooting period and avoid plugging and rainfall from system elements with organic waste substrates. Nutrient solution was maintained at pH levels and electrical conductivity ranged from 5.5 to 6.5 and 1800 to 2000 mS, respectively.

Samples preparation

The aeroponic transplant beds, was carried out in May 7 of 2015, day from which the first sampling was performed. Subsequently, each week, always the same day for the next six weeks plants were collected in absolute competition. Three samples of air and root tissue, were analyzed. In the first few weeks, was necessary to collect several plants to form the sample required by the plant tissues soil laboratory of the Universidad Nacional de Colombia, Medellin-Colombia. In addition, samples were taken to find the dried shoot mass and root biomass, these samples were disposed for 24 hours at 80°C. A procedure was performed in laboratories of the Universidad Catolica del Oriente, Colombia.

Statistical analysis

The experimental unit was formed by a container with three plants, with four replications at each sampling. The statistical analysis was performed with the Statistical Analysis System software (SAS) using the General Linear Model (GLM Proc; SAS9.1; SAS Institute, Cary, NC, USA) for the analysis of variance, the RGR procedure (regression) for the study of polynomial functions and NLIN procedure for the study of non-linear functions. To identify significant difference among treatments and statistical significance for all comparisons was made at $p<0.05$. Tukey's multiple range test was used to compare the mean values of treatments.

Results

Rooted cuttings were transplanted into the aeroponic system on May 7th, and the first cut started on June 18th, 2015. Hence, first stalks were harvested at 49 dat. Three cuts were performed at 56 dat, which from all harvest plants was completed. As a first step in developing the absorption curves, results from the aboveground, root and total biomass per plant (Figure 1), obtained at week 6 (time in which lasted the vegetative cycle of the species).

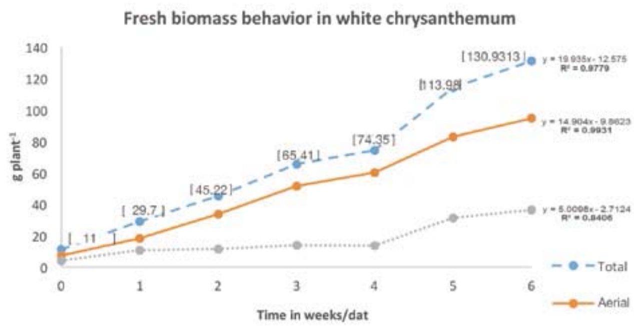

Figure 1. Fresh biomass behavior in white chrysanthemum during aeroponic vegetative cycle.

Seedlings starts with an average biomass of 7.2 g and 3.99 g of root biomass, for a total of 11.19g. At the beginning of harvest, ending the week 6 (49 dat) plants averaged 94.613g of biomass, 36.3183g of root, and total of 130.9313g.

From total biomass measurement, quantity of nutrients recorded throughout the evaluation time, is calculated. When these are calculated throughout plant, technically speaking absorption occurred. When measurement is achieved in one part or special plant organ (root, leaves, flowers or fruit, etc.), is when the extraction occurs. In both cases, total amount of elements obtained through multiplying the total dry by the content of each reported in tissue analysis element, were recorded.

Figure 2, shows the extraction of nutrients from the aboveground part during the growing season. Quantities are expressed per plant, which facilitates calculations of absorption-extraction for different planting densities. In fact, days among week 0 and week 1, corresponds to plant rooting period, which ranges from 12 to 16 days.

In the case of nitrogen, it was observed that most extraction is presented in week fourth, among 28 and 35 days after transplanting. In addition, the plant uptakes 30.59% of the total N, corresponding to 0.19 g. However, among 21 and 42, the plant extraction reaches 70% of N (0.435 g). Phosphorus removal presents an irregular behavior.

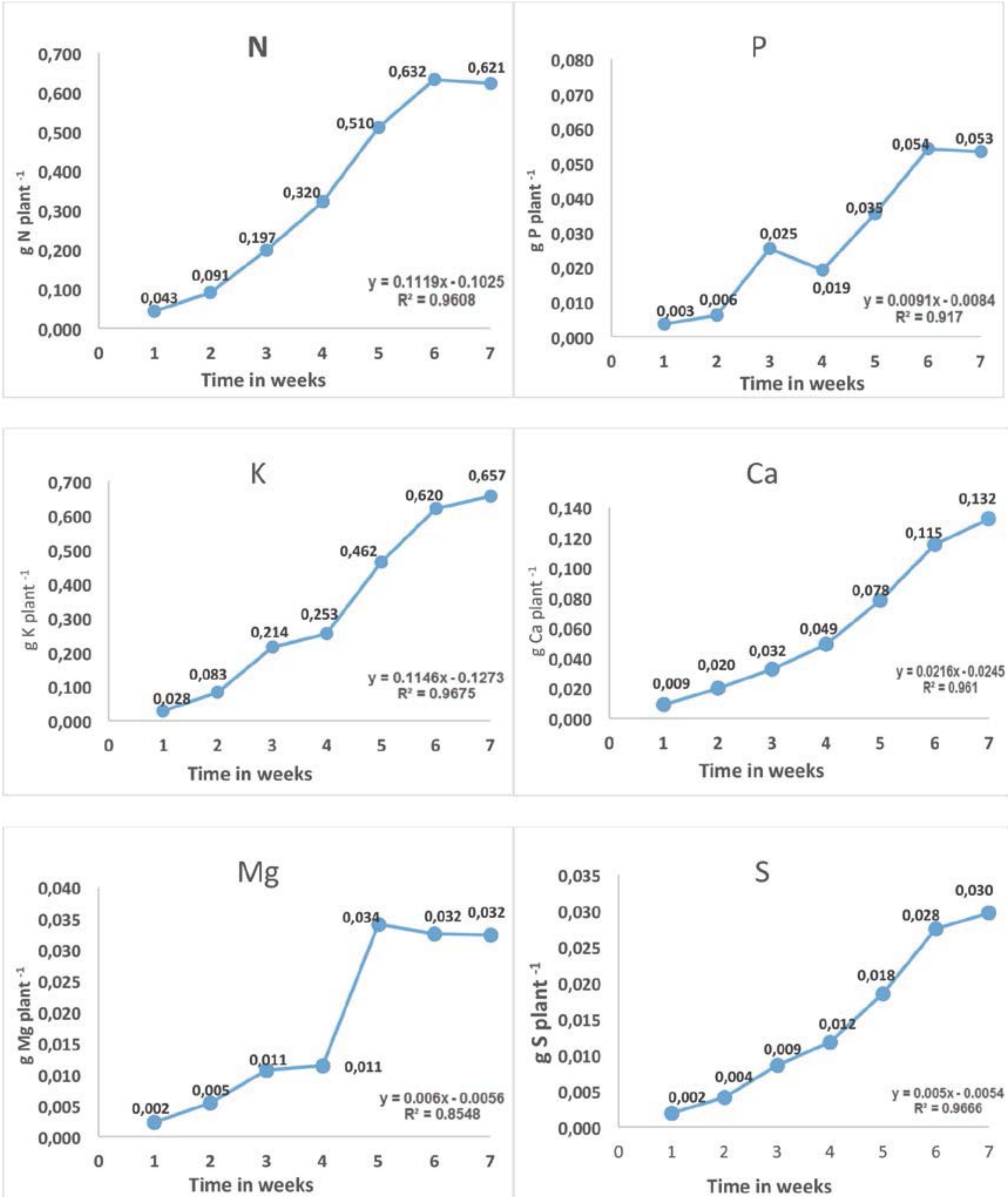

Figure 2. Extraction of major and minor nutrients from aerial biomass in white chrysanthemum, during the aeroponic cycle.

At the end of week 2 (21dat) and week 5 (42dat), the extracted nitrogen achieved was 71.09% (0.038 g). Most extraction of potassium is reported at the end of week 4, 35 dat, during this week, the plant extracted 31.87% (0.209 g) and close to 55.9% (0.3672 g) from the element uptake among 28 and 42 dat (weeks 4 and 5, respectively).

These data indicates the major elements (N-P-K), were extracted from the aboveground part of plant in greatest quantity during the period among 28 and 42 dat, which corresponds to weeks 4 and 5, respectively. Ca, Mg and S, secondary elements show a similar behavior, characterized by an increasing absorption, which ranged from 35 and 42 dat (week 5). Mg

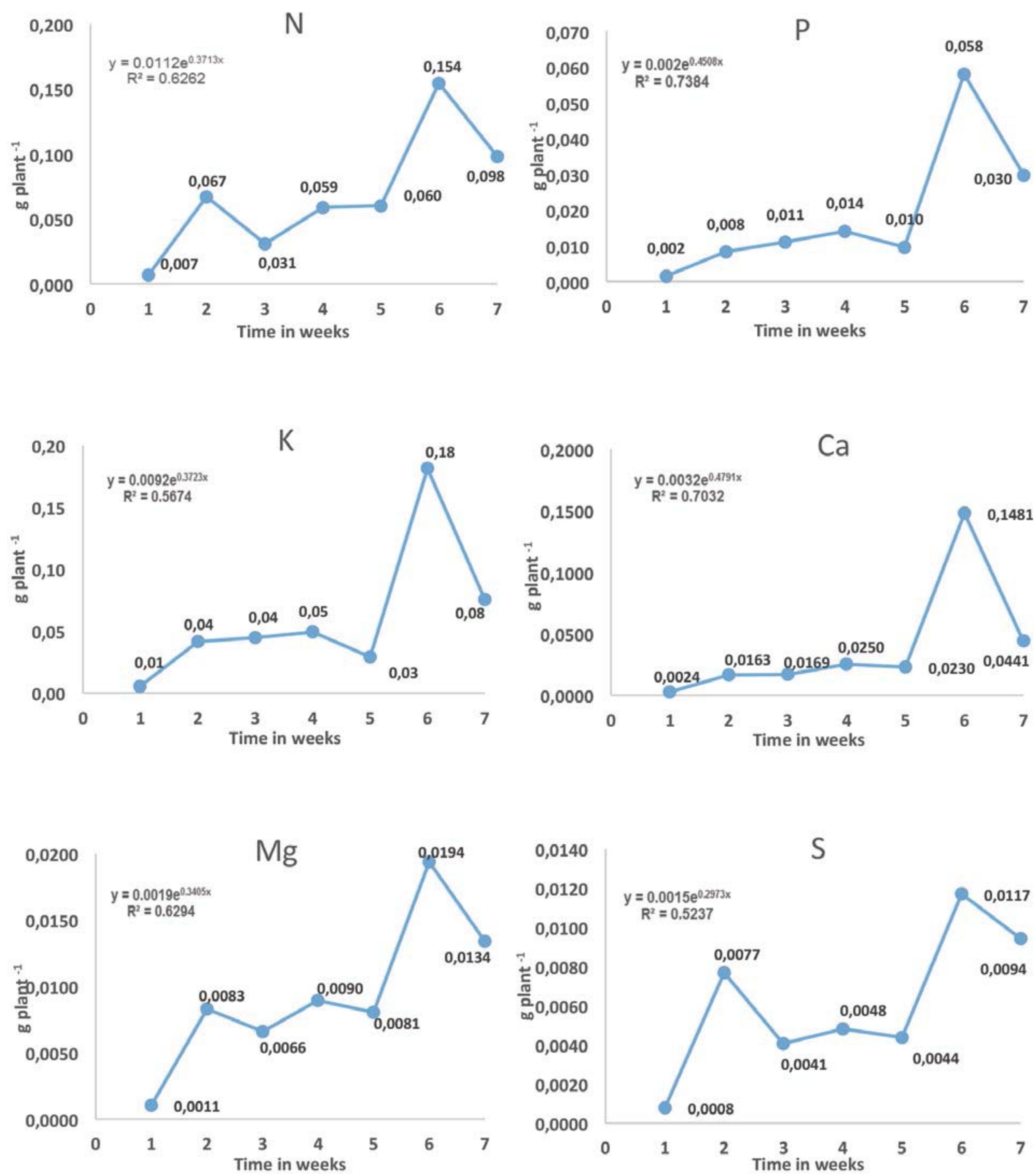

Figura 3. Extraction of major and minor nutrients from root biomass in white chrysanthemum, during the aeroponic cycle.

From data presented in Table 1, is possible to determine the amount of fertilizer to use and the most appropriate application timing.

represented the strongest case, since it was observed total element was extracted until 35 dat, where 70% (0.0226 g) was recorded and ranged from 28 and 35 dat (week 4). For Ca, this behavior occurred among 28 and 42 dat, with greatest emphasis among 35 and 42 dat. In this period of two weeks (weeks 4 and 5), the plant uptakes close to 51% of total Ca (0.067 g). Sulfur performed levels and behavior similar to those of Ca reported, with an increasing extraction at weeks 4 and 5, corresponding to 53% and 0.0157g of this element in aboveground leaf tissues (Figure 2).

Stresses that higher extraction element was K (0.657 g $plant^{-1}$), subsequently, N (0.632 g $plant^{-1}$) and third place Ca (0.132 g.$plant^{-1}$). Levels of P, Mg and S, performed similar accumulations as follows: 0.053g; 0.034g and 0.030g $plant^{-1}$, respectively.

Most of the research carried out in absorption curves, exhibit extractions from aboveground parts such as leaves, fruits, flowers, stems, etc. Under the aeroponic system used in this study, is possible to quantify the root plant zone. Perhaps due to the complexity performed under soil root systems, nothing or few is known about the behavior of nutrients in this plant organs. Consequently, fertilization plans do not consider contributions to the plant root zone. Results of nutrient in the evaluated plant root zone, are presented in Figure 3.

Overall, nutrient extraction and their accumulation in plant root zone, performed a similar behavior for the evaluated plant organs. In Figure 3, was observed ranged from 35 and 42 dat (week 5), which showed an increasing extraction as follows: Ca 84.5%; K, 83.33%; P, 82%; S, 62.4%; N, 61%; and Mg, 58%. In addition, a decreasing level was observed, possibly due to an increasing translocation into the aerial part. When Figures 2 and 3 are crossed, shows an accumulation in the aboveground part and this coincides with timing when is performed a decreasing in plant root accumulation.

Table 1 and Figure 4, shows and summarize the nutrients absorbed by white chrysanthemum during the first half of 2015. This information is intended as a basis for initiating plant nutrition programs that optimize the use of fertilizers.

Table 1. White chrysanthemum absorption under aeroponic system

Week	Days	Absorption per plant (g)					
		N	K	Ca	P	Mg	S
1	0-7	0.0494	0.0338	0.0113	0.0050	0.0034	0.0027
2	8-14	0.1578	0.1243	0.0359	0.0144	0.0137	0.0118
3	15-21	0.2282	0.2583	0.0494	0.0363	0.0172	0.0126
4	22-28	0.3791	0.3024	0.0736	0.0332	0.0203	0.0166
5	29-35	0.5388	0.4915	0.1010	0.0451	0.0420	0.0228
6	36-42	**0.7864**	**0.8017**	**0.2631**	**0.1121**	**0.0518**	**0.0392**
7	43-49	0.7196	0.7322	0.1761	0.0830	0.0457	0.0391

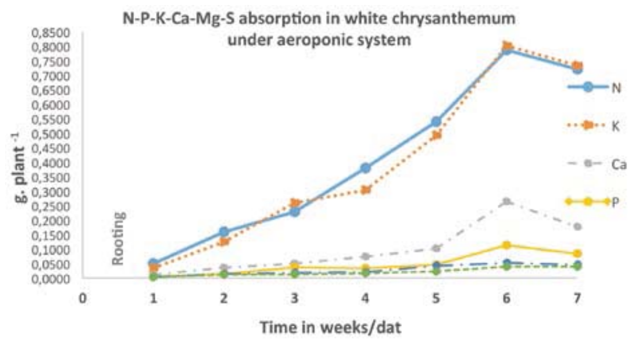

Figure 4. Performance of major nutrients and secondary absorbed by white chrysanthemum under aeroponic system

As an example, in Table 2, an exercise with the elements N, K and Ca is proposed; for a 36m^2 bed with 3600 plants. The total amount to apply, for example N, is 6.5 kg of fertilizer 46-0-0 (Table 2).

Table 2. Proposal to calculate fertilizers based on aeroponic absorption curves for white chrysanthemum

Element	absorbed g. $plant^{-1}$	Planting density. bed^{-1}	Total g. bed^{-1}	Total kg. bed^{-1}	% element in fertilizer	Kg fertilizer
N	0.7864	3800	2988.32	2.98832	46	6.50
K	0.8017	3800	3046.46	3.04646	60	5.08
Ca	0.2631	3800	999.78	0.99978	40	2.50

During this period of time, plant absorbs 71% of N, which corresponds to 0.56 g N per plant; 2122g of N per bed; and 4.615 kg of fertilizer per bed. The rest of N (295 Kg, approx.) Absorbs among 0 and 13 dat. This can be interpreted as two application periods: the first, is the day when transplanting cuttings to field conditions; and the second, at the beginning of Week 3 (14dat). Is important to note that research should be replicated to have achieved a standardization, aeroponic curves additionally mark a trend in nutrient uptake to be validated under soil conditions.

Discussion

Nutritional requirements are based on biomass production per plant. With these results we can infer the behavior of a number of plants in a specific area. Generally, most fertilization plans are based on nutritional uptake from the aboveground part, however, little investigation is focused on the nutrients removal through plant root system, due to the difficulty in harvesting this plant organ. Aeroponics, provides an opportunity to assess the nutritional behavior of this plant root zone.

From Figure 1, is possible to infer white chrysanthemum performed a steady growth pattern until week 4, therefore, its development is accelerated and during weeks 4 and 5, the aboveground biomass had achieved an increasing which ranged from 51% to 55.7% plant root biomass, this increasing in root biomass lasted two weeks close to 52%. This indicates that under the production-system protocol used in this study, could increase two stages of plant growth and development as follows: 1 up to week 4, and 2 up to weeks 4 and 6.

In addition, Ciampitti & García (2007) and Sancho (1999), highlight information obtained under this methodology to determine the most appropriate application timing, which must match the longest time for nutrient uptake reflected in the absorption-extraction curves and also with the plant physiological stages and nutrient translocation among plant organs.

Earliest studies on white chrysanthemum nutrition, were reported by Boodley & Meyer (1996), who showed that during the first four growth weeks, had achieved an increasing demand resulted from N and K elements, consequently, remained more or less constant. Maximum N level ranged from 4% and 5%, while K ranged from 5% and 6% per dry weight. Ca and Mg, performed a greatest absorption in the first 2 weeks, while P was absorbed in more quantity from weeks 5 to 8, which stabilized among 0.50% and 0.75% per dry weight. In addition, Dantas, Diniz & Haag (1975), in Brazil, indicated that a cultivar of *White chrysanthemum* called “Suzuki”, extracted 1600 mg of K, 269 mg of Ca, 231 mg P, 116mg of Fe, 113 mg of Mg, 91 S mg, 23 mg Mn, 14 mg Zn and 0.74 mg Cu in a plant growth period of 140 days.

Under the proposed methodology, raised beds floor, which are constructed by plastic darkness soil resembles, and root system is sprayed regularly with a completely nutrient solution (Hogland & Arnon, 1950), throughout an electronically controlled micro-sprinklers, creating a humid environment close to 100%.

Additionally, these are systems addressed to monitor nutrient intake through evaluation the leachate without their effluents become pollutants, helping to optimize the use of fertilizers and water resources (Steidle, Zolnier & de Carvalho, 2014).

On the other hand, González & Bertsch (1992), in Costa Rica, determined nutrient content of *Chrysantemum morifoliun* cv. Super White under greenhouse conditions, the evaluation cycle was 12 weeks, where seven samples were taken. From dry weight of the whole plant, these authors reported K and N contents, which were more nutrients absorbed from chrysanthemum, in amounts up to three times greatest than Ca, P and Mg. Corresponding nutrient amounts were as follows : K, 1404 mg; N, 699 mg; Ca, 263 mg; P, 94 mg; and 56 mg of Mg. As for the minor elements, the absorption amounts were as follows: Fe, 20 mg; Mn, 4 mg; B, 0.9 mg; Zn, 0.6 mg; and 0.4 mg of Cu.

Chica & Morales (2012), also reported differences in both time and in the amount absorbed by thyme (*Thymus vulgaris* L.) elements, where most plant absorption were as follows: 2.3 g N, K with 2.1 g, Mg with 0.82 g, followed by Ca and S with 0.64 g and 0.42 g, respectively. The lowest absorption element was P, with 0.38 g.

In addition, a trend was evident in absorption timing, among weeks 9 and 10, which was the period of maximum absorption of K, Mg and Ca. In the case of N, P and S, plant absorption performed an increasing tendency during the evaluation time, which indicates that if not reap a week 12, could continue to accumulate these elements. Additionally, it was observed an absorption tendency to retain the same behavior as air extraction and plant root biomass, separately.

Conclusion

This study evaluated the absorption-extraction curves in white chrysanthemum, bearing this in mind, the present work is intended to conclude that under the evaluated conditions in aeroponic system, maximum levels of total nutrients Ca (84.5%), K (83.33%), P (82%), S (62, 4%), N (61%), and Mg (58%), were absorbed from week 5 after transplantation, which provides more accurate and reliable estimates of nutrient extraction in *White chrysanthemum* from air and root biomass, which performed a similar behavior. Given these concerns, plant fertilization can be oriented in two applications as follows: one at transplantation timing and the other, at the end of week 4.

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