Scientific communication

Growth, yield, nutrient accumulation and export and thermal sum of Italian zucchini

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ABSTRACT

Studies on plant nutrition are essential for a correct fertilizer management, improving yield and quality of the product, and it also may contribute for an updating recommendation. The aim of this study was to evaluate growth, nutrient accumulation and export, thermal sum and yield of zucchini cultivar Corona F1. The experiment was carried out from August 8 to October 25, 2013, in Santo Antônio de Posse, São Paulo State. At the end of the research, 84 days after transplanting (DAT), we observed 95 cm average height with 36 leaves and 45.8 t ha^{-1} maximum yield. The nutrient accumulation, in g plant^{-1}, was: N (14.2) > K (9.3) > Ca (8.0) > Mg (2.5) > S (1.2) > P (0.9) and in mg plant^{-1}, Mn (49.3) > Fe (34.9) > Zn (19.6) > B (16.4) > Cu (2.1) and export, in kg ha^{-1}, was N (94.9) > K (44.1) > Ca (43.0) > Mg (12.6) > S (6.3) > P (5.3), in g ha^{-1}, Mn (271.0) > Fe (159.2) > Zn (105.6) > B (82.8) > Cu (11.9). The highest nutrient demand occurred between 40 and 50 DAT. Cultivar Corona F1 cycle was completed within 1.538 degree-days.

Keyword: *Cucurbita pepo*, growth, plant nutrition, horticulture, sustainability.

RESUMO

Crescimento, produtividade, acúmulo, exportação de nutrientes e soma térmica de abobrinha italiana

Pesquisas com nutrição de plantas são essenciais para a correta fertilização, melhorando produtividade e qualidade do produto, além de poder contribuir para a atualização da recomendação. O objetivo do experimento foi avaliar o crescimento, acúmulo e exportação de nutrientes, soma térmica e produtividade da cultivar Corona F1. O trabalho foi conduzido no período de 2 de agosto a 25 de outubro de 2013, em Santo Antônio de Posse-SP. Ao final do experimento, 84 dias após o transplante (DAT), a altura média observada foi de 95 cm com 36 folhas e produtividade máxima obtida de 45,8 t ha^{-1}. Concluiu-se que o acúmulo de nutrientes, em g planta^{-1}, foi de: N (14,2) > K (9,3) > Ca (8,0) > Mg (2,5) > S (1,2) > P (0,9) e em mg planta^{-1}, de Mn (49,3) > Fe (34,9) > Zn (19,6) > B (16,4) > Cu (2,1) e a exportação, em kg ha^{-1}, foi de N (94,9) > K (44,1) > Ca (43,0) > Mg (12,6) > S (6,3) > P (5,3), em g ha^{-1}, Mn (271,0) > Fe (159,2) > Zn (105,6) > B (82,8) > Cu (11,9). A maior demanda por nutrientes ocorreu entre 40 e 50 DAT. A cultivar Corona F1 precisou de 1.538 graus dias para completar seu ciclo.

Palavras-chave: *Cucurbita pepo*, crescimento, nutrição de plantas, horticultura, sustentabilidade.

Studies on accumulation and export of nutrients show quantity and period of high gains of these nutrients as function of plant age, indicating when nutrient addition is necessary. Thus, these are important tools for management and fertilization of crops as also helping update existing recommendations (Furlani & Purquerio, 2010; Purquerio *et al.*, 2016; Moraes *et al.*, 2018; Mattar *et al.*, 2018).

Few studies on crop nutrition of Italian zucchini have been carried out. Most of them are about cucurbits of higher economic value, such as melon and watermelon (Pôrto *et al.*, 2012). The found studies on zucchini evaluated nitrogen and potassium doses (Pôrto *et al.*, 2012; Araújo *et al.*, 2013, 2014; Costa *et al.*, 2015; Andrean *et al.*, 2017).

In addition to this lack of studies, the fertilizer recommendation in the state of São Paulo is the same for other five species (zucchini, pumpkin, winter squash, loofah and cucumber), with phenology and probable differentiated nutritional demand (Trani & Raij, 1997). In this same recommendation, primary macronutrient content in fresh mass harvested for an average yield from 10 to 20 t ha^{-1} is presented. In the recommendation for the state of Minas Gerais, the expected yield is from 15 to 18 t ha^{-1} (Fontes, 1999). These yields are lower than the ones reached by hybrids available in the market these days, in several production systems. Results of yields verified in literature are very variable (29.9 to 71.4 t ha^{-1}) (Strassburger *et al.*, 2011b; Pôrto *et al.*, 2012; Araújo *et al.*, 2013; Costa *et al.*, 2015) as function of growing cycle and harvest (unripe), superior to what was cited by Trani & Raij (1997) though. Thus, higher mass production requires

higher nutrient quantity.

For Italian zucchini, few reports on growth and gain of dry mass were found (Rouphael & Colla, 2005; Strassburger *et al.*, 2011a) and just one study on macronutrient accumulation throughout the growing cycle, for Novita hybrid (Araújo *et al.*, 2001). In this study, which was published 15 years ago, the authors observed extraction, in kg ha^{-1}, of K (370.3), Ca (241.8), N (145), Mg (70.8), P (15.4), S (14.6) and export, in kg ha^{-1} of K (121), N (96), Ca (11), P (15), Mg (9), S (5), at 64 days.

More studies on this crop are necessary, since nutritional misbalance, both because of lack or excess of nutrients, is a stressing factor for the plant (Furlani & Purquerio, 2010) and it influences directly on production and final quality of product. Thus, data on accumulation and extraction of nutrients for new hybrids are essential to help refine existing fertilizer recommendations.

The use of methods for calculating thermal sum or degree days (GD) is based on premise that a plant needs a certain amount of energy to complete a given phenological phase or total cycle. These data allow to estimate the growing cycle duration and avoid periods in which the environment temperature may be limiting (Morais *et al.*, 2010).

The aim of this study was to evaluate growth, nutrient accumulation and export, thermal sum and yield of Italian zucchini, cultivar Corona F1, grown during winter/spring.

MATERIAL AND METHODS

The experiment was carried out in the field, near the city of Santo Antônio de Posse (22º34'08"S 47º00'02"O, altitude 591 m), from August (seedling transplanting) to October 25, 2013. According to Köppen, the climate is Cwa, 21.1°C average annual temperature and 1333.1 mm average annual rainfall (Cepagri, 2017). During the experimental period, average annual air temperature was 20.6°C and rainfall was 139.3 mm. Average minimum and maximum temperatures ranged from 8°C to 32°C for the crop (NeSmith,

1997), considering the average 13.9°C and 27.4°C, respectively. The soil was classified as Red-Yellow Latosol (Embrapa, 2013), the chemical properties in 0 to 20 cm layer are: M.O.= 23 g dm^{-3}; pH= 5.8; P= 125 mg dm^{-3}; K= 4.0 mmol$_c$ dm^{-3}; Ca= 36 mmol$_c$ dm^{-3}; Mg= 10 mmol$_c$ dm^{-3}; H+Al= 31 mmol$_c$ dm^{-3}; C.T.C.= 81.3 mmol$_c$ dm^{-3} V= 62%.

The seedlings of cultivar Corona F1 (Agristar) were sown in 200-cell trays, in a nursery, on July 19, 2013.

Planting fertilization was performed according to the result of soil analysis and the expertise of Agristar Company in the crop management. The authors used, in each linear 30-m seedbed, 1 kg simple superphosphate, 0.16 kg potassium chloride and 0.26 kg ammonium sulfate, totalizing 11.5 kg N ha^{-1}, 39.9 kg P$_2$O$_5$ ha^{-1} and 20.6 kg K$_2$O ha^{-1}.

Transplanting was done in 0.50-m spacing between plants and 1.50 m between lines, in which each plant covered 0.75 m² (13,333 plants ha^{-1}).

The experimental design was completely randomized with four replicates; the treatment's evaluations were performed on 0, 14, 28, 42, 56, 70 and 84 days after transplanting (DAT). Inside each block, three plants were evaluated for most traits and there were three border plants among the evaluated plants (2.25-m² useful plot). Border lines were also installed throughout the experiment. The total area was 270 m² (360 plants).

The first evaluation (0 DAT) of mass and nutrient content in plant tissue was done at seedlings transplantation date, when the plant showed three definitive leaves.

In the first week, the authors applied 0.62 kg 13-40-13 (N-P$_2$O$_5$-K$_2$O) per plot. From the second week up to the end of the crop cycle, 24 applications of 0.21 kg 25-05-25 were done, totalizing 4.9 kg. We used 1.6 kg calcium nitrate splitted into five fertilizations from 30 DAT on. In total, we applied 349.7 kg N ha^{-1}, 174.9 kg P$_2$O$_5$ ha^{-1}, 295.3 kg K$_2$O ha^{-1} and 66.6 kg Ca ha^{-1}. Drip-irrigation was carried out, with a dripping tube line per crop line. The soil was maintained at field capacity,

monitored by tensiometers.

During the first 21 DAT, plants were kept under a low tunnel (60 cm), covered with white non-woven fabric *(*Fozpanos, 0.145 g m^{-2}), in order to avoid pest attack, virus vectors. No incidence of viruses was verified during the crop cycle. Phytosanitary control was performed as required for aphid (*Aphis gossypii*), whitefly (*Bemisia tabaci*), pickleworm (*Diaphania nitidalis*), beetle (*Diabrotica speciosa)* and black cutworm *(Agrotis ipsilon).*

In each evaluation, plant height, number of leaves, fresh and dry mass of the plant (shoot area, fruits and root) and yield of marketable fruits were obtained. Due to different plant sizes throughout the growing cycle and in order to accumulate necessary dry mass for laboratorial analyses, in the first evaluation a hundred plants were collected, in the second evaluation ten plants and in the other evaluations three plants per replicate. Plants were harvested three times per week, collecting unripe fruits, within commercial standard (15 to 20-cm length and mass close to 0.2 kg).

To evaluate mass, plants were cut at soil level and divided into shoot area (leaves and stem) and fruits. Roots were collected in a 20x20x20-cm soil volume. Then, parts were weighed to determine fresh mass. After weighing, all the material was washed and packed in paper bags and taken to be dried in forced air circulation until constant mass (60°C). After dried, the material was weighed and submitted to chemical analysis, in order to determine nutrient content in the plant tissue, according to the methodology proposed by Malavolta *et al.* (1997).

Due to the inexistence of a specific recommendation for zucchini leaf diagnosis, at 56 DAT, ripe and expanded leaves from the middle third of the plants were collected, aiming to compare with contents in the plant tissue for pumpkin of Trani & Raij (1997).

Data were analysed using nonlinear three-parameter regression model, defined by the best statistical fit and coefficient of determination (R^2). SigmaPlot 12.5 was used for the analyses.

Daily nutrient accumulation rates were obtained through subtraction between adjusted accumulation values of two consecutive days. The value of the previous day was subtracted from the value of the following day, determining the amount by which one exceeded the other. The inflection points of the adjusted curves corresponded to the moments in which the maximum rates of daily nutrient accumulation occurred. The periods of maximum accumulation of dry mass and nutrients were determined through the points of minimum and maximum curvature in the sigmoid models, calculated following the method cited by Venegas et al. (1998).

We calculated nutrient export by multiplying the values of accumulation in the fruit at 84 DAT by the yield calculated per hectare (13,333 plants ha^{-1}). The amount of nutrients per ton of fruits was obtained dividing the total accumulation in the plant by the calculated yield.

Throughout the experiment, data were collected at minimum and maximum temperature (°C) using a sensor, linked to a datalogger (CR1000, Campbell) installed close to the experimental area.

At the end of the cultivation, the thermal sum, in degree days (GD), was calculated based on the equation proposed by NesSmith (1997):

$$GD = \sum_{i=1}^{n} \left[\frac{(Tmax + Tmin)}{2} - Tb \right]$$

Where Tmax and Tmin were daily maximum and minimum air temperatures, Tb the temperature base for crop (8°C), and n number of days.

When Tmin was lower than Tb, Tb was the value to be considered. When Tmax exceeded 32°C, the formula [32-2(Tmax-32)] was used. Tb and temperature of 32°C was used, based on NeSmith (1997) methodology.

RESULTS AND DISCUSSION

For cultivar Corona F1, the authors observed yield of 45.8 t ha^{-1}, value close to 40 t ha^{-1} observed by Araújo et al. (2001) for caserta type Novita (76 DAT). Results for yield of Italian zucchini verified in literature are very variable (29.9 to 71.4 t ha^{-1}) (Strassburger et al., 2011b; Pôrto et al., 2012; Araújo et al., 2013; Costa et al., 2015) as function of growing period and harvest, since zucchini always is harvested unripe. However, these values are superior to the average yield 10 to 20 t ha^{-1}, observed in recommendation for liming and fertilization for the state of São Paulo (Trani & Raij, 1997).

Thermal sum totalized 1,538 degree days, value superior to the one verified by Araújo et al. (2001), 1,370 degree days. Nevertheless, Araújo et al. (2001) did not take into consideration the temperature conditions which were inferior to Tb or superior to 32°C, thus the number of degree days might be superior. For cv. Caserta and Afrodite, Strassburger et al. (2011a) and Rouphael & Colla (2005), respectively, verified that higher solar radiation availability, favored production and distribution of dry mass (MS), as well as all growth indexes, reinforcing data on studies which evaluated thermal sum.

Considering plant growth, up to 84 DAT, an increase in height (95 cm) and number of leaves (36) were noticed (Figure 1A). If necessary, to extrapolate the observed data, to detriment of DAT, phenological traits, such as number of leaves, can be used to monitor plant development and assist in nutrient distribution in seasons and regions of cultivation under different weather conditions which interfere with plant development (Moraes et al., 2016).

Plant grows slowly up to 27 DAT, intensifying the production of MS from that point until the end of growing cycle (Figure 1B). Maximum accumulation was estimated between 27 to 67 DAT, totalizing 320.5 g plant^{-1}, 79% of total MS of 406.2 g plant^{-1} at 84 DAT. Continuously growing in MS production of zucchini was also observed by Araújo et al. (2001), with total 229.6 g plant^{-1} at 76 DAT and Strassburger et al.(2011a) for cv. Caserta, with 455.3 g plant^{-1} at 68 DAT. Difference in plant dry mass is related to climatic conditions, as well as the management used and genotype.

MS accumulation curve for other cucurbits, such as melon, presents three well defined stages, the first is slow, the second is fast and in the third stage the accumulation rate decreases in relation to the second (Silva Júnior et al., 2006). Using Figure 1B, the authors could visualize that Italian zucchini also presented three accumulation stages.

For leaves and stems [shoot part (PA)], the authors verified maximum accumulation between 23 and 56 DAT with estimated value of 176.1 g plant^{-1}, representing 76% of the total accumulation (232.1 g plant^{-1}). After 70 DAT a stabilization tendency was verified. Strassburger et al. (2011a) observed continuous accumulation of dry mass in vegetative part of the plant,

Table 1. Extraction (EXT) and export (EXP) of nutrients by Italian zucchini Corona F1, ratio between export and extraction (REE) and quantity of nutrients extracted per ton of fruits (QNETF), 84 days after transplanting. Santo Antônio de Posse, Instituto Agronômico, 2013.

	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
	(kg ha^{-1})						(g ha^{-1})				
EXT	189.5	12.0	124.1	106.2	33.0	15.4	219.2	28.2	465.8	657.5	262.0
EXP	94.9	5.3	44.1	43.0	12.6	6.3	82.8	11.9	159.2	271.0	105.6
	(%)										
REE	50	44	36	40	38	41	38	42	34	41	40
	(kg t^{-1})						(g t^{-1})				
QNETF	4.1	0.3	2.7	2.3	0.7	0.3	4.8	0.6	10.2	14.3	5.7

218.8 g plant⁻¹ at 68 DAT. Aumonde *et al.* (2011) explain the decrease in shoot mass accumulation, in annual crops (such as vegetables), considering fruits being strong drains and priority metabolic, compared to vegetative drains. Thus vegetative growth ceases or is significantly reduced in fruiting phase. Dry mass accumulation in fruits was accelerated from 40 to 70 DAT, with an estimated gain of 128.2 g plant⁻¹, or 77% of the total accumulation of 165.9 g plant⁻¹.

At the end of the experiment, MS of PA represented 57% of total MS, whereas the fruits represented 41%. Similar result was verified by Strassburger *et al.* (2011a) who found superior contribution of fruits of 52% of total MS (236.5 g plant⁻¹). The result observed is not in accordance with literature, in which fruits show higher dry mass accumulation, since they represent the largest drains of photoassimilates, as verified for other cucurbits just like Vidigal *et al.* (2007) for Tetsukabuto hybrid pumpkin, Aguiar Neto *et al.* (2014) for melon and Almeida *et al.* (2014) for watermelon, with results between 60 to 84% of MS in fruits in relation to the total. This difference is due to the way Italian zucchini fruit is commercialized (unripe), making impossible the maximum accumulation of MS in this part of the plant. Strassburger *et al.* (2011a) also reported that fruit growth rate interfered little on the vegetative part; contradicting the tendency that greater growth rate of fruits reduces the growth rate of the vegetative part.

Root dry mass at the end of growing cycle was 6.1 g plant⁻¹. In relation to total dry mass, 406.2 g plant⁻¹, represented only 1.5%, being little significant.

Comparing the results of leaf contents collected at 56 DAT, with contents suggested by Trani & Raij (1997) for pumpkin, the authors observed that values of N (38.5 g kg⁻¹), Mg (6.1 g kg⁻¹), B (46.3 mg kg⁻¹), Fe (100.7 mg kg⁻¹) and Zn (59.9 mg kg⁻¹) are within indicated range. Contents of S (3.5 g kg⁻¹) and Mn (279.2 mg kg⁻¹) are above recommended values. Values of K (16.9 g kg⁻¹), P (2.9 g kg⁻¹) and Cu (5.3 mg kg⁻¹) are below. The difference verified for S, Mn, K, P and Cu in leaf analysis was due to genetic traits, since reference values for comparison are values for pumpkin, due to the inexistence of data for zucchini. The authors highlight that despite the
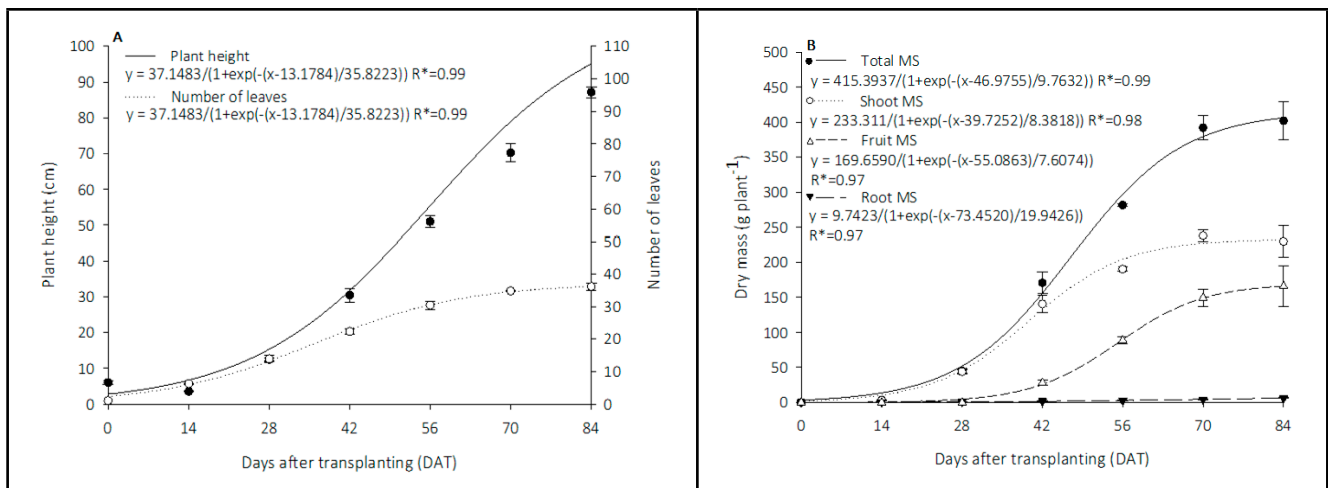

Figure 1. Plant height and number of leaves (A) and dry mass (B) of Italian zucchini Corona F1, in relation to days after transplantation. Average ± standard error of four replicates. Santo Antônio de Posse, Instituto Agronômico, 2013.
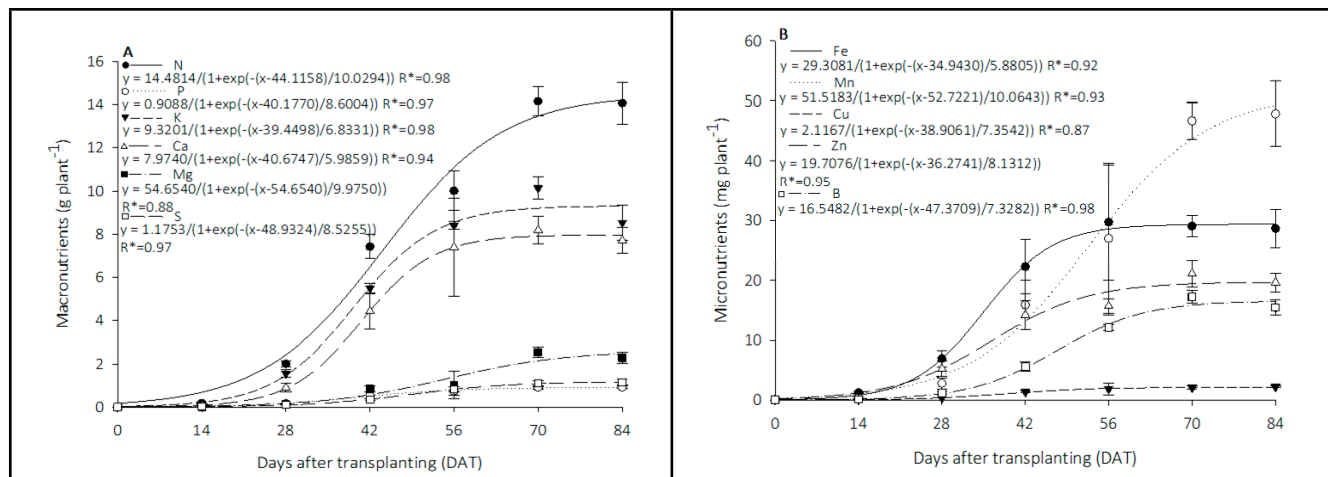

Figure 2. Accumulation of macro (A) and micronutrients (B) by Italian zucchini Corona F1, in relation to days after transplantation. Average ± standard error of four replicates. Santo Antônio de Posse, Instituto Agronômico, 2013.

differences observed in leaf analysis, no nutritional restriction during the experiment was noticed and the study estimated interesting production levels (45.8 t ha^{-1}).

Plant nutrient accumulation was slow up to 28 DAT, from this date on, an increase for N, K, Ca, Fe, Zn and Mn was noticed, and for other nutrients this increase was verified after 42 DAT (Figure 2 A and B). For N, Mg and Mn, an increasing accumulation up to the end of the experiment was noticed, for the rest of the nutrients a stabilization tendency near 70 DAT was verified, though. The same N pattern of accumulation was verified by Araújo et al. (2001); however, for P, K, Ca and Mg, the authors observed a decreasing accumulation from 76 DAT on. Gaitán et al. (2012) reported an increasing accumulation up to 60 DAT for N, P, K, Ca and Mg. We highlight that these mentioned authors evaluated accumulation of whole-plant, without differentiating parts as it was done in this study.

In cucurbits, an N increase, up to a certain limit, provide an increase in plant leaf area; thus, an effect on photoassimilate production can be noticed and, consequently, on fruit production (Pôrto et al., 2012). This nutrient was the most absorbed by the plant, and its value is estimated in 14.2 g plant[-1] at 84 DAT, and maximum accumulation from 24 to 64 DAT with 11 g plant[-1], representing 77% of the total. This result is different from the ones reported by Araújo et al. (2001), in which potassium (37 g plant[-1]) was the most accumulated nutrient, followed by N (14.5 g plant[-1]) at 64 DAT.

P was the less absorbed macronutrient by the plant, 0.9 g plant[-1] at 84 DAT. Maximum accumulation was from 23 to 57 DAT, representing 76% of the total (0.7 g plant[-1]). This nutrient is part of the chemical structure of essential compounds such as nucleic acids, phospholipids and coenzymes, and it is responsible for energy release process (Malavolta, 2006).

K controls cell turgidity, activates enzymes involved in the processes of respiration and photosynthesis and transport of carbohydrates. According to Araújo et al. (2014) and Andrean et al. (2017), an increase of doses of this nutrient, results in a higher content of potassium, pH and 'ratio' relation on Italian zucchini fruits, and also in an increase in number of male flowers. This macronutrient was the second most accumulated, 9.3 g plant[-1] at 84 DAT. Maximum accumulation occurred from 26 to 53 DAT, with 7 g plant[-1], representing 76% of the total.

Ca, after N and K, as well as for most of the cultivated plants (Malavolta, 2006) was the third most accumulated nutrient (8 g plant[-1]). Maximum accumulation occurred between 29 to 53 DAT, corresponding to 76% of the total estimated value.

Maximum estimated accumulation of Mg was 2.5 g plant[-1] at 84 DAT. Higher uptake was verified between 35 and 75 DAT, equivalent to 80% of total value. This nutrient is a component of the chlorophyll molecule, besides being an enzymatic activator (Malavolta, 2006).

S is a structural component of proteins and coenzymes, taking part in vital processes, such as respiration and photosynthesis. Maximum accumulation was observed from 32 to 66 DAT, representing 77% of the total uptake, 1.2 g plant[-1].

For micronutrients, the accumulation sequence in mg plant[-1] was Mn (49.3) > Fe (34.9) > Zn (19.6) > B (16.4) > Cu (2.1). For Mn, the highest accumulation occurred between 33 and 73 DAT. This micronutrient differed from the others, as it increased up to the end of the cycle, without a stabilization tendency. The highest accumulation occurred for Fe from 23 to 47 DAT, Zn between 20 to 53 DAT, B from 33 to 62 DAT and Cu from 24 to 54 DAT. For all micronutrients, during higher accumulation, the authors observed values between 76 and 79% of total.

Daily nutrient accumulation rates allowed the elaboration of fertilization programs in function of time. In addition, nutrients over a different time period are necessary, making it possible to provide these nutrients when they are required and, thus, avoid lack of the nutrient or luxury consumption throughout the growing cycle (Furlani & Purquerio, 2010). The authors noticed an increase in these rates up to a maximum value, maximum daily accumulation rate
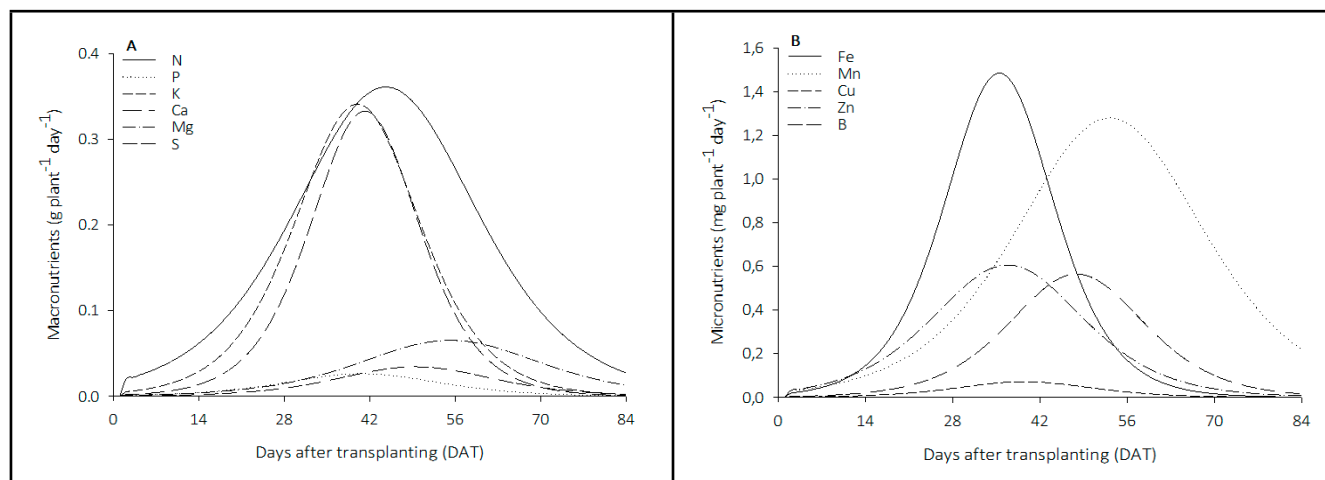

Figure 3. Daily accumulation rates of macro (A) and micronutrients (B) by Italian zucchini Corona F1, in relation to days after transplantation. Santo Antônio de Posse, Instituto Agronômico, 2013.

(TMAD), with subsequent decrease until the end of the experiment. TMAD for macronutrients N, P, K, Ca, Mg and S were, respectively, 0.36; 0.03; 0.34; 0.33; 0.06; 0.03 g plant[-1], reached at 45, 41, 40, 41, 55 and 49 DAT, respectively (Figure 3 A). TMAD for Fe, Mn, Cu, Zn and B were, respectively, 1.49; 1.28; 0.07; 0.6; 0.56 mg plant[-1], reached at 35, 53, 39, 37 and 48 DAT (Figure 3 B).

Nutrients can be divided into two TMAD groups, earlier nutrient demand (close to 40 DAT), including N, P, K, Ca, Fe, Cu and Zn and the second group, later nutrient demand (close to 50 DAT), including Mg, S, Mn, B.

Part of the extracted nutrients returns to soil via decomposition of the vegetal remains and part is removed via fruits (export). Thus, it is important to quantify and replenish, the nutrients accumulated in the harvested part of the plant. The order of extraction (EXT) and export (EXP) of the nutrients were the same, being presented in a decreasing order: N > K > Ca > Mg > S > P > Mn > Fe > Zn > B > Cu (Table 1). Different sequences and amounts were observed by Araújo *et al* (2001), for EXT, in kg ha^{-1}, K (370.3) > Ca (241.8) > N (145) > Mg (70.8) > P (15.4) > S (14.6) and for EXP, K (121) > N (96) > P (15) > Ca (11) > Mg (9) > S (5), with 40 t ha^{-1} yield. For hybrid Aline 60.7 t fruits ha^{-1}, Araújo *et al.* (2015) observed EXT, in kg ha^{-1}, of K (193,7) > Ca (163,9) > N (154,5) > Mg (51,9) > P (25,4) > S (13,6) and EXP of K (107.95) > N (91.7) > P (16.6) > Ca (12.8) > Mg (12.3) > S (7.2). These authors observed that K was the nutrient extracted and exported in the greatest amount, to the detriment of N observed in this study. As seen for MS, this result is related to higher mass production of PA to detriment of fruits. For EXT (kg ha^{-1}), Gaitán *et al.* (2012), verified higher value of N to detriment of K, considering the sequence observed Ca (198.7) > N (179.5) > Mg (55) > K (36.4) > P (17,8), corroborating the results in this study.

The ratio between extraction and export (REE) ranged from 34 to 44% for all nutrients with exception for N, 50%, differing from what was verified by Araújo *et al.* (2001, 2015): P was much higher, 97 and 65%, and Ca much lower,

5 and 8%, respectively. In this study, although showing the smallest amount absorbed, Cu was, in percentage, the most exported nutrient (42%).

The amount of nutrients extracted per ton of produced fruit (QNETFP) was N (4.1 kg t[-1]) P (0.3 kg t[-1]) and S (0.3 kg t[-1]), close to values observed by Araújo *et al.* (2001), N (3.6 kg t[-1]), P (0.4 kg t[-1]) and S (0.3 kg t[-1]), whereas K, Ca and Mg were quite divergent, 2.7 kg t[-1], 2.3 kg t[-1] and 0.7 kg t[-1], in this experiment, which was 9.3 kg t[-1], 6 kg t[-1], 2.3 kg t[-1] and 1.8 kg t[-1] respectively.

Comparing the results of extraction obtained with the recommendation for the state of São Paulo (Trani & Raij, 1997), the authors observed the amount of N (189.5 kg ha^{-1}) was in the upper limit of the proposed fertilizer range (140 to 190 kg ha^{-1}). This fact may be due to be calculated for an expected yield (10-20 t ha^{-1}) which was inferior to the one observed in this study (45.8 t ha^{-1}). Studying doses of N in Italian zucchini, Costa *et al.* (2015) verified yield and dose close to the ones obtained in this experiment, 45.4 t ha^{-1} and 180 kg N ha^{-1}, respectively, whereas Pôrto *et al.* (2012) observed productive response lower (29.9 t ha^{-1}) with much superior dose (331 kg ha^{-1}).

For P, considering transformation of the amount observed in P_2O_5 (multiplying by 2.29) a total of 27.5 kg ha^{-1} of P_2O_5 was found. This value is lower than the lowest limit of recommended fertilizer range, 200 to 400 kg ha^{-1}. This is related to the fact that P_2O_5 shows low dynamics in soil, and has a strong tendency to be fixed and to react with other components such as Fe, Al and Ca, among others, forming poorly soluble compounds. Thus its application assumes primarily the role of satisfying the soil requirement by adding several times higher amounts than those required by plants (Malavolta, 2006).

For K, transformation into K_2O was carried out (multiplying by 1.20). The authors observed that the plant required a total of 148.9 kg ha^{-1} of K_2O, value lower than the range, 160 to 320 kg ha^{-1}, (Trani & Raij, 1997). The value verified in this study was close to the one found by Costa *et al.* (2015) (137.8 kg ha^{-1}), which allowed to obtain maximum

yield (23.8 t ha^{-1}). The authors highlight that nutrient use efficiency was not considered, and if this use efficiency was supposed to be considered, the amounts of these nutrients to be provided in fertilization would be higher.

The authors concluded that, for cultivar Corona F1, gain of dry mass was slow up to 27 DAT, intensifying until the end of the cycle, totaling 406.2 g plant[-1]. At 84 DAT, the plant reached 95 cm average height, 36 leaves and yield of 45.8 t ha^{-1}. The decreasing order of nutrient accumulation, in g plant[-1], was N (14.2) > K (9.3) > Ca (8.0) > Mg (2.5) > S (1.2) > P (0.9) and in mg plant[-1], Mn (49.3) > Fe (34.9) > Zn (19.6) > B (16.4) > Cu (2.1), whereas export in kg ha^{-1} was N (94.9) > K (44.1) > Ca (43) > Mg (12.6) > S (6.3) > P (5.3), in g ha^{-1}, Mn (271.0) > Fe (159.2) > Zn (105.6) > B (82.8) > Cu (11.9). Thermal sum totalized 1,538 degree days.

ACKNOWLEDGEMENTS

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