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MANEJO DO NITROGÊNIO NA PRODUÇÃO FORA DO SOLO DE PONTAS DE ESTOLÕES DE MORANGUEIRO

DISSERTAÇÃO DE MESTRADO

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Santa Maria, RS, Brasil

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MANEJO DO NITROGÊNIO NA PRODUÇÃO FORA DO SOLO DE PONTAS DE ESTOLÕES DE MORANGUEIRO

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Dissertação apresentada ao Curso de Mestrado do Programa de Pós-Graduação em Agronomia, Área de Concentração em Produção Vegetal, da Universidade Federal de Santa Maria (UFSM, RS), como requisito parcial para obtenção do grau de
Mestre em Agronomia.

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Universidade Federal de Santa Maria
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A Comissão Examinadora, abaixo assinada,
aprova a Dissertação de Mestrado

MANEJO DO NITROGÊNIO NA PRODUÇÃO FORA DO SOLO DE PONTAS DE ESTOLÕES DE MORANGUEIRO

elaborada por
Djeimi Isabel Janisch

Como requisito parcial para obtenção do grau de
Mestre em Agronomia

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Santa Maria, 29 de fevereiro de 2012.

“Aos meus pais Sulani e Francisco
e irmã Bárbara, pela credibilidade,
incentivo, apoio e abraço caloroso nos
retornos para casa...
dedico.”

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RESUMO

Dissertação de Mestrado
Programa de Pós-Graduação em Agronomia
Universidade Federal de Santa Maria

MANEJO DO NITROGÊNIO NA PRODUÇÃO FORA DO SOLO DE PONTAS DE ESTOLÕES DE MORANGUEIRO

AUTORA: DJEIMI ISABEL JANISCH
ORIENTADOR: JERÔNIMO LUIZ ANDRIOLO
Data e Local da Defesa: Santa Maria, 29 de fevereiro de 2012.

O objetivo deste trabalho foi determinar a resposta da concentração de N na solução nutritiva na produção e crescimento das pontas de estolões e no crescimento, absorção e acumulação de N na planta matriz em sistema para produção de mudas com torrão. O experimento foi conduzido entre setembro de 2010 e março de 2011. Plantas matrizes de morangueiro das cultivares Oso Grande e Camino Real foram cultivadas em sistema sem solo em *bags* de polietileno contendo areia como substrato. Concentrações de N de 5,12 (T1); 7,6 (T2); 10,12 (T3 testemunha); 12,62 (T4) e 15,12 (T5) mmol L^{-1} na solução nutritiva foram comparadas. O aumento na concentração de N de 5,12 para 15,12 mmol L^{-1} reduziu o crescimento da coroa, das raízes e o IAF das plantas matrizes de morangueiro, mas não afetou a emissão e crescimento das pontas de estolões. Não há aumento da absorção e acumulação de nitrogênio em plantas matrizes acima da concentração de 7,62 mmol L^{-1} de N na solução nutritiva. Dentre os órgãos, a acumulação de N decresce de folíolos, raízes pecíolos para coroa. O clorofilômetro apresenta boa relação com a concentração de N nas folhas e pode ser usado para monitorar o status de N na cultura. Conclui-se que a concentração de N na solução nutritiva para a produção comercial de pontas de estolões pode ser reduzida para 5,12 mmol L^{-1}.

Palavras-chave: *Fragaria x ananassa* Duch. Propagação. Nutrição.

ABSTRACT

Master's Thesis
Programa de Pós-Graduação em Agronomia
Universidade Federal de Santa Maria

NITROGEN MANEJEMENT IN STRAWBERRY RUNNER TIPS PRODUCTION AT SOILESS SISTEM

AUTHOR: DJEIMI ISABEL JANISCH
ADVISOR: JERÔNIMO LUIZ ANDRIOLO
Date and Place: Santa Maria, February 29th, 2012.

The objective of this research was to determine the effect of N concentration in the nutrient solution on strawberry runner tips production and growth and on the strawberry stock plants growth, N uptake and accumulation in a system for plug plants production. The experiment was conducted between September 2010 and March 2011. Strawberry stock plants of cultivars Camino Real and Oso Grande were grown in a soiless system in polietylene bags with sand as substrate. N concentration of 5.12 (T1), 7.6 (T2), 10.12 (T3 control), 12.62 (T4) e 15.12 (T5) mmol L^{-1} was compared. The increase of N concentration from 5.12 to 15.12 mmol L^{-1} reduces growth of crown, roots and LAI of strawberry stock plants but did not affect emission and growth of runner tips. There is any increasing in N uptake and accumulation on strawberry stock plants up 7.62 mmol L^{-1} N in nutrient solution. Between organs, N accumulation decrease from leaflet, roots, petioles to crown. A hand-held chlorophyll meter shows good relation with N concentration in leaflets and can be used for monitoring N crop status. It was concluded that the N concentration in nutrient solution for commercial production of runner tips can be reduces to 5.12 mmol L^{-1}.

Key words: *Fragaria x ananassa* Duch. Propagation. Nutrition.

SUMÁRIO

INTRODUÇÃO

O morango (*Fragaria x ananassa* Duch.) figura entre as pequenas frutas de maior interesse comercial. Apresenta alta adaptabilidade ambiental, sendo cultivado do Alaska ao extremo Sul da América (BISH, et al., 2003). Os maiores produtores mundiais são Estados Unidos, Turquia, Espanha e México (FAO, 2009). No Brasil, Minas Gerais, São Paulo e Rio Grande do Sul (RS) são os principais estados produtores. As tradicionais regiões produtoras no Rio Grande do Sul, são o Vale do Caí, Serra Gaúcha e Região Sul, totalizando uma produção estimada em 16 mil toneladas na safra 2006/2007 (MADAIL, 2008). No entanto, a produção de morango comercial em menor escala ocorre em praticamente todas as regiões do Estado.

No RS, a cultura ocupa atualmente 533 ha (EMATER/RS, 2011). Sendo possível afirmar que vem ganhando maior expressividade em produção e consumo. Um exemplo são os municípios de Ipê e Vacaria, os quais pertencem ao mais novo pólo de produção de morango: os Campos de Cima da Serra (PAGOT, 2010). Esses dois municípios aumentaram em 2,5 e 9 vezes, respectivamente, a área cultivada de 2006 a 2011, ocupando juntos atualmente 140 ha (EMATER/RS, 2011).

O morangueiro é uma planta perene, mas cultivada como anual, sendo necessária a renovação da lavoura a fim de iniciar um novo ciclo produtivo para manutenção da produtividade e sanidade. O plantio comercial no Brasil é feito com mudas do tipo raízes nuas. Estas mudas são produzidas em viveiros e cultivadas no solo a partir de plantas matrizes obtidas da propagação *in vitro*. No início da primavera são plantadas em canteiros e com o estímulo fotoperiódico de dias longos (13-14 horas) e temperaturas elevadas (20-26ºC), emitem estolões (SONSTEBY, 1997). Estes estolões possuem gemas vegetativas das quais se desenvolvem as plantas filhas, que em contato com o solo enraízam. No início do outono, período indicado para implantação das lavouras destinadas à produção de frutas, as mudas são arrancadas, tendo parte do sistema radicular e aéreo eliminado antes do plantio (SANTOS e MEDEIROS, 2003). Com a proibição do uso do Brometo de Metila para desinfecção do solo dos viveiros, desenvolveu-se principalmente nos EUA e Europa, a produção de mudas com torrão – *plug plants* – a partir das pontas de estolões, com o cultivo das plantas matrizes em sistemas fora do solo (TAKEDA e HOKANSON, 2003; ARMEFLHOR, 2006).

No Brasil, a produção de mudas de morangueiro ainda é uma atividade incipiente, sendo realizada em solos contaminados e comercializada sem padrões definidos de

classificação pela qualidade. Resulta disso elevada mortalidade no plantio e desuniformidade da lavoura. Para buscar mudas de melhor qualidade do que aquelas produzidas no Brasil, os produtores da fruta importam do Chile e da Argentina. Estima-se que aproximadamente 80% das mudas atualmente empregadas no Brasil são provenientes da importação desses países (OLIVEIRA, et al., 2005). Essas mudas importadas também apresentam inconvenientes como danos no transporte, atraso na entrega e alto custo, além de também não possuírem garantia de qualidade. As mudas representam 24% do custo de implantação da lavoura, sendo um dos fatores determinantes da produtividade (WREGE, et al., 2007). Tomando como base a área cultivada atualmente no Rio Grande do Sul e uma média de 50.000 plantas por hectare, a demanda por mudas gira em torno de 26.650.000 anualmente. Se considerarmos a área nacional cultivada de 3,5 mil hectares (ANTUNES e JÚNIOR, 2008) a demanda brasileira de mudas de morangueiro gira em torno de 175.000.000 por ano.

Com base na demanda e dependência atual da importação, fica evidente a necessidade de desenvolver a produção nacional de mudas de morangueiro. Com esse objetivo, foi elaborado o Zoneamento Agroclimático para produção de mudas dessa cultura para a produção de mudas do tipo raiz nua, o qual recomendou que a produção de mudas seja feita nas regiões de maior altitude do Estado do Rio Grande do Sul (WREGE, et al., 2007). Estas regiões garantiriam um mínimo de acúmulo de horas de frio na fase de produção de mudas, favorecendo a qualidade das mudas e em conseqüência a produtividade de frutas. Entretanto, isso implica na concentração da produção de mudas por viveiristas especializados e a necessidade de transporte para as diferentes regiões de produção da fruta. O Zoneamento não levou em consideração a possibilidade de produção fora do solo em ambiente protegido pelo método de *plug plants*. Para esse tipo de muda, a incidência de frio nas pontas de estolões mostra efeito negativo, estimulando o estolonamento e reduzindo a produção de frutas (SCHMITT, et al., 2012). Isso indica que através deste método, a produção de mudas poderia ser feita de forma descentralizada em pequenas unidades de produção localizadas nas diferentes regiões e atenderia os padrões de muda certificada, as quais devem ser produzidas fora do solo (CESM, 1998).

Atualmente a Portaria nº 172, de 10 de outubro de 2011 (MAPA, 2011), propõe o Projeto de Instrução Normativa (IN) que visa aprovar as Normas de Produção e Comercialização de Material de Propagação de Morangueiro (*Fragaria* x *ananassa* Duch.) bem como seus padrões de identidade e de qualidade. Esta IN, além de garantir a qualidade das mudas utilizadas, busca atender as normas para a Produção Integrada de Morango, que preconiza a utilização de mudas oriundas de viveiros fiscalizados ou de mudas

próprias obtidas a partir de matrizes provenientes de laboratórios registrados no MAPA. O desenvolvimento de tecnologia adaptada às condições brasileiras é essencial para que a produção de mudas através de métodos com maior nível de tecnologia, como aquele das *plug plants*, também possa vir a ser considerada nessa IN.

A produção de mudas do tipo *plug plants* passa necessariamente pelo cultivo das plantas matrizes em sistemas fora do solo. As principais referências desse sistema são aquelas de Durner, et al. (2002) nos Estados Unidos da América e da (ARMEFHLOR, 2006) na França. Nesses países, são empregadas soluções nutritivas semelhantes àquelas empregadas para produção de frutas. Não foram encontrados na literatura resultados sobre o efeito de diferentes concentrações de nutrientes da solução nutritiva sobre o crescimento e desenvolvimento das plantas matrizes e das pontas de estolões para produção de *plug plants*. Em outras espécies tem sido demonstrado que a concentração de nutrientes, especialmente o nitrogênio, afeta o crescimento vegetativo e a partição da massa seca entre os órgãos da planta (YIN, et al., 2003).

O objetivo geral dessa pesquisa foi determinar a concentração de nitrogênio na solução nutritiva a ser utilizada para o cultivo de plantas matrizes de morangueiro que maximize a produção de pontas de estolões. Os objetivos específicos foram determinar o seu efeito na produção e diâmetro da coroa das pontas de estolões e crescimento da planta matriz e na absorção e acumulação do nitrogênio nos órgãos da planta, a fim de inferir critérios de manejo desse nutriente durante a fase propagativa dessa cultura.

Nitrogen concentration of the nutrient solution in growth of stock plants and production of strawberry runner tips

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ABSTRACT

The objective of this work was to determine growth and dry matter partitioning among organs of strawberry stock plants under five N concentrations in the nutrient solution and its effects on emission and growth of runner tips. The experiment was conducted in a polyethylene greenhouse in Santa Maria, state of Rio Grande do Sul, Brazil, from September 2010 to March 2011, in a soilless system with Oso Grande and Camino Real cultivars grown on sand polyethylene bags. Nitrogen concentrations of 5.12 (T1), 7.6 (T2), 10.12 (T3 control), 12.62 (T4) and 15.12 (T5) mmol L^{-1} in the nutrient solution were compared in a 5 x 2 factorial randomised experimental design. All runner tips bearing at least one expanded leaf (patent requested) were weekly collected and counted during the growing period and number of leaves, DM of leaves, crown and root, specific leaf area and leaf area index were determined at the ending date. Increasing the N concentration of the nutrient solution from 5.12 to 15.12 mmol L^{-1} reduces growth of crown, roots and LAI of strawberry stock plants but did not affect

emission and growth of runner tips. It was concluded that for the commercial production of plug plants it can be reduced to about 5.12 mmol L^{-1}.

Key words: *Fragaria x ananassa*, hydroponics, propagation, fertigation.

Concentração de nitrogênio da solução nutritiva no crescimento das plantas matrizes e na produção de pontas de estolões de morangueiro

RESUMO

O objetivo do trabalho foi determinar o crescimento e a partição de massa seca entre órgãos de plantas matrizes de morangueiro cultivadas sob cinco concentrações de N na solução nutritiva e seu efeito na emissão e crescimento de pontas de estolões. O experimento foi conduzido em abrigo coberto com polietileno, em Santa Maria, Estado do Rio Grande do Sul, Brasil, de setembro de 2010 a março de 2011, em sistema de cultivo fora do solo com as cultivares Oso Grande e Camino Real plantadas em *bags* de polietileno contendo areia como substrato. Concentrações de N de 5,12 (T1); 7,6 (T2); 10,12 (T3 testemunha); 12,62 (T4) e 15,12 (T5) mmol L^{-1} na solução nutritiva foram comparadas em um esquema fatorial 5 x 2 em delineamento inteiramente casualizado. Todas as pontas de estolões emitidas com pelo menos uma folha expandida (patente requerida) foram semanalmente coletadas e contadas durante todo o período de emissão. O número de folhas, MS de folhas, coroas e raízes e área foliar específica e índice de área foliar das plantas matrizes foram determinadas ao final do experimento. O aumento na concentração de N de 5,12 para 15,12 mmol L^{-1} reduziu o crescimento da coroa, das raízes e o IAF das plantas matrizes de morangueiro, mas não afetou a emissão e crescimento das pontas de estolões. Conclui-se que a concentração de N na solução nutritiva para a produção comercial de pontas de estolões pode ser reduzida para 5,12 mmol L^{-1}.

Palavras-chave: *Fragaria x ananassa*, hidroponia, propagação, fertirrigação.

1. INTRODUCTION

In last years, there was a trend in United States and Europe to replace the production of strawberry bare root transplants by plug plants (DURNER et al., 2002; ARMEFLHOR, 2006). Although the restriction for using methil bromide was the origin of this technological change, growers had fast seen many advantages of this new type of transplants, like lower water requirements for crop establishment, higher transplant survival after planting and improved crop yield (TAKEDA and HOKANSON, 2003; HOCHMUTH et al., 2006).

In Brazil, the production of strawberry transplants is inexpressive and they are imported from the Patagonia region (OLIVEIRA et al., 2006). They are often delivered after the good planting time and at high prices. Growers search for new production methods able to furnish high quality transplants at the good planting time for each production region of the country. This goal can be reached by the "plug plants" production method, as it has been reported in the literature (VERDIAL et al., 2004; OLIVEIRA et al., 2007; GIMÉNEZ et al., 2008). In such method, stock plants are grown in hydroponical facilities but little attention has been paid to the composition of the nutrient solution used for plant fertigation.

Hydroponical production systems have been patented for producing strawberry plug plants (BISH et al., 2003; ARMEFLHOR, 2006), and several other systems have been described in the worldwide literature. Stock plants growing in bags or pots filled with substrate and placed in the soil surface or above the soil were proposed by BISH et al. (2003). In the BISH's system, plants were fertigated and the nutritive solution drained to waste, while in the LIETEN's (2000) system it was collected and reused. In all soilless systems, stock plants have to reach its potential number of runner tips, to reduce production costs (TAKEDA and HOKANSON, 2003). The composition of the nutrient solution is one of the main factors affecting plant growth and it has to be adapted to environmental conditions and cultivars. For growing strawberry stock plants, it has been reported that the composition of the nutrient

solution affects the production and quality of runner tips (DURNER et al., 2002; BISH et al., 2001).

Nitrogen has been considered as the key nutrient in plant growth and yield, affecting photosynthesis and dry matter partitioning (YIN et al., 2003). For the strawberry crop at propagative phase, nitrogen concentrations in the range from 2.16 mmol L^{-1} to 15.25 mmol L^{-1} in the nutrient solution have been reported in the literature (BISH et al., 2001; ARMEFLHOR, 2006). In strawberry fruiting plants, high N concentrations increased vegetative growth and early emission of stolons, reducing fruit yield (HENNION and VECHAMBRE, 1997), but less effects on growth and yield were also reported (CANTLIFFE et al., 2007). In the wild species *Fragaria chiloensis*, N increased runner emission and reduced stolon length, but this effect was genotype dependent (TWORKOSKI et al., 2001). In Santa Maria, RS, OLIVEIRA et al. (2010) showed any effect of N concentration on production of bare root transplants in a sand growing bed. They attributed such result to competition for radiation among plants on the bed and/or for carbon assimilate among plant organs.

The objective of this work was to determine growth and dry matter partitioning among organs of strawberry stock plants under five N concentrations in the nutrient solution and its effects on emission and growth of runner tips.

2. MATERIAL AND METHODS

The experiment was conducted from 22 September 2010 to 03 March 2011, inside a polyethylene greenhouse in Santa Maria, state of Rio Grande do Sul, Brazil. Average air temperatures and global solar radiation were, respectively: 17.46°C and 1164.80 kJ m^{-2} in September, 17.7°C and 1509.87 kJ m^{-2} in October; 20.34°C and 1584.27 kJ m^{-2} in November; 23.33°C and 1704.34 kJ m^{-2} in December; 24.5°C and 1713.75 kJ m^{-2} in January; 24.04°C and 1424.05 kJ m^{-2} in February. A closed soilless system was used (GODOI et al., 2009). The

substrate was sand in 0.21 m diameter and 1.2 m length white polyethylene bags. Sand physical characteristics were 0.01-0.03 m gauge, 1.6 kg dm^{-3} bulk density and 0.243 L dm^{-3} maximum water retention capacity. Bags were placed over fibber cement tiles, at 0.80 m height above the soil. The nutrient solution was supplied six times a day for 15 min by drip fertigation from a polyethylene reservoir for optimal water and nutrient availability to plants.

The nutrient solution reported by HENNION and VESCHAMBRE (1997) for the strawberry crop was used as control, adjusted to nutrient concentrations of, in mmol L^{-1}: 8.26 NO_3^-, 1.86 NH_4^+, 4 $H_2PO_4^-$, 6 K^+, 2.0 Ca^{+2}, 1 Mg^{+2} and 1 SO_4^{-2}. Micronutrients quantities were, in mg L^{-1}, 0.03 Mo; 0.42 B; 0.06 Cu; 0.50 Mn; 0.22 Zn and 1.0 Fe.

Treatments were five N concentrations in the nutrient solution: 5.12 (T1), 7.6 (T2), 10.12 (T3 control), 12.62 (T4) and 15.12 (T5) mmol L^{-1}, at electrical conductivities (EC) of 1.09; 1.3; 1.6; 1.76 and 2.0 dS m^{-1}, respectively, during all the experiment period. The pH was adjusted in the range between 5.5 and 6.5, by HPO_3^- or KOH 1N additions whenever necessary. The cultivars Oso Grande and Camino Real were used, in a 5 x 2 factorial randomised experimental design and twenty replications of one plant. Separated units of the hydroponical growing system were used for each nutrient concentration. Fertilizers were potassium nitrate, ammonium nitrate, calcium nitrate-Calcinit®, potassium monophosphate-MKP®, potassium sulphate and magnesium sulphate. Nitrogen concentrations were differed by modifying ammonium nitrate and potassium sulphate quantities in the nutrient solution. Ionic concentrations of $H_2PO_4^-$, Ca^{+2}, Mg^{+2} and K^+ were as the control in all treatments and concentration of SO_4^{-2} was 2 mmol L^{-1} in T1.

Micropropagated stock plants of both cultivars were acclimatized and planted in bags on 22 September 2010. The bags were arranged in four lines at a plant density of 12 plants m^{-2}, with 4.5 dm^3 of substrate for each plant. The runner emission period was from 17 October 2010 to 3 March 2011, when the experiment was ended. It was recorded on 50% plants of

each treatment. During the experimental period, all runner tips bearing at least one expanded leaf (patent requested) were weekly collected, counted and averaged on 29 October, 17 and 30 November, 17 e 29 December, 12 January, 01 and 16 February and 3 March. Ten runner tips from plants of each treatment was monthly sampled for to determine its crown diameter, the number of visible root nodules and dry matter (DM) after drying at 65ºC until constant mass was reached. At the end of the experiment, six stock plants of each treatment were harvested, the number of leaves counted and DM of leaves, crown and root was determined. Specific leaf area (SLA) was estimated by means of a relationship between DM and $5.02 \times 10^{-5}.m^2$ diameter leaf discs sampled in nine leaves of each plant. Leaf area index (LAI) was estimated from SLA and total leaf DM of plants. Results were submitted to analysis of variance and polynomial regression using the software Sisvar 4.1.

3. RESULTS AND DISCUSSION

The N concentration of the nutrient solution did not affect the production of runner tips by stock plants of both cultivars (data not shown) ($p>0.05$). The average number was 54 tips per stock plant. The number of runner tips collected during the growing period decreased polinomially (Figure 1). The highest estimated number was reached at 72 days after planting (DAP). At this time an average of 8.35 tips per stock plant was collected. Crown diameter and DM of tips were also not affected and average values were 5.71 mm and 0.4 g per tip, respectively. Emission and growth of tips were similar between cultivars, but average number of root nodules was 5.56 on Camino Real and 2.41 on Oso Grande runner tips.

Total and crown DM of stock plants did not differed among cultivars, but decreased linearly from T1 to T5 (Figure 2a, b). Growth of roots decreased in a negative polynomial patter with highest intensity from T1 to T2, without significant (Figure 2c). Growth of leaves increased linearly in Oso Grande while in Camino Real it increase only until 8.2 mmol L^{-1} N

in the nutrient solution (Figure 2d). Number of leaves increased in Oso Grande from T1 to T2, decreasing thereafter (Figure 3a), and LAI decreased polinomially in both cultivars (Figure 3b).

It is surprising the lack of N effect on emission and growth of strawberry runner tips. In *Fragaria chiloensis*, TWORKOSKI et al. (2001) reported an increasing number of stolons on plants grown in nutrient solutions with N concentrations from zero to 5.7 mmol L^{-1}. In a similar work using *Fragaria chiloensis*, ALPERT (1991) reported a 20% increase in stolon growth by effect of N doses from 0 to 3.6 mmol L^{-1}. Nevertheless, the range of N concentrations used by both authors was lower than those of the present experiment. At low N availabilities plant growth and developmental processes might be affected by isometric and allometric relationships. Strawberry plant development has been considered as triggered manly by air temperatures between 20-26°C and day length ranging from 13-14 hours (SONSTEBY, 1997). However, in spite of environmental variables, a new developmental phase can take place only when a minimum growth has been reached by the plant at the previous phase, to assure its isometry (MCCONNAUGHAY and COLEMAN, 1999). In this way, it could be interpreted that N concentrations used by TWORKOSKI et al. (2001) and ALPERT (1991) were low enough to isometrically reduce plant growth and, as a consequence, runner emission. This suggests that the lowest N concentration of 5.12 mmol L^{-1} used in the present experiment was not limiting for strawberry plant growth and development.

The crop management practices for plant and stolon growth can affect production and crown diameter of runner tips. In this work, only first order runner tips bearing with one expanded leaf were collected and its crown diameter was higher than that reported by OLIVEIRA et al., 2010 and GIMÉNEZ et al., 2008. These workers used a sand growing bed for simultaneously producing bare root transplants on the bed surface and runner tips on suspended stolons growing downward between beds. Present results agree with DURNER et

al., 2002, to whom runner tips collected in weekly intervals are bigger and lead to more uniform transplants. In the OLIVEIRA's work, no difference was found in emission of runner tips at N concentrations from 8, 11, 14 to 17 mmol L^{-1} and it was attributed to competition for assimilates between plant and runner tip growth, as final plant density by mother and daughter plants on the bed surface reached 339 plants m^{-2}. In the present experiment, plant density was of 12 plants m^{-2} and stolons were not kept to grow, as a way to reduce such competition. Nevertheless, production and crown diameter of runner tips were also not affected and the assimilate limiting hypothesis was not confirmed. Probably, temperature and photoperiod are the key environmental variables controlling the propagation of the strawberry plant, as suggested by SONSTEBY (1997), and the N concentration of 5.12 mmol L^{-1} is not limiting for runner tip production.

In Southern Brazil, strawberry growers replant their crops mainly in April and May. Plug plants to be used in this period had to be collected at least 30 days ago. Figure 1 shows the maximum production of runner tips from mid-November to mid-December, decreasing strongly thereafter. It is a time period too early for commercial plug plant production. Cultural practices had to be searched to overcome it. Transplants of horticultural crops have been produced mainly in 128 cell-polystyrene trays for economical reasons. For strawberry plug plants produced in November-December, trays with bigger cells might be used, but production costs would be increased. Other possibilities might be the cold storage of runner tips for further rooting and plug plant production, as suggested by HOKANSON et al. (2004), or using runner tips for producing news stock plants as suggested by DAL PICIO et al. (2012).

Present results have implications for the commercial production of strawberry runner tips. The N concentration of the nutrient solution can be reduced from the about 10 mmol L^{-1} nowadays in use to about 5 mmol L^{-1} with environmental and economical benefits. Management practices may also be reviewed. The fact that DM and crown diameter of runner

tips were not affected by either N availability and growth of the stock plant suggests that runner tips are able to produce the carbon assimilates they need for its growth. If they depend on water and nutrients from the stock plant, it was only at initial developmental stages, before root emission. Thus, shoot growth of stock plants might be reduced and controlled by cultural practices like pruning, defoliation or increasing plant density. Benefits would be less consumption of nutrient solution and higher surface use efficiency of growing beds.

4. CONCLUSIONS

The N concentration of the nutrient solution from 5.12 to 15.12 mmol L^{-1} reduces growth of crown, roots and LAI of strawberry stock plants but did not affect emission and growth of runner tips. In the commercial production of plug plants it can be reduced to about 5 mmol L^{-1}.

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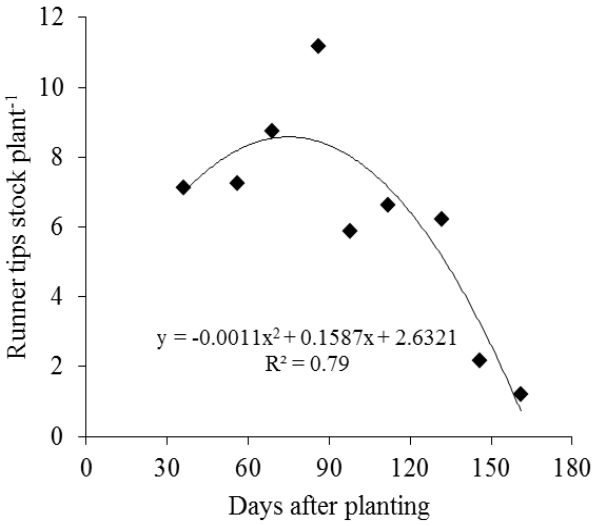

Figure 1. Average number of runner tips collected during the experiment from strawberry stock plants grown at N concentrations of 5.12 (T1), 7.6 (T2), 10.12 (T3 control), 12.62 (T4) and 15.12 (T5) mmol L^{-1} in the nutrient solution.

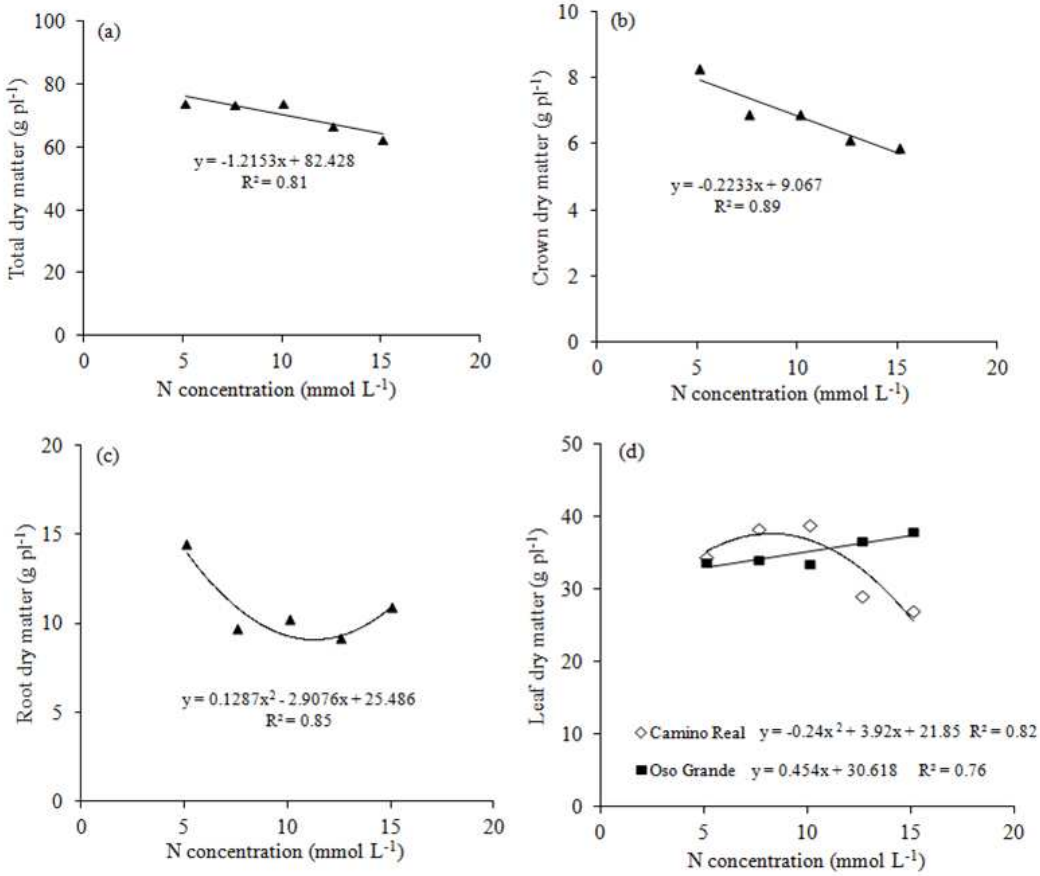

Figure 2. Total (a), crown (b), root (c) and leaf (d) dry matter of strawberry stock plants grown at N concentrations of 5.12 (T1), 7.6 (T2), 10.12 (T3 control), 12.62 (T4) and 15.12 (T5) mmol L^{-1} in the nutrient solution.

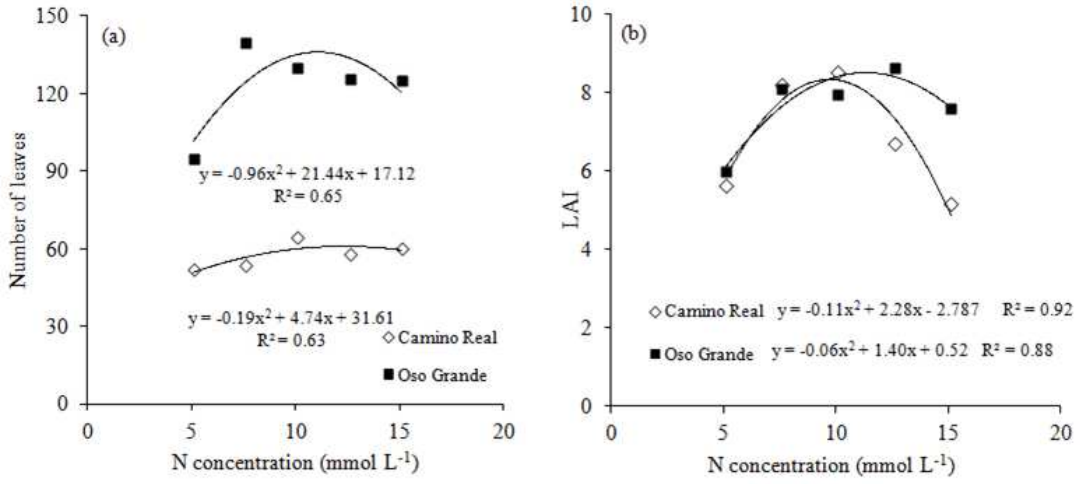

Figure 3. Number of leaves (a) and leaf area index (LAI) (b) of strawberry stock plants grown at N concentrations of 5.12 (T1), 7.6 (T2), 10.12 (T3 control), 12.62 (T4) and 15.12 (T5) mmol L^{-1} in the nutrient solution.

Nitrogen monitoring during growth and its accumulation by strawberry stock plants for runner tips production

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Abstract - The aim of this work was to determine N uptake and accumulation in strawberry stock plants grown for runner tips production under five N concentrations in the nutrient solution and its relationships with a hand-held chlorophyll meter as a tool for monitoring the N status of this crop. From September 2010 to March 2011, strawberry stock plants of cultivar Oso Grande and Camino Real were grown in a soilless system on sand polyethylene bags. Nitrogen concentrations of 5.12 (T1), 7.6 (T2), 10.12 (T3 control), 12.62 (T4) and 15.12 (T5) mmol L^{-1} in the nutrient solution were compared. During the growing period, weekly all runner tips at last on expanded leaf was collected. Fortnightly was measured a chlorophyll index in leaf of stock plants, and at ending, nitrogen and nitrate in all organs was determining. Leaflets have the highest N concentration and petiole the highest nitrate concentration in stock plants. In strawberry stock plants there is any increase in nitrogen uptake and accumulation at nitrogen concentrations in the nutrient solution upper than 7.62 mmol L^{-1}. Runner tips production was unaffected by the N doses. Chlorophyll meter can be used for monitoring the N status of this crop.

Index terms: *Fragaria x ananassa,* plug plants, nutrition, chlorophyll meter.

Monitoramento do nitrogênio durante o crescimento e sua acumulação por plantas matrizes de morangueiro para produção de pontas de estolões

Resumo – O objetivo do trabalho foi determinar a absorção e acumulação de nitrogênio em plantas matrizes de morangueiro cultivadas para produção de pontas de estolões sob cinco concentrações de N na solução nutritiva e a relação com a medida de clorofila por medidor portátil como ferramenta para monitorar o status nutricional da cultura. De setembro de 2010 a março de 2011, plantas matrizes de morangueiro das cultivares Oso Grande e Camino Real foram cultivadas em sistema sem solo em *bags* de polietileno contendo areia como substrato. Concentrações de N de 5,12 (T1); 7,6 (T2); 10,12 (T3 testemunha); 12,62 (T4) e 15,12 (T5) mmol L^{-1} na solução nutritiva foram comparadas. Durante o período, semanalmente todas as pontas de estolões com pelo menos uma folha expandida foram coletadas. Quinzenalmente foi medida clorofila nas folhas das plantas matrizes e ao final, plantas foram coletadas para determinação de N e nitrato nos órgãos. Os folíolos apresentaram a maior concentração de nitrogênio e os pecíolos a maior concentração de nitrato. Em plantas matrizes de morangueiro não há aumento da absorção e acumulação de nitrogênio acima da concentração de 7,62 mmol L^{-1} de N na solução nutritiva. A produção de pontas de estolões não é afetada pelas doses de N. O clorofilômetro pode ser usado para monitorar o status de N na cultura.

Termos para indexação: *Fragaria x ananassa,* mudas com torrão, nutrição, clorofilômetro.

Introduction

Strawberry is a perennial species, but in Brazil it is grown as annual. Planting is done every year to reduce risks of pests and diseases and maximize yield and quality. Although bare root transplants are widely used, there is nowadays a trend to replace them by plug transplants in trays. Mainly advantages of strawberry plug transplants are higher survival after planting, better crop stand and higher yield (Hochmuth et al., 2006). For using the plug plant method, a high source of runner tips at the good time is necessary. For this goal, hydroponical

facilities have been used (Bish et al., 2001; AMERFLHOR, 2006). Cultivar, environmental conditions and crop practices like the composition and concentration of the nutrient solution can affect growth of plants and runner tips.

Effects of N availability on strawberry plant growth and development and fruit yield have been previously studied. Concentrations in leaf blades of 19, between 20 - 28 and 40 g kg^{-1} have been considered as deficient, sufficient and excessive, respectively (Pritts & Handley, 1998). Nevertheless, it has been reported that N concentration in strawberry leaves decreases along the growing period (Cantliffe et al., 2007). Although N can stimulate plant vegetative growth, such effect may be weak or negative. Emission of runner tips was increased by decreasing the N concentration of the nutrient solution from 120 to 30 mg L^{-1} (Bish et al., 2001). In a day neutral strawberry cultivars grown in soil, Otto et al. (2009) concluded that N fertigation have little effect on stolon emission. Nitrogen fertilization in soil for producing strawberry bare root transplants increased the N content in roots and crown and the chlorophyll index, but decreased starch and other nonstructural carbohydrates content in these organs, resulting in further higher early fruit yield (Méndez et al., 2009; Kirschbaum et al., 2010).

In a growing system for production of strawberry plug plants, runner tips are not kept to rooting and they depends on the mother plant for water and nutrients, which are transported through stolon, being the predominant sink of the plant (Blancke & Coocke, 2004). Interactions between N concentration in plant tissues and number of stolons have been reported in strawberry wild species, which with the lowest N concentration being the most responsive in stolon number (Tworkoski et al., 2001).

In a NFT hydroponic system, plants were grown at NO_3^--N concentrations of 3.75, 7.5 and 15.0 mmol L^{-1} (Darnell & Sttute, 2001). They observed that N uptake rates and tissue N concentration increased, but no effect was reported on nitrate reductase (NR) activity in

leaves and roots, nor in vegetative and fruit dry weight. They concluded that the inability of strawberry plant to increase growth in response to increasing NO_3^--N is not due to limitations in uptake but in nitrate reduction and/or assimilation. However, the NR activity is affected by the nitrate-ammonium ratio in nutrient solution (Tabatabaei et al., 2008). The ratio of 15% ammonium in the nutrient solution increased the NR activity, reducing the NO_3 concentration in leaves (Taghavi et al., 2004).

It has been demonstrated that of the total N assimilated in leaves, the major part is in enzymes and proteins associated with chloroplasts and that the photosynthesis rate is nitrogen dependent (Chapman & Barreto, 1997). In horticultural and fruiting crops like zucchini, sweet peeper and tomato, the indirect measure of chlorophyll by using hand held meters are proposed as a tool for managing N fertilization (Pôrto et al., 2011). In strawberry plants, significant linear positive relationships have been adjusted between SPAD readings and total N content in several cultivars, suggesting they could be used to N diagnosis status during the fruiting period (Güler et al., 2006). However, great variability of N concentration in leaves were recorded among cultivars, ranging from 1.68 to 2.46 g kg^{-1} in Güler's data, and in total plant N concentration ranging from 1.66 to 3.63 g per plant in data of Li et al., (2010). Such results show the need to calibrate the chlorophyll meter for each cultivar or group of cultivars.

For optimizing nitrogen fertilization, it is necessary to understand the response of the strawberry plant to nitrogen supply at different environmental conditions and to have a tool for monitoring the nutritional status. The aim of this work was to determine N uptake and accumulation in strawberry stock plants grown for runner tips production under five N concentrations in the nutrient solution and its relationships with a hand-held chlorophyll meter as a tool for monitoring the N status of this crop.

Material and Methods

The experiment was conducted from September 2010 to March 2011, inside a polyethylene greenhouse at Departamento de Fitotecnia, UFSM, state of Rio Grande do Sul, Brazil (29°42' S; 53°42' W - 95 m). Average air temperatures and global solar radiation during the experiment period was, respectively: 17.46°C and 1164.80 kJ m^{-2} in September, 17.7°C and 1509.87 kJ m^{-2} in October; 20.34°C and 1584.27 kJ m^{-2} in November; 23.33°C and 1704.34 kJ m^{-2} in December; 24.5°C and 1713.75 kJ m^{-2} in January; 24.04°C and 1424.05 kJ m^{-2} in February. A closed soilless system was used (Godoi et al., 2009). The substrate was sand in 0.21 m diameter and 1.2 m length white polyethylene bags. Sand physical characteristics were 0.01-0.03 m gauge, 1.6 kg dm^{-3} bulk density and 0.243 L dm^{-3} maximum water retention capacity. Bags were placed over benches at 0.80 m height above the soil. The nutrient solution was supplied six times a day for 15 min by drip fertigation from a polyethylene reservoir for optimal water and nutrient availability to plants.

The nutrient solution reported by Hennion & Veschambre (1997) for the strawberry crop was used as control, adjusted to nutrient concentrations of, in mmol L^{-1}: 8.26 NO_3^-, 1.86 NH_4^+, 4 $H_2PO_4^-$, 6 K^+, 2.0 Ca^{+2}, 1 Mg^{+2} and 1 SO_4^{-2}. Micronutrients quantities were, in mg L^{-1}, 0.03 Mo; 0.42 B; 0.06 Cu; 0.50 Mn; 0.22 Zn and 1.0 Fe.

Treatments were five N concentrations in the nutrient solution: 5.12 (T1), 7.6 (T2), 10.12 (T3 control), 12.62 (T4) and 15.12 (T5) mmol L^{-1}, at electrical conductivities (EC) of 1.09; 1.3; 1.6; 1.76 and 2.0 dS m^{-1}, respectively. The pH was adjusted in the range between 5.5 and 6.5, by H_3PO_4 or KOH 1N additions whenever necessary. The cultivars Oso Grande and Camino Real were used, in a 5 x 2 factorial randomised experimental design and twenty replications of one plant. Separated units of the hydroponical growing system were used for each nutrient concentration. Fertilizers were potassium nitrate (38.7% K^+ and 13.8% N-NO_3^-), ammonium nitrate (30.0% N), calcium nitrate-calcinit® (14.4% N-NO_3^-; 1.1% N-NH_4^+ and 19% Ca^{+2}), potassium monophosphate-MKP® (28.7% K^+ and 22.8% $H_2PO_4^-$), potassium

sulphate (44.9% K^+ and 18.4% SO_4^{-2}) and magnesium sulphate (9.9% Mg^{+2} and 18.4% SO_4^{-2}). Nitrogen concentrations were differed by modifying ammonium nitrate and potassium sulphate quantities in the nutrient solution. Ionic concentrations of $H_2PO_4^-$, Ca^{+2}, Mg^{+2} and K^+ were as the control in all treatments and concentration of SO_4^{-2} was 2 mmol L^{-1} in T1.

Micropropagated stock plants of both cultivars were acclimatized and planted in bags on 22 September 2010. The bags were arranged in four lines at a plant density of 12 plants m^{-2}, with 4.5 dm^3 of substrate for each plant. The beginning of runner emission was on 17 October 2010 and ended on 3 March 2011, recorded on 50% plants of each treatment. During the experimental period, all runner tips bearing at least one expanded leaf (patent requested) were weekly collected. Senescent leaves on stock plants were periodically removed.

Fortnightly, from 16 October to the end of the experiment, relative leaf chlorophyll content, expressed as Falker Chlorophyll Index (ICF), was determined using a digital chlorophyll meter (clorofiLOG® CFL 1030 - Falker). The ICF is a dimensionless measure of total (a+b) chlorophyll obtained from absorbance of chlorophylls in three wave lengths. For to calibrate this tool, a sample of leaves was collected, ICF determined and immediately caried to the laboratory for to determine the real concentration of chlorophyll (a + b), expressed in mg g^{-1} of fresh weight (Hiscox et al., 1978). The relationship between ICF and chlorophyll can be estimated by following linear equations: Chl(a+b) = 0.0467ICF - 0.0529 R^2 = 0.86, for Oso Grande and Chl(a+b) = 0.0607ICF - 1.0047 R^2 = 0.95 for Camino Real. The ICF readings were made on all three leaflets of the last second full expanded leaf of the main crown on twenty plants per treatment, between 8:00 and 10:00 am and averaged to obtain the ICF of the plant.

The experiment was ended on 3 March 2011. Six stock plants of each treatment were harvested and separated into leaflet, petioles, crown, roots and runner tips. Dry mass was determined after drying at 65ºC until constant mass was reached. Total N and N-NO_3^- in

tissues were determined by micro-Kjeldahl (Tedesco et al., 1995). The N concentration in runner tips was determined in samples collected on 26 January 2011, near the end of runner tips emission period.

Results were submitted to analysis of variance and the significance of differences among means was determined by the Tukey's test at 5% probability or polynomial regression using the software STATISTICA®.

Results and Discussion

Nitrogen concentration in tissues differed by effect of its concentration in the nutrient solution and also among plant organs (Figure 1). The lowest tissue concentration was recorded at the lowest nutrient solution concentration (T1) in all organs and data fitted an exponential model on root, petiole, leaflet and crown tissues. Among organs, N concentration in tissues was lower in petiole (9.10g kg^{-1}) and crown (11.50 g kg^{-1}) and higher in roots (17.80 g kg^{-1}) and leaflets (20.60 g kg^{-1}). Of the total N uptake by plants, 62.4% was accumulated in leaflets, 16.4% in roots, 14.5% in petioles and 6.75% in the crown. The lowest proportion in the crown was due its low dry matter, which represented on average 10% of the whole plant.

In runner tips, the average of both cultivars of tissue N concentration showed a polynomial pattern by effect of its concentration in the nutrient solution (Figure 2A). The maximum estimated N concentration in runner tips was 20.8 g kg^{-1} reached at 11.8 mmol L^{-1} N in the nutrient solution. A polynomial allometric relationship was adjusted between accumulation of N and dry matter in runner tips (Figure 2 B). On average during the experimental period, number and growth of runner tips did not differed between cultivars and among N concentration in the nutrient solution (data not shown).

Nitrate concentration in tissues differed among organs and cultivars in response to N concentration in the nutrient solution (Figure 3A, B). The lowest average concentration was 0.83 mg g^{-1} in leaflets of Camino Real and the highest 2.74 mg g^{-1} in petioles of Oso Grande.

In roots, Camino Real showed higher nitrate concentration than Oso Grande, while in the crown, petioles and leaflets it was higher in Oso Grande (Figure 3 C).

Relationships between chlorophyll index measurements and N concentration determined at the laboratory were adjusted at the end of the experiment (Figure 4A). Nitrogen concentration in leaflets of the whole plant can be estimated by the polynomial equation: $Nleaf=-0.15\ ICF^2 + 15.77ICF - 360.32$, $R^2=0.97$, for both cultivars in the range between 14.8 and 22.05 g kg^{-1} N (Figure 4A). The total plant N concentration can also be estimated from the N concentration in leaflets by the linear equation: $Nplant=1.02Nleaf - 6.29$, $R^2=0.89$, for both cultivars (Figure 4B).

Data of chlorophyll index on leaflets of both cultivars at the end of the experiment showed polynomial patterns for the nitrogen concentration in the nutrient solution (Figure 5A). Chlorophyll in the plant decreased up than 11.6 mmol L^{-1} probably due to water stress (Kaya et al., 2002). But, when data of measurements made at fortnight intervals during all the growing period was pooled together, a logarithmic pattern was adjusted and the chlorophyll index was highest at the highest nitrogen concentration in the nutrient solution (Figure 5B). During the time growing period of plants, chlorophyll index decreased in both cultivars under all nitrogen concentrations in the nutrient solution (Figure 5 C).

Present results showed a maximum N concentration of 21.8 g kg^{-1} in leaflets, considering the averaged of both cultivars (Figure 1C). In the vegetative growth phase before fruiting, Archbold & MacKown (1997) reported also the highest total N concentration in leaflets and the lowest in petioles. Nevertheless, Darnell & Stutte (2001) reported a maximum concentration of 31.2 g kg^{-1} in roots of fruiting plants. In our experiment, concentration in roots was of 17.2 g kg^{-1}. These differences may be a consequence of the growing system. In the NFT system used by Darnell & Stutte (2001) nutrients might diffuse from the rooting media into roots by mass flow, as reported by Goméz et al., (2003) in cucumber while roots

growing in soil or in solid media had to search for water and nutrients. Concerning the N concentration in leaves, it might be affected by the PAR flux reaching the plant canopy, because N assimilation depends on photosynthesis. The Darnell & Stutte's data were obtained in fruiting plants in spring, while present results were of plants at the propagative stage in summer.

Nitrate partitioning among organs are similar to that found by Haghighat et al., (2006), while in the Darnell & Stutte (2001) work, no effect of external $N\text{-}NO_3^-$ concentrations higher than 3.75 mmol L^{-1} in the nutrient solution was observed on strawberry plant growth and fruit yield. They concluded that the enzyme NR in roots and leaves of the strawberry plant saturates at this external N concentration. Similar conclusion was reported by Cantliffe et al., (2007) on strawberry fruiting plants at a $N\text{-}NO_3^-$ concentration of 2.8 mmol L^{-1} in the nutrient solution. However, present results suggest that during the propagation phase for runner tip production the saturation happens at higher external concentrations, around 7.62 mmol L^{-1}. The saturation of the NR at higher external nitrogen concentration than that used by Darnell & Stutte and Cantliffe may be ascribed to the N form in the nutrient solution. Although nitrate is the main form of N uptake by plants, it has been demonstrated in the literature that the addition of $N\text{-}NH_4^-$ modulates the relative uptake of anions and cations (Sonneveld 2002) and consequently total N concentration in plant tissues (Tabatabaei et al., 2008). In the present experiment, $N\text{-}NH_4^-$ was 8% (T1), 9% (T2), 23% (T3), 33% (T4) and 41% (T5), respectively. This was done to reach different N concentrations without changing the cation balance and the ionic equilibrium of the nutrient solution. In fact, reduced strawberry root and shoot growth has been reported in nutrient solutions using only one form of N (Sas et al., 2003; Tabatabaei et al., 2008). Additions of $N\text{-}NH_4^-$ in the nutrient solution enhanced NR activity (Tagahavi et al., 2004; Tabatabaei et al., 2008) and growth (Yoon, 2009). Nutrient solutions described at literature used for the strawberry crop contain from 3 to 25% of ammonium in its

composition (Giménez et al., 2008). For the commercial production of strawberry runner tips 13% N-NH_4^- in the nutrient solution has been indicated (ARMEFHLOR, 2006) and it seems confirmed by our results.

While total N concentration did not increase above the external N concentration of 7.62 mmol L^{-1} in the nutrient solution, NO_3^- concentration in plant tissues showed polynomial patterns (Figure 3 A and B). This may be a consequence of disturbances in the plant water flux by salinity, because increasing the external N concentration increases also the EC of the nutrient solution. Physiological disturbances in strawberry plant growth like scorched leaves and tip burn symptoms at high nutrient solution concentrations have been reported in the literature (Guttridge et al., 1981; Sonsteby et al., 2009) and were also observed at present experiment, mainly at T4 and T5. In strawberry fruiting plants, reduction in vegetative growth and fruit yield at EC higher than 1.0 - 1.3 dS m^{-1} was recorded (Andriolo et al., 2009; Caruso et al., 2011). In the present experiment, the average EC in T4 and T5 were 1.76 and 2.0 dS m^{-1}, respectively, and plant water flux and NO_3^- transport within the plant may have been reduced. However, NO_3^- accumulation represented only 13% of the total N in the plant, being 3.8% in leaflets, 27.8 % in petioles, 16.5% in the crown and 11.5% in roots, on average of both cultivars. It can be concluded that NO_3^- accumulation in the strawberry plant is of minor importance. For commercial production of runner tips and strawberry plug plants, present results showed that total N concentration of the nutrient solution can be reduced to 5.12 mmol L^{-1}, being until 8% in the NH_4^+ form.

A polynomial relationship has been adjusted between the chlorophyll index and N concentration in leaflets in the range of external nitrogen concentrations in the nutrient solution between 5.12 and 15.12 mmol L^{-1} (Figure 4A). A linear relationship between chlorophyll and N concentration in the same leaves of strawberry fruiting plants was found by Güler et al. (2006), regardless of cultivar. In strawberry transplants grown in a soil nursery, a

significant effect on chlorophyll content was induced by N fertilization rates from zero to 150 kg N ha^{-1} (Méndez et al., 2009). Based on present results, it can be concluded that the ICF can be used to estimate the nitrogen status of strawberry stock plant in the range between 43 and 50.5 ICF. Nevertheless, fortnightly chlorophylls measurements done in the present research on the last second full expanded leaf of the main crown during the growing period (Figure 5 C) showed a dilution pattern similar to that reported in the literature for several crops (Rattin et al, 2002; Skonieski et al., 2012). The crop nitrogen dilution curve has been explained as an allometric relationship between growth of plant metabolic compartments during its growth and development (Lemaire et al., 2008). During the vegetative growth phase, N is remobilized from shaded leaves at the bottom of the canopy to well illuminated ones at the top. In the reproductive phase, dry mass accumulation is shifted from leaves to storage and structural organs like steams, fruits, grains or tubers, having lower N concentration than leaves. In fruiting strawberry crops a reduction in N concentration in mature leaves has been observed (Cantliffe et al., 2007). At the propagative phase, such relationship was not yet been demonstrated. In this crop, stolons are weak sinks, as they reached about 30% of the stock plant dry mass at the end of the experimental period. The present dilution curve represents the physiological ageing of the strawberry plant during its propagative phase. At late summer, with a decrease of temperature and photoperiod, strawberry plants translocate N from leaves to roots and crown, reducing the chlorophyll content resulting in yellow and after red leaves, starting the dormancy or semi dormancy period (Guttridge, 1985). The chlorophyll meter was able to show this reduction and has to be taken into account when using the chlorophyll index to estimate its nitrogen status.

Conclusions

1- In strawberry stock plants there is any increase in nitrogen uptake and accumulation at nitrogen concentrations in the nutrient solution upper than 7.62 mmol L^{-1}.

2- The runner tips production was unaffected by the N concentrations.

3- Chlorophyll meter can be used for monitoring the N status in the propagative phase of this crop.

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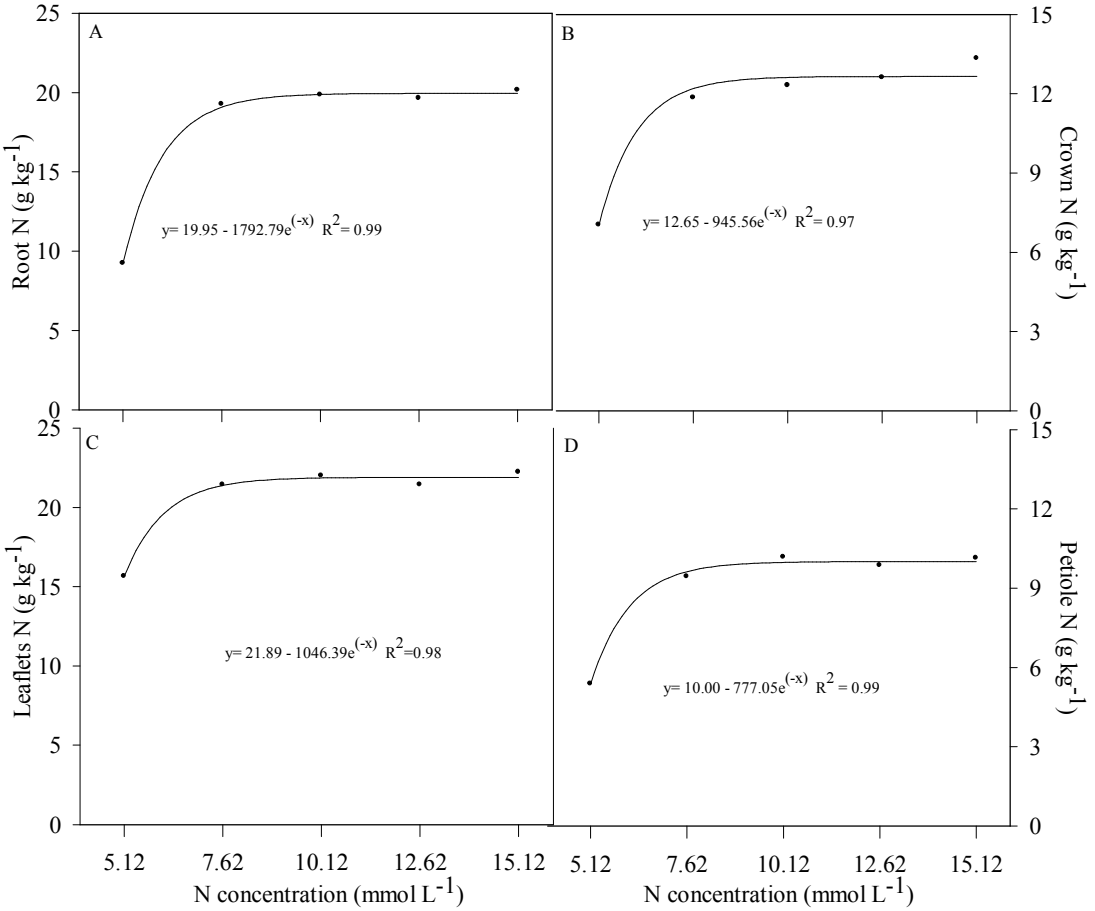

Figure 1. Nitrogen concentration of roots(A), petiole(B), leaflet(C) and crown(D) of strawberry stock plants grown under nitrogen concentrations from 5.12 to 15.12 mmol L^{-1} in the nutrient.

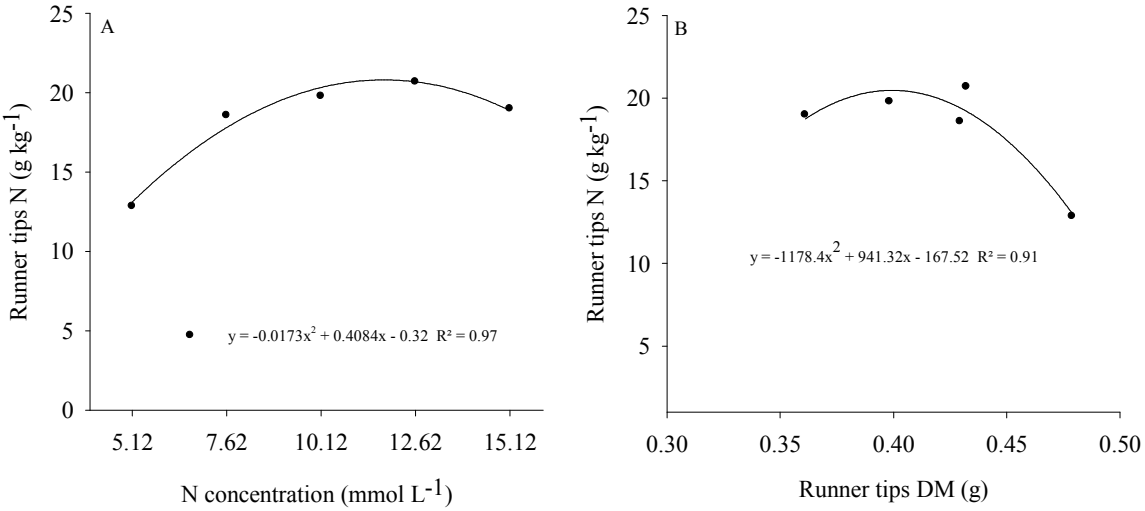

Figure 2. Nitrogen concentration of strawberry runner tips of strawberry stock plants grown under nitrogen concentrations from 5.12 to 15.12 mmol L^{-1} in the nutrient solution (A) and relation between dry matter and nitrogen concentration of runner tips (B).

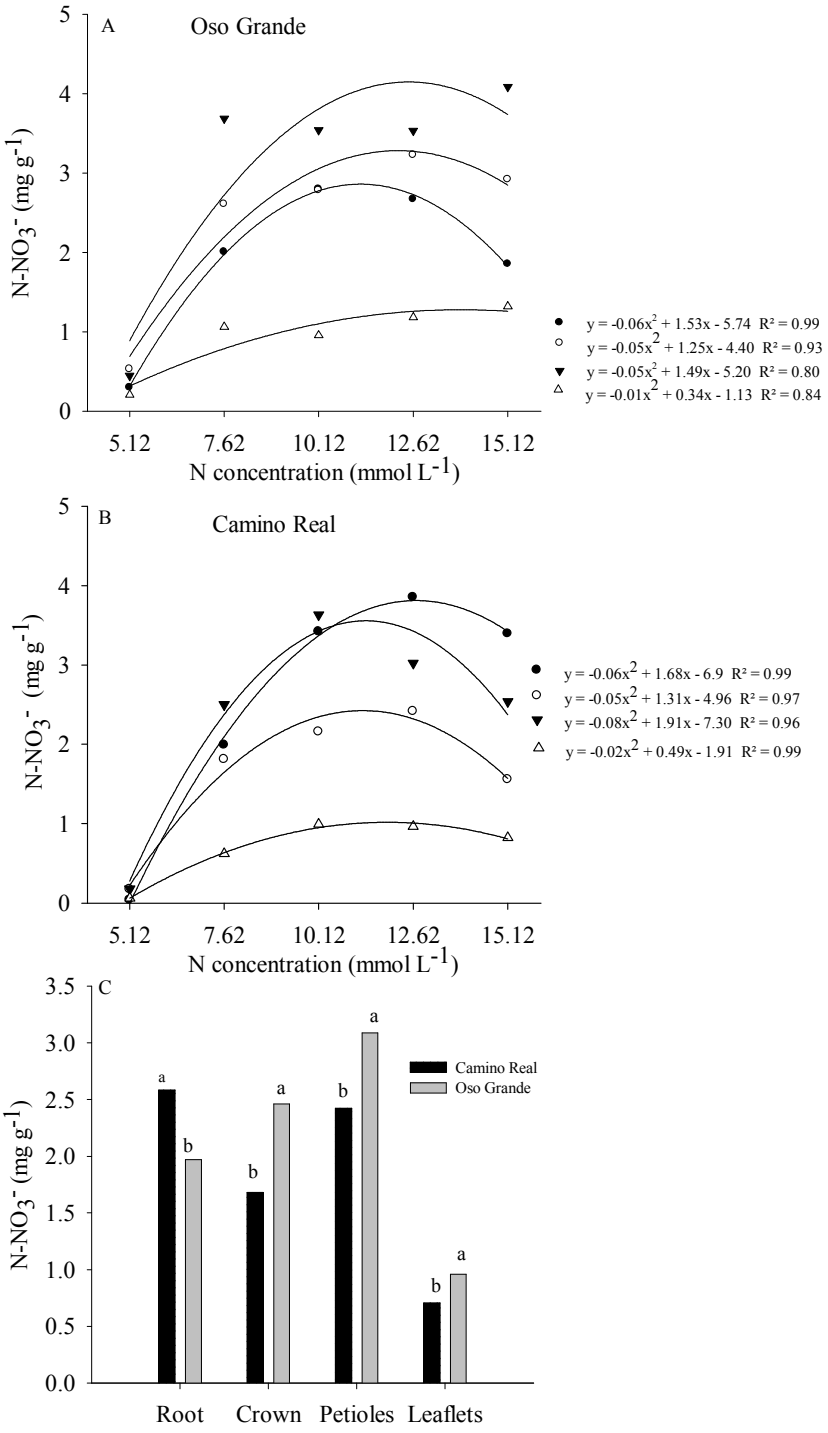

Figure 3. N-NO_3^- concentration at organs of Oso Grande (A) and Camino Real (B) strawberry stock plants grown under nitrogen concentrations from 5.12 to 15.12 mmol L^{-1} in the nutrient solution and average of nitrate concentration in organs of both cultivars (C). Means followed by the same letters do not differ by the F test, at 5% probability. Δ leaflets, ▼petioles, ○ crown, ● root.

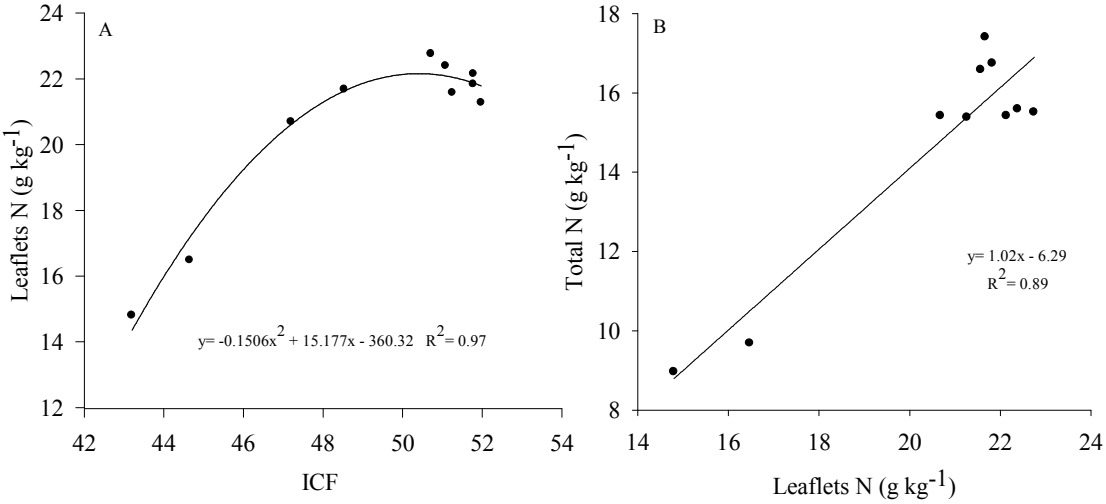

Figure 4. Relationship between Chlorophyll Index (ICF) and N concentration in leaflets of the whole plant (A) and between N concentration in leaflets of the whole plant and total N concentration of strawberry plant (B) grown under nitrogen concentrations from 5.12 to 15.12 mmol L^{-1} in the nutrient solution.

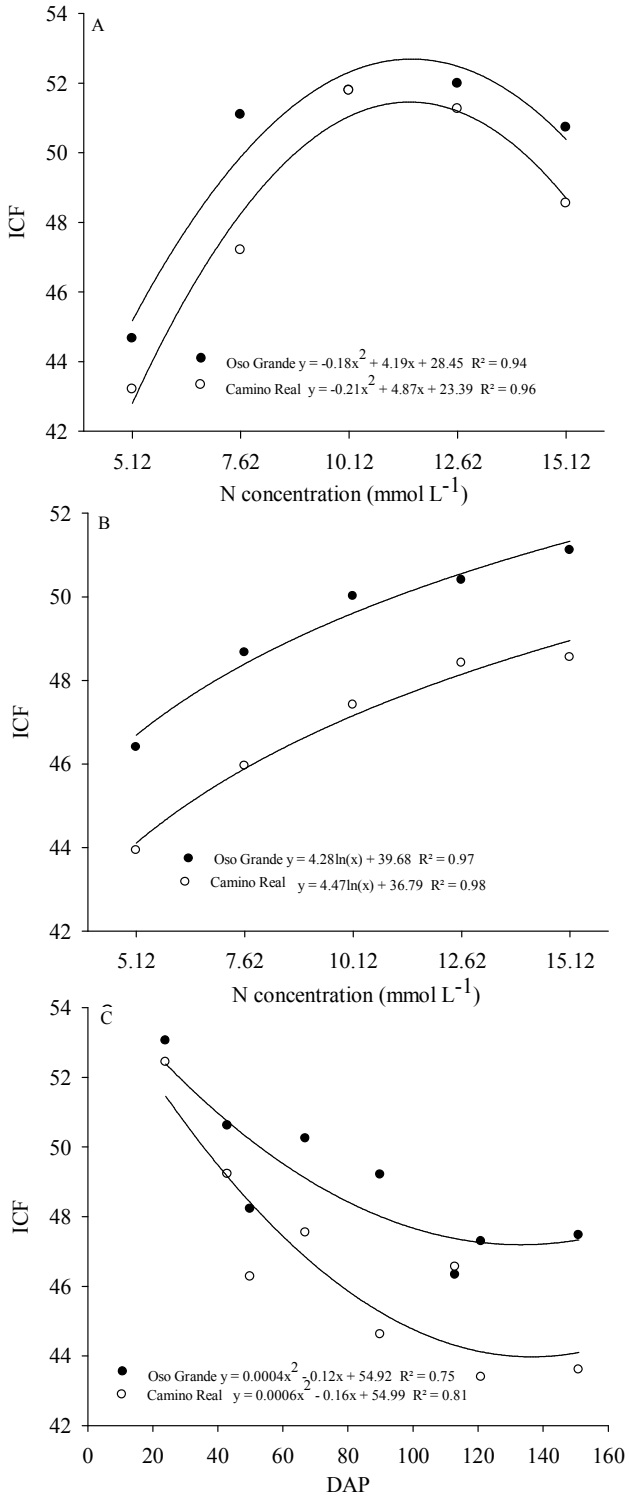

Figure 5. Chlorophyll Index (ICF) of the last second full expanded leaf of Camino Real and Oso Grande strawberry stock plants grown under nitrogen concentrations from 5.12 to 15.12 mmol L^{-1} in the nutrient solution at ending of experiment (A), average of all the experiment period (B) and during the experiment period (C).

DISCUSSÃO

Os resultados deste trabalho indicam que o morango é pouco exigente em N na fase de propagação. Sendo o segundo nutriente mais absorvido (HENNION e VESCHAMBRE, 1997), é possível inferir que a resposta aos demais nutrientes seja similar, contrariando o procedimento comum de empregar altas doses de fertilizantes. Assim, soluções nutritivas pouco concentradas podem ser empregadas. Esta redução na utilização de fertilizantes traz benefícios ambientais e econômicos. A redução da quantidade de nutrientes lixiviados do sistema evita a salinização do solo e a contaminação do lençol freático. A redução de fertilizantes implica também em menor custo de produção.

A baixa resposta ao N nesta fase permite a utilização de sistemas simplificados sem prejuízo na produtividade. O manejo da solução nutritiva torna-se mais simples, podendo ser testado o emprego de fertilizantes de solubilização lenta no plantio. Substratos orgânicos e fertirrigação descontínua podem ser empregados, em sistemas simples, econômicos e de fácil manejo, acessíveis a produtores com baixa formação tecnológica. A possibilidade de simplificação no manejo nutricional é também uma alternativa para produção orgânica, na qual as mudas são atualmente o maior entrave. A IN 64-2008 (MAPA) que regulamenta o Sistema Orgânico de produção prevê que a partir de 2013 as mudas utilizadas na produção orgânica de frutas sejam produzidas também de forma orgânica. Até o momento, estas lavouras são implantadas em sua maioria a partir das mudas importadas em função da indisponibilidade de mudas nacionais adequadas e de qualidade. A baixa resposta do morangueiro ao N possibilita a manutenção das matrizes em recipientes contendo substrato orgânico, permitindo a adição de fertilizantes orgânicos ou organominerais. A utilização do sistema fechado, com recirculação da água e nutrientes contribui com a sustentabilidade do sistema. A produção pode ainda ser realizada em ambiente protegido. Este ambiente reduz o efeito da chuva na lixiviação de nutrientes, permite o controle da temperatura e umidade, diminuindo a incidência de pragas e doenças e em conseqüência melhorando a qualidade sanitária das mudas. Com este intuito, trabalho realizado por Paranjpe et al., (2004) no EUA mostra ser realmente possível a produção orgânica de mudas. No entanto trabalhos precisam ser desenvolvidos em âmbito local para avaliação de substratos e sistemas de fertilização.

Indicam também que a produção descentralizada de mudas pode ser possível. Mesmo que haja efeito da vernalização sobre as mudas produzidas em altitude, esse efeito poderia ser compensado pelas vantagens das mudas com torrão de alta qualidade e disponíveis na época

correta para cada produtor, uma vez que a produção de pontas de estolões é alta. Isso vem ocorrendo no Vale do Caí. Produtores já utilizam por conta própria o que eles denominam "mudas puxadas". A partir dos estolões emitidos pelas plantas conduzidas em substrato após a frutificação, formam as mudas em pequenos copos plásticos – tipo café – para renovação e ampliação da lavoura, obtendo economia e precocidade na produção (ILHA e GADEA, 2011). Coletar pontas em plantas após a produção de frutas pode trazer implicações negativas na sanidade e manutenção das características de distinguibilidades, homogeneidade e estabilidade do cultivar. No entanto esta atitude dos produtores mostra que a tecnologia de produção de mudas em torrão é promissora no Estado, inclusive na região considerada pelo Zoneamento inapta para produção de mudas. As pesquisas para o aperfeiçoamento deste sistema de produção, como nutrição e manejo das matrizes, são importantes para o desenvolvimento de uma tecnologia acessível e eficiente.

A aquisição de matrizes com qualidade genética comprovada, o cultivo destas fora do solo, e a produção de mudas com torrão permite uma maior produtividade de mudas por área e a possibilidade de utilização de áreas impróprias. Isso se torna vantajoso principalmente se considerarmos que a cultura do morangueiro é característica de pequenas propriedades, as quais apresentam limitação de espaço e a rotação de área para minimizar a contaminação não é possível. Além disso, o custo inicial das matrizes pode ser amortizado utilizando-se os primeiros estolões emitidos para formação de novas matrizes (DAL PICIO et al., 2012 no prelo) e ao final do período, utilizá-las para produção de frutas (DAL PICIO et al., dados não publicados).

Produzir no Brasil mudas de morangueiro com qualidade e economia permitiria aumentar a área cultivada e a produtividade, estimular a produção em escala familiar, a agroindústria, a produção orgânica, com benefícios sociais diretos e indiretos. Diretos na renda do setor agrícola e geração de empregos. Indiretos na qualidade de vida e saúde da população, que atualmente encontra os morangos disponíveis nos supermercados no topo da lista dos produtos com maior resíduos de agrotóxicos, o que em contrapartida reduz o consumo da fruta (ANVISA, 2011).

CONCLUSÕES

Soluções nutritivas pouco concentradas em N, em torno de 5,12 mmol L^{-1}, podem ser empregadas no cultivo fora do solo de plantas matrizes para produção de pontas de estolão de morangueiro. O ajuste do fornecimento desse nutriente durante o período de crescimento e desenvolvimento propagativo da planta pode ser feito através da determinação indireta da clorofila por medidor portátil na penúltima folha expandida.

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