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Bibliographic Review

Nitrogen fertilization characteristics in fertirrigated tomato and Sweet pepper crops

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Abstract

The fertirrigation is characterized by the fertilizers application via irrigation, thus, these are applied directly on the wet bulb of the soil, avoiding great losses. The nitrogen occupies a prominent position, regarding both the quantity required and the problems of nitrate leaching, volatilization and deficit. The objective of this revision was to describe the main characteristics associated to the nitrogen management in areas of tomato and sweet pepper cultivation in fertirrigated systems. The fertirrigation use has shown to be a technically viable alternative to increase yield, for both tomato and sweet pepper. Although, there is the need to adequate the doses and sources, aiming to decrease the losses of nitrogen, especially in the form of nitrate, being important to consider improvements in the methods of application, dosages, sources, characteristic periods of greater demand of the crops, besides of its interaction with other elements. The amount of fertilizers applied still is widely variable, in function of the difficulty of nutrients need adjustment according with different stages of crops development in different regions and seasons of the year, what justifies both the need for new researches and the dissemination of information, so these may have the possibility of being used by the producers in order to adjust the best cost benefit, aiming economic and environmental gains.

Keywords: *Capsicum annuum* L.; fertirrigation;; *Lycopersicon esculentum* Mill; nitrogen.

Características da adubação nitrogenada por fertirrigação na cultura do tomate e pimentão

Resumo

A fertirrigação é caracterizada pela aplicação de fertilizantes via irrigação, sendo assim estes são aplicados diretamente no bulbo úmido do solo, evitando maiores perdas. O nitrogênio ocupa uma posição de destaque, no que diz respeito tanto a quantidade requerida, como também, aos problemas de lixiviação de nitratos, volatilização e deficiência. O objetivo desta revisão foi descrever as principais características associadas ao manejo de nitrogênio em áreas de cultivos de tomate e pimentão em sistemas fertirrigados. A utilização da fertirrigação tem demonstrado ser uma alternativa tecnicamente viável para a elevação do rendimento tanto em tomate como em pimentão, havendo a necessidade de adequações de doses e fontes visando diminuir as perdas de nitrogênio especialmente na forma de nitrato, sendo importante considerar um aprimoramento nos métodos de aplicação, dosagens, fontes, períodos característicos de maior exigência das culturas, além de sua interação com outros elementos. A quantidade de fertilizantes aplicada mostra-se ainda amplamente variável em função da dificuldade de ajuste da necessidade de nutrientes de acordo com as diferentes fases de desenvolvimento das culturas e nas diferentes regiões e épocas do ano, o que justifica a necessidade tanto de novas pesquisas quanto da difusão de informações para que estas tenham possibilidade de adoção pelos produtores a fim de ajustar o melhor custo benefício com vistas a ganhos econômicos e ambientais.

Palavras-chave: *Capsicum annuum* L.; fertirrigação; *Lycopersicon esculentum* Mill; nitrogênio.

Características de la fertilización nitrogenada por fertirriego en cultivos de tomate y pimiento

Resumen

El fertirriego se caracteriza por la aplicación de fertilizantes a través del agua de riego, por lo que estos se aplican directamente al bulbo húmedo en el suelo, evitando pérdidas expresivas. El nitrógeno ocupa una posición destacada en relación tanto

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a la cantidad requerida, sino también a la deficiencia y los problemas de lixiviación de nitratos, volatilización y otras perdidas. El objetivo de esta revisión es describir las principales características asociadas con la gestión del nitrógeno en zonas de cultivo de tomates y pimientos en sistemas de fertirriego. El uso de fertirriego ha demostrado ser una alternativa técnicamente viable para elevar el rendimiento tanto de tomate como de pimiento, por lo que requiere ajustes a las tasas y fuentes para disminuir las pérdidas de nitrógeno, en particular en forma de nitrato, siendo importante considerar una mejora en métodos de aplicación, las dosis, fuentes, periodos característicos de una mayor demanda por los cultivos, además de su interacción con otros elementos. La cantidad de fertilizante aplicado se muestra todavía ampliamente variable en función de la dificultad de ajustar las necesidades de nutrientes de acuerdo a las diferentes etapas de desarrollo del cultivo y en las diferentes regiones y épocas. Así se justifica la necesidad tanto de nuevas investigaciones como de la difusión de información para que se tenga la posibilidad de adopción por parte de los productores para ajustar el mejor valor con miras a beneficios económicos y ambientales.

Palabras clave: *Capsicum annuum* L.; fertirriego; *Lycopersicon esculentum* Mill; Nitrógeno

Introduction

The fertirrigation is characterized by the application of fertilizers through irrigation, thus providing lesser losses of nutrients on the soil (GENUNCIO et al., 2010). According to FERNANDES et al. (2002), this allows to keep the availability of water and nutrients close to the values for the development and production of agricultural crops, in this sense the doses must be adjusted to the crops need during the phonological cycle of the same.

The fertirrigation is a technique which grants the application of water and nutrients directly in the moist bulb, being this local where are found the greater volumes of absorbent roots of the plants, improving the efficacy of water and fertilizers usage. If this resource is used correctly, respecting the time demand and quantities of water and nutrients for each phonological stage, occurs improvements both in the yield and quality of the produced fruits (QUESADA-ROLDÁN and BERTSCH-HERNÁNDEZ, 2012).

FERREIRA et al. (2006) highlights the nitrogen (N) as having an important role in biosynthesis of sugars on the leaves, which can be translocated to the fruits, increasing the concentration of soluble solids. With the development of the fertirrigation, began to emerge on the market a wide range of fertilizers for this practice, in function of solubility or purity degree (SUZUKI et al., 2010).

The nitrogen occupies a prominent position among the other nutrients, regarding both the quantity required and the problems of nitrate leaching, volatilization and deficit. This is one of the elements of greater presence in chemical fertilization, applied in areas of intensive agriculture, such as the fertirrigated systems, therefore, greater the application of this element on the soil, greater the generation of nitrate (NO_3), which presents an elevated potential of soil and water pollution through leaching (JADOSKI et al., 2010).

Among the most used nitrogen fertilizers in fertirrigation are found the nitrates (of potassium, ammonium and calcium), besides of the ammonium sulfate and urea, highlighting that the nitrogen present in these sources can present in the nitric, ammoniacal or amidic form (MAROUELLI and SILVA, 2002).

The aim of this revision was to describe the main characteristics associated to the nitrogen management in areas of cultivation of solanaceous tomato (*Lycopersicon esculentum* Mill.) and sweet pepper (*Capsicum annuum* L.), in fertirrigated systems.

Management of the nitrogen fertilization in tomato and sweet pepper

According to FACTOR et al. (2008), the greenhouse cultivation and the application of products via fertirrigation presents good results, especially regarding the alternatives for cultivations in seasons which are unfavorable for many crops, like the solanaceous, such as the sweet pepper and tomato. In crops which demonstrate a deeper root system DONAGEMMA et al. (2008) verified that when occurs the use of the total dose of nutrients indicated for the crop, applied in installments, in two steps under fertirrigation, especially in the second dose made available, provided deeper roots systems, thus better results.

GRAZIA et al. (2006) studying sweet pepper seedlings with the availability of nitrogen under fertirrigation, obtained favorable results for the crop, such as the improvement in water retention, ionic exchanges, yield elevation and in the precocity.

Water and nutrients are also factors that

tend to affect more the tomato yield, this fact generates the need of a efficient control of the soil moisture and mineral nutrition, in order to obtain a agricultural production with elevated quality and yield (MACEDO and ALVARENGA, 2005). As stated by DOOREMBOS and KASSAM (1994), the tomato stands out among other vegetables, due to its high efficiency in water usage, being this of an average of 11 kg m^{-3}, which provides yields of up to 10 kg per plant, when adequately irrigated.

According to HERNÁNDEZ et al. (2008) to produce a ton of tomato fruits are necessary 32.7 kg of nitrogen, 4.2 kg of phosphorus, 57.8 kg of potassium, 36.3 kg of calcium and 4.4 kg of magnesium. CHAILLOUX (2003) states that the doses of mineral nutrients made in greenhouse cultivation are superior to the one used in open field, due the obtaining of higher yields, according to this author these doses may vary from 275 to 750 kg ha^{-1} of N, 120 to 400 kg ha^{-1} of P_2O_5 and 430 to 1.200 kg ha^{-1} of K_2O.

ANDRIOLO et al. (2004) emphasizes that in order to reduce the risk of nitrogen deficit in the tomato crop, were fixated high quantities in the solution, being these in up to 20 mmol N L^{-1}, this increase in the concentration can present negative consequences, such as contamination of water catchments through the nitrate leaching.

ARMENTA-BORJÓRQUEZ et al. (2001) highlights that elevated rates of N application and doses in certain circumstances may not be harmful to the tomato yield and quality. However, directly affect the production costs, being a waste of fertilizers and source of contamination of soils and aquifers. Yet, IMAS et al. (1997) state that the adequate use of nitrogen sources is important, because the incorrect use of the relations $N\text{-}NH_4/N\text{-}NO_3$ can cause nutritional problems in plants, due to the stimulus of formation and exudation of organic acids by the roots, being that these acids, if produced without a correct balance, may affect the solubility of metals and the absorption of phosphorus by the plants.

BUGARÍN-MONTOYA et al. (2011), analyzing the concentration percentage for the accumulation of nitrogen in function of time, for the plants of sweetpepper and tomato, found results proving that the nitrogen concentration decreases during the plants growth. For the tomato, it was measured a total of accumulated dry matter in 49.2%, a maximum rate of nitrogen absorption of 4.4 kg ha^{-1} per day, an extraction of 276.8 kg ha^{-1} and a yield of 6.88 kg per plant. For the sweet pepper, the maximum rate of nitrogen absorption kept at 5.3 kg ha^{-1} per day, the extraction was of 321.9 kg ha^{-1} and the obtained maximum yield was of 3.93 kg, demonstrating to be superior.

The ideal amount of nitrogen to be applied is of fundamental importance, SCHRÖDER et al. (2000) showed that excesses or deficits must be estimated to avoid unnecessary expanses with the crop and environmental problems. For this to occur, it is necessary the use of a good indicator for the demonstration of this balance of application.

Studying the efficiency of the methods or programs of fertirrigation, being these, treatment of literature, treatment of absorption curves and treatment of fertirrigation adjustment, QUESADA-ROLDÁN and BERTSCH-HERNÁNDEZ (2012) showed that there was no influence of the type of method used on the commercial yield of tomato, however, occurred differences when were characterized different hybrids, probably due to existing morphophysiological differences between them.

In the potassium and nitrogen application, through located irrigation system, OLIVEIRA and BÔAS (2008) did not observe significant variations for the distribution and uniformity of these elements, their studies also demonstrate that a more delayed application, with the system operating for longer, makes the fertilizer applications better distributed and uniform, increasing its efficiency when allied to well calculated and accurate washing time.

GODOY et al. (2003), in studies done with the sweet pepper crop, using nitrogen fertilization estimated by the nitrogen sufficiency index (NSI) and measurement through chlorophilometer, obtained results which shows that this method is efficient when there is the search for indications for the application or availability of N in the plants with doses adjusted to the plant needs, thus obtaining a greater efficacy of use by the plant.

When searching for a simple model for obtaining absorption curves of macro and micronutrients of the bell pepper aerial part, FONTES et al. (2005) estimated the nitrogen and potassium doses for the fertirrigation in greenhouse, verifying that the corrected (CD) and estimated doses (ED) for nitrogen would be respectively 308 and 190 kg ha^{-1}, they also observed that a good application grants greater yield and quality for the crop fruits.

SILVA et al. (2001), studying the nutritional behavior of bell pepper plants submitted to

application of N and K through drip irrigation, obtained that N (dose of 26.6 g m^{-2}) raised the shoots nutrients concentration, not affecting the flowering and the early fruiting, however did not show increase in fruits yield. SANTOS et al. (2003) also reports in their researches the non obtaining of yield increase of bell pepper crop with the application of nitrogen and potassium fertilizer, highlighting the need of more specific studies for the crop, its nutritional needs and more adequate doses for the application, in order to avoid contaminations.

Similar results are found by CAMPOS et al. (2008), who demonstrated in studies with nitrogen application in fertirrigated bell pepper that the crop responded positively with 2.64 kg of fruits per plant, having adequate size for the market, in the estimated dose of 221 kg ha^{-1} of nitrogen. BÁEZ et al. (2002) analyzing the bell pepper crop under fertirrigated system, verified that the maximum fruit quality was obtained with the application of 435 kg ha^{-1} of nitrogen, while that the maximum yield was obtained with the application of 342 kg ha^{-1} of N.

According to ARAÚJO et al. (2009a) the highest doses of N negatively influence in the bell pepper fruits length, thus obtaining smaller fruits, yet occurs increase in diameter, average weight and number of these fruits. As stated by the same authors, the maximum number of fruits occurred with the dose of 182.5 kg ha^{-1} of N, already considering the commercial characteristics, the number of fruits of better categories was obtained with the dose of 400 kg ha^{-1} of N, being that the control which did not receive N presented 200% lesser in numbers, with a total of 5.5 fruits per plant.

MARCUSSI et al. (2004a), studying an accumulation curve of N and K in fertirrigated bell pepper plants in greenhouse, determined that the doses applied above 50% of the already measured by the accumulation curve, presented greater fruits yield, being this considered a good method for fertirrigation determination, provided it has been calibrated respecting the temperature and other climatic factors.

According to MEDINA et al. (2010), the N dose to be applied must be increased in 63%, decreased by half for P and kept for K, having as base a total of 130-120-160 kg ha^{-1} for NPK, respectively. To INZUNZA-IBARRA et al. (2010) the greater concentration of nitrogen in grams per plant occurred under plastic cover (mulching) with availability of irrigation of 83 cm of water.

To ACUÑA et al. (2005), positive effects in the sweet pepper crop with drip irrigation were obtained with the application of superficial N, generating an increment of 68.8% in yield, showing a fruit recovery efficacy of 193 kg per N kg, that is, an increase of 73.6% just with the application of N. BOWEN and FREY (2002) assessing dry matter and yield in bell pepper crops under staking with fertirrigation by dripping, observed that the thickness of the pericarp and the fruits size were increased when with the application of a dose of 63 kg ha^{-1} of N via fertirrigation.

When comparing absorptions of nutrients through fertirrigation in sweet pepper plants, with the real nutritional need of the crop, MARCUSSI et al. (2004b) visualized that the crop greater extraction was between the 120 and 140 days after transplantation, correlating positively these values with the greater accumulation of dry matter. It was also verified that K was the most absorbed nutrient between the 60 and 100 days after the transplantation, while N, Ca and S are required in higher degree at the end of the cycle.

Assessing the sweet pepper crop under application of nitrogen fertirrigation, QAWASAMI et al. (2008) determined that N use through fertirrigation favors the plant, increasing its absorption of phosphorus and potassium synergistically to the nitrogen, also showing that with a dose of 150 kg ha^{-1} was obtained the better crop yield, with greater demand peak by the crop estimated at the 90 and 150 days after the planting.

When considering the doses applied via fertirrigation in tomato crop, are characterized four or five different stages of crop development, being that, generally the greater doses of phosphate fertilization are made on the first stage, being decreased in the second stage and then not varying on the others. However, the nitrogen, potassium, calcium and magnesium application tends to be disregarded on the first stage, yet, they start on the second, increasing the doses gradually until the end of the crop cycle, as can be observed in studies done by DIAZ et al. (2009) and HERNANDEZ et al. (2008).

HEBBAR et al. (2004) analyzing nitrogen, phosphorus and potassium together, observed that sources 100% soluble in water increased the production in 10%, in relation to fertilizers partially soluble. As for the N sources, SILVA et al. (2003) did not observed negative effect on the yield and quality of tomato, on the other hand, the used sources demonstrated to alter the soil chemical characteristics.

In relation to the nutrients necessary in the fertirrigation for tomato crop, the nitrogen (N) is one of the elements which stands out in this production system, being characterized both for the availability sources as for the amount demanded by the plant, being considered satisfactory doses of 2.0 to 2.5 g of N for each kilogram of fruits obtained (SCAIFE and BAR-YOSEF, 1995).

The application of high quantities of nitrogen fertilization without the knowledge of the provision capacity of the soil and of the period of greater demand of the tomato plant, leads to decrease of efficiency of the same, which for the tomato plants crop generally do not exceeds 50%, such fact generates a substantial increase of mineral N that remains on the soil and of nitrate content that is lost by leaching (ARAÚJO et al., 2009b).

When studying the different nitrogen doses effect on the tomato crop, ROMERO et al. (2009) verified that the variables total yield of the fruits and quality after harvest characterized by firmness, Brix and weight loss, did not suffer negative influence of the dose of 250 kg ha^{-1} when compared to the dose of 450 kg ha^{-1} of N.

According to ANDRIOLO et al. (2004), it was not found difference between increasing doses on the tomato plant yield. However, during autumn, the used N concentration could be reduced on the final stages of the crop cycle, while that, during spring, due to a greater growth on this development stage, was verified an increase in the deficit and leaching of N, in function of the greater water demand of the crop during this time of the year.

The establishment of adequate N K relations by cultivation stage is also important for the tomato crop, being directly linked to problems that affect the crop yield behavior, because this relation determines the balance between the vegetative and reproductive processes, due to the potassium act as regulator of growth in conditions of high nitrogen availability, creating a barrier to physiological disorders which may affect the fruits, directly acting on the durability during the harvest and after harvest (ARMENTA-BORJÓRQUEZ et al., 2001).

GENUNCIO et al. (2010) found results which evidenced that there is no significant difference between the proportions 1:2 and 1:3 of N:K on the commercial and non commercial tomato fruits yield, besides the average weight and fruits diameter, pH, total titratable acidity and content of soluble solids of the fruits. Yet, the proportion 1:3 stimulated the vegetative growth of the tomato plants more significantly.

According to HERNANDEZ et al. (2009) the use of a relation N:K of 1:2 in tomato protected cultivation with fertirrigation is sufficient, generating adequate yield and quality during the period spring-summer, which is characterized by and increment of the respiration and transpiration of the plants due to higher temperatures, while in periods such as the winter, the relation must be wider, around 1:2.5.

As for the N:K relation found in the foliar analysis of the tomato plant, DÍAZ et al. (2009) verified that the best results of endocarp firmness and texture are found in a N:K foliar relation of 1:0.75, while the concentrations of 1:0.45 and 1:0.9 led to superior percentages of fruits with irregular shape. The relation 1:0.75 also resulted in smaller rates of fruits in better commercial categories, due to the higher average mass of these.

ROMERO et al. (2002) highlight that the producers tend to use elevated nitrogen doses via fertirrigation during the tomato plant cycle, besides of preferentially adhere to nitric sources. These authors confirmed that doses of 250 kg ha^{-1} in a proportion of 75% NH_4/25% NO_3 are so efficient in yield and post harvest quality as doses of 450 kg ha^{-1} with 25% NH_4/75% NO_3 commonly used by most of the producers, being that, these different proportions do not present negative results as for the calcium and potassium doses related to these sources.

The use of different sources of nitrogen fertilization in industrial and table tomato presented results, that according to SILVA et al. (2003), demonstrates that there is no different in terms of production between the different sources, however, they observed that as higher the ammonium and urea concentration in the total N, smaller was the pH and greater the aluminum concentration on the soil, being that his factor can compromise the production in subsequent cultivations.

The use of ammonium and urea through fertirrigation in substitution to nitrate during the tomato fruits development presents good efficiency, demonstrating that is possible to reduce the nitrate use, emphasizing that these last caused a greater production cost in relation to the other sources of N, thus implying in a reduction of subterraneous and superficial aquifers contamination (ROMERO et al., 2009).

SOUZA et al. (2010) verified the effect of Swine Wastewater after Filtration (SWF) as source of

nutrients via fertirrigation, these observed that there was increase in the tomato fruits yield, in response to the nitrogen increment via SWF, they also state that possibly the sugars produced in the leaves have been designed to the increase in mass and number of fruits per plant.

According to SUZUKI et al. (2010) it was not observed significant differences between the sources, on the tomato total yield, emphasizing that all tested sources of mineral fertilization met the crop needs. These results, according to the authors, allow choosing sources according to the easiness of preparation and application via fertirrigation, or still, through the unitary cost of each applied nutrient.

Conclusions

The use of fertirrigation has been proved to be an alternative technically viable for the yield increase, both for tomato and sweet pepper. The adequacy of the provision of nitrogen fertilization has shown to be necessary, both when aiming agronomic questions related to crop yield, as for environmental preservation, being important to consider improvements in the application methods, dosages, sources, characteristic periods of greater demand of the crops, besides of the interaction with other elements. There is the need of aiming the reduction in losses of nitrogen for the environment, in special regarding the leaching in the form of nitrates, which present high potential of soil contamination, as well as for the superficial and subterraneous waters.

In the actual conditions of cultivation, the amount of fertilizers applied still is widely variable, in function of the difficulty of adjustment of need of nutrients according to the different stages of crops development and in the different regions and seasons of the year, what justifies both the need for new researches as for diffusion of information, so that this can be used by the producers in order to adjust the better cost benefit aiming economic and environmental gains.

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