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Fertilizer containing nitrification inhibitor in tomato cultivation for industrial processing

Fertilizante contendo inibidor de nitrificação em cultivo de tomate para processamento industrial

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Abstract

An alternative to increase the N use efficiency may be to control its availability in order to mitigate losses and provide it throughout the crop cycle. In this context, the use of fertilizers with inhibitors of nitrification or urea hydrolysis is highlighted. Thus, the objective was to evaluate the use of controlled-release and stabilized fertilizers in total or partial substitution of conventional fertilization in the industrial tomato crop. The experiment was carried out under field conditions, in an area irrigated by central pivot, in a Red Dystrophic Latosol. The experimental design was a randomized block with seven treatments and five replicates. Where the (*) amount of NPK fertilizer in t ha^{-1} consisted of: 1. NSF - natural soil fertility; 2. PGM - planting with granule mixture (1.5*) + urea coverage (0.12*) and potassium chloride (KCl) (0.3*) + absence of foliar application; 3. Fertilizer with nitrification inhibitor (DMPP) 0.3 - PGM (1.0*) + coverage with DMPP (0.3*) and KCl (0.42*) + foliar application; 4. DMPP 0.25 - PGM (1.0*) + coverage with DMPP (0.25*) and KCl (0.3*) + foliar application; 5. DMPP 0.15 - PGM (0.9*) + coverage with DMPP (0.15*) and KCl (0.2*) + foliar application; 6. DMPP 0.05 - PGM (0.6*) + coverage with DMPP (0.05*) and KCl (0.1*) + foliar application; 7. DMPP 0.7 - planting with NPK with DMPP (0.7*) + absence of foliar application. The use of fertilizers with nitrification inhibitor (DMPP) does not increase fruit yield and quality in relation to the use of conventional fertilizers (PGM), but may be an alternative in the cultivation of industrial tomatoes.

Additional keywords: foliar analysis; soil analysis; *Solanum lycopersicum* L.; yield.

Resumo

Uma alternativa para aumentar a eficácia de utilização de N pode ser o controle de sua disponibilidade, de forma a amenizar as perdas e fornecê-lo durante todo o ciclo da cultura. Neste contexto, destaca-se o uso de fertilizantes com inibidores da nitrificação ou da hidrólise da ureia. Assim, objetivou-se avaliar o uso de fertilizantes estabilizados e de liberação gradual em substituição total ou parcial da adubação convencional na cultura do tomate industrial. O ensaio foi realizado em condição de campo, em área irrigada por pivô central, sob Latossolo Vermelho distrófico. O delineamento experimental foi o de blocos casualizados, com sete tratamentos e cinco repetições, em que (*) quantidade de fertilizante NPK em t ha^{-1} consistiram em: 1. FNS – fertilidade natural do solo; 2. PMG – plantio com mistura de grânulos (1,5*) + cobertura com ureia (0,12*) e cloreto de potássio (KCl) (0,3*) + ausência de foliar; 3. Fertilizante com inibidor de nitrificação (DMPP) 0,3 – PMG (1,0*) + cobertura com DMPP (0,3*) e KCl (0,42*) + foliar; 4. DMPP 0,25 – PMG (1,0*) + cobertura com DMPP (0,25*) e KCl (0,3*) + + foliar; 5. DMPP 0,15 – PMG (0,9*) + cobertura com DMPP (0,15*) e KCl (0,2*) + foliar; 6. DMPP 0,05 – PMG (0,6*) + cobertura com DMPP (0,05*) e KCl (0,1*) + foliar; 7. DMPP 0,7 – plantio com NPK com DMPP (0,7*) + + ausência de foliar. O uso de fertilizantes com inibidor de nitrificação (DMPP) não aumenta a produtividade e a qualidade do fruto, em relação ao uso de fertilizante convencional (PMG), mas pode ser uma alternativa no cultivo de tomate industrial.

Palavras-chave adicionais: análise foliar; análise de solo; *Solanum lycopersicum* L.; produtividade.

Introduction

Among the vegetables grown in Brazil, tomato is the most important when considering the socioeconomic aspects that highlight it, mainly, due to the generation of employment and income in all the sectors that compose its respective production chains (Vilela et al., 2012). Specifically, the state of Goiás is responsible for almost 65% of the national production (Silva Júnior et al., 2015).

Highly weathered soils, such as the latosols that occupy a large part of the Brazilian Cerrado, present undesired chemical properties such as high acidity, low natural fertility, low CEC and high P fixation. N is often the most limiting nutrient in agricultural production systems and its addition as fertilizer is commonly required to achieve maximum yields (Watts et al., 2014).

The N management, as well as the technology of the fertilizer employed, has an influence on the efficiency of nitrogen fertilization (Lana et al., 2008). Depending on the climatic conditions, in sandy or medium soils, several N reactions occur in the soil: mineralization, nitrification, denitrification and volatilization. Specifically, nitrification has great relevance, since NO_{3-}, the final product of the reaction, is likely to be lost to groundwater and surface water through leaching and to the atmosphere through the denitrification process, potentiating economic and environmental problems (Pierzynski et al., 2009).

An alternative to increase the N use efficiency may be to control its availability so as to reduce losses and provide N during the whole crop cycle, thus increasing its efficiency in the use of N fertilizer. Another way is to combine fertilizers with chemicals that inhibit nitrification or urea hydrolysis (Abalos et al., 2014; Hu et al., 2014).

The addition of nitrification inhibitors to granular fertilizers may be a solution in various edaphoclimatic situations. Their effectiveness depends on the molecule chosen. The DMPP (3,4-dimethylpyrazole phosphate) molecule may be effective in this process, without phytotoxic effects and with potential to increase crop yield and quality (McCarty, 1999; Pasda et al., 2001, Rocco & Blu, 2006; Abalos et al., 2014; Hu et al., 2014). However, studies are still needed to verify the combination of conventional fertilization at planting associated with this molecule for several crops of economic importance, such as tomato for industrial processing.

In view of the above, the objective was to evaluate the use of controlled-release and stabilized fertilizers in total or partial substitution of conventional fertilization in the industrial tomato crop.

Material and methods

The experiment was conducted under field conditions, in an area (16˚35'48.81" South latitude and 49˚16'41.13" West longitude and an altitude of 729 m) present in the Cerrado, under pivot, from May 28 to October 12. The soil was classified as Red Dystrophic Latosol according to the procedures proposed by Embrapa (2013), with clay, silt and sand content, in the 0-0.2m layer, of 450; 230 and 320 g kg^{-1}, respectively. The main chemical attributes, determined according to Embrapa (2011), are described in Table 1.

Table 1 - Soil chemical attributes of the layer 0-0.2 m before installing the industrial tomato experiment.

O.M.	V	pH	P(Mehlich1)	K	Ca	Mg	CCE	Cu	Fe	Mn	Zn	Al	H + Al
---- (%) ----		$CaCl_2$	--- (mg dm^{-3}) ---		---- ($cmol_c$ dm^{-3}) ----			------ (mg dm^{-3}) ------				($cmol_c$ dm^{-3})	
1.4	57.7	5.1	2.9	91	2.0	1.1	5.8	0.7	22	8.6	1.6	0.0	2.44

O.M. - Organic Matter; V - base saturation; K, P, Cu, Fe, Mn e Zn - Mehlich 1 extractor; Ca, Mg - extration with KCl.

The climate of the region is type Aw, according to the Köppen-Geiger classification, being defined as tropical humid with dry season in the winter. The rainfall and temperatures occurred during the conduction of the experiment are in Figure 1.

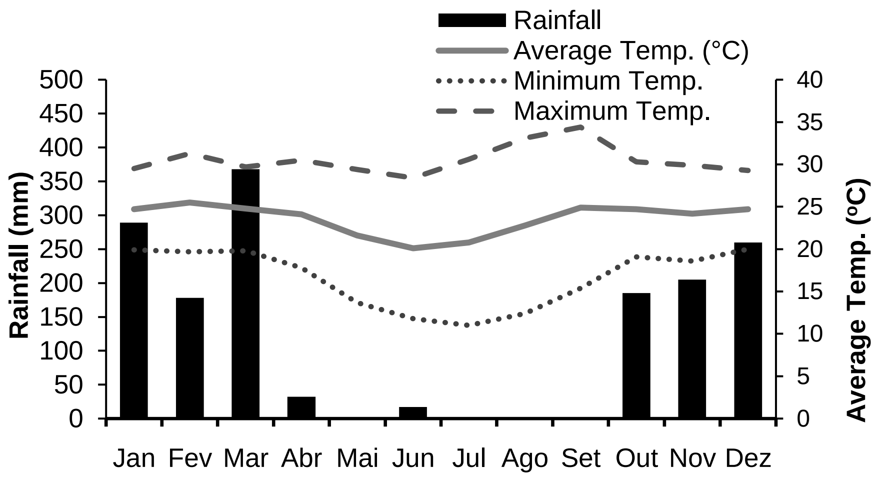

Figure 1 - Rainfall (mm) and average air temperature (°C) occurred during the experiment.

The experimental design was a randomized block with seven treatments and five replicates. Each experimental unit consisted of 5 m in length and 6 m in width. Before the installation of the experiment, plowing was performed with a reversible disc plow at a depth of 20 cm, followed by two harrowings, one with a hinge type offset disc harrow and the other with a leveled harrow. Subsequently, with humid soil, furrowing was performed with 1 m between rows, with subsequent staking of the plots and manual distribution of the fertilizers. There was no liming.

The fertilizers used, partially coated with polymers and stabilized with DMPP, are shown in Table 2. The 2NT technology consists of the combination of granules with Tef-N technology (stabilized nitrogen with 3.4-DMPP nitrification inhibitor) and coated granules, so that 25% of the N is slowly released for three to four weeks.

Table 2 - Products used in the test field with the industrial tomato crop.

Products	N	P	K	Mg	S	Cu	Zn	B	Mn	Mo	Fe
						(%)					
NPK 04-30-16(1)	4	30	16		1,6	-	-	-	-	-	-
NPK with DMPP	15	15	14	2,1	7,0	-	-	-	-	-	-
NPK com DMPP	24	5	5	2,0	5,0	-	-	-	-	-	-
Urea	45	-	-	-	-	-	-	-	-	-	-
KCl	-	-	60	-	-	-	-	-	-	-	-
Foliar 1	20	5	5	1,7	39,0	0,02	0,02	0,01	0,05	0,001	0,05
Foliar 2	7	12	40	2,0	11,0	0,02	0,02	0,01	0,05	0,001	0,05
Foliar 3	13	40	13	0,1	1,0	0,02	0,02	0,01	0,05	0,001	0,05

Density = 1,0 kg m^{-3}; (1) - Mix of the granules.

The applied doses of the products are described according to Table 3, where NSF is the control treatment, without addition of fertilizer source. These doses were determined by virtue of a commercial demand to meet the expectation of the production sector for a possible reduction in the volume of fertilizer applied with the maintenance or increase of the yield average. Table 4 shows the total quantities supplied regarding each nutrient.

Foliar applications were performed between 9:00 a.m. and 11:30 a.m., when the average meteorological parameters were: relative humidity of 70.6%; ambient temperature of 25.3 ºC and winds of 4.2 km h^{-1}. The irrigation system was activated after 48 hours from the application. A CO_2-pressurized backpack precision sprayer was used, coupled to a spray bar with a useful width of 2.5 m, with six flat-jet-type spraying nozzles (XR 110.02), spaced 0.45 m apart. 150 L ha^{-1} of syrup was applied at a pressure of 3.5 bar. In the preparation of the syrup, an adjuvant composed of N and P_2O_5 was used in order to provide stability.

Table 3 - Doses of fertilizers in the industrial tomato crop.

Fertilizers	Application time	Treatments						
		NSF	TMG	DMPP 0.3	DMPP 0.25	DMPP 0.15	DMPP 0.05	DMPP 0.7
		(kg ha^{-1})						
NPK with DMPP	Transplanting	-	-	-	-	-	-	700
NPK 04-30-16	Transplanting	-	1500	1000	1000	900	600	-
NPK with DMPP	Coverage at 10 DAT	-	-	300	250	150	50	-
Urea	Coverage from 20 to 30 DAT	-	120	-	-	-	-	-
KCl	Coverage from 30 to 40 DAT	-	300	420	300	200	100	400
Foliar 1	÷ three foliar applications at vegetative phase (15, 21 and 28 DAT)	-	-	7	10	20	40	-
Foliar 2	÷ three foliar applications at reprodutive phase (42, 48 and 56 DAT)	-	-	10	10	20	40	-
Foliar 3	÷ three foliar applications at vegetative phase (18, 25 and 32 DAT)	-	-	9	10	20	40	-

NSF - Natural soil fertility, without fertilizer addition; TMG - Transplanting with mix of granules

The opening of furrows and manual distribution of the fertilizers were performed at a uniform depth so that there was no direct contact with the roots of the tomato seedlings. The transplanting of seedlings was done manually, with a population of 50,000 plants ha^{-1}. Tomato seedlings of the cultivar Heinz H 9553, previously treated with imidacloprid 700 g kg^{-1}, were used in the ratio of 30 g 100 L^{-1} of water

For the phytosanitary treatment, pre- and post-emergent herbicides were applied for the control of weeds. In the control of pests and diseases, preventive applications were performed with rotation of active principles and mode of action. During the whole experimental period, soil moisture was monitored with a tensiometer and irrigation was performed whenever the field capacity reached 60%.

Tabela 4 - Sum of the quantities of nutrients applied to soil, in the transplanting, leaf, and coverage for industrial tomato culture.

Treatments	N	P	K	Mg	S	Cu	Zn	B	Mn	Mo	Fe
	(kg ha^{-1})										
NSF	-	-	-	-	-	-	-	-	-	-	-
TMG	110.0	450.0	420.0	-	24.0	-	-	-	-	-	-
DMPP 0.3	115.3	320.2	432.5	6.0	34.9	1.56	1.56	0.78	3.9	0.08	3.9
DMPP 0.25	104.0	318.2	358.3	5.4	33.6	1.8	1.8	0.90	4.5	0.09	4.5
DMPP 0.15	80.0	288.9	283.1	3.8	32.1	3.6	3.6	1.80	9.0	0.18	9.0
DMPP 0.05	52.0	205.3	181.7	2.5	32.5	7.2	7.2	3.60	18.0	0.36	18.0
DMPP 0.7	115.0	105.0	345.0	14.7	49.0	-	-	-	-	-	-

NSF - Natural soil fertility, without fertilizer addition; TMG - Transplanting with mix of granules

During soil sampling for chemical analysis, 60 days after fertilization at planting, as recommended by Anghinoni (2007), seven simple samples per plot were collected per depth, with six simple random samples between the rows and one on the planting row. Samples were collected at depths of 0-0.2 m and 0.2-0.4 m, with the aid of a Dutch auger. In the soil samples, the following determinations were made: pH in $CaCl_2$; V%, CEC, m%, available P and K, Ca and Mg, Al, H + Al and organic matter, according to the methodologies of Embrapa (2011).

For foliar diagnosis, thirty leaves without petiole were collected per plot. The fourth leaf from the apex was collected at full flowering and from the first mature fruit, according to Malavolta et al. (1997). These samples were placed in paper bags and taken to the laboratory.

The material was washed with distilled water and placed in paper bags for the oven-drying process with forced ventilation at 60 °C. After reaching a constant dry mass, the leaves were ground and submitted to chemical analysis for determination of the total leaf contents of N, P, K, Ca, Mg, S, Cu, Fe, Mn and Zn (Malavolta et al., 1989).

In the evaluation of the yield of tomato plants, it was decided to concentrate the fruit harvest in two seasons, at 118 and 122 days after transplanting (DAT), to harvest the highest number of mature fruits. All the mature fruits of the central plants of each plot were collected, considering four planting rows of 3 m. The area for determining the yield was 12 m^2 of useful area per plot, discarding the plants located in the rows of the edges of the borders.

During harvest, the fruits were separated into three classes: mature, green and defective. For the quantification of total production, all fruits were counted and weighed according to each established class. From the data obtained at harvest, the yield averages based on mature fruits, suitable for processing, were calculated.

The physicochemical analysis of fruits was performed only at 122 DAT. Total soluble solids, total titratable acidity and pulp yield were determined. The concentration of soluble solids was expressed in degrees brix (ºBrix).

For the determination of soluble solids, the methodology recommended by the Adolfo Luts Institute (Pregnolatto & Pregnolatto, 1985) was used. With these data, pulp yields and total soluble solids (TSS) were calculated using the following equations:

$$PULP = [Yield \times 0.95 \times Brix]/28$$

in which: PULP = Pulp yield (t ha^{-1}); Yield = field-determined yield (Mg ha^{-1}); Brix = laboratory-determined Degree Brix.

$$TSS = [Yield \times Brix]/100$$

in which: TSS = Total Soluble Solids; Yield = field-determined yield (Mg ha^{-1}); Brix= laboratory-determined Degree Brix.

The treatments effect significance was estimated using the F-test (p<0.05). The means were compared using the Tukey test.

Results and discussions

No differences were observed in the soil chemical attributes evaluated in relation to the applied treatments, except for Ca, where there was difference only between treatments DMPP 0.15 and DMPP 0.7, the first being approximately 47% lower than the second (Table 5). This result may be related to the high nutrient extraction by the tomato crop, also described by Fontes (2000) in trials with hybrids. According to the criteria of interpretation proposed by Sousa & Lobato (2004), the average levels obtained in the soil analyses were in the low class for P (4.89 mg dm^{-3}), O.M. (1.34%), Ca (1.22 $cmol_c$ dm^{-3}); in the suitable class for K (92.64 mg dm^{-3}), Mg (0.67 $cmol_c$ dm^{-3}); and when the CEC at pH 7.0 is greater than 4 $cmol_c$ dm^{-3}, it is suitable, however, even with the low values of Ca, no incidence of apical rot was observed.

Tabela 5 - Soil attributes after treatments application in industrial tomato culture.

Treatments	O.M. (%)	pH $CaCl_2$	P	K	Ca	Mg	H + Al	Al	CCE	V	m
			--- (mg dm^{-3}) ---		----------------- ($cmol_c$ dm^3) ---------------					------ (%) ------	
NSF	1.32	5.14	1.55	87.40	1.03 ab	0.74	2.13	0.0	4.12	48.34	0.0
TMG	1.37	5.04	7.81	95.50	1.33 ab	0.81	2.46	0.0	4.84	48.45	0.0
DMPP 0.3	1.30	4.96	4.79	92.00	1.16 ab	0.63	2.65	0.0	4.67	42.49	0.0
DMPP 0.25	1.31	5.07	7.95	98.10	1.39 ab	0.59	2.48	0.0	4.70	47.06	0.0
DMPP 0.15	1.33	5.03	5.51	88.10	0.87 b	0.57	2.57	0.0	4.22	39.75	0.0
DMPP 0.05	1.38	4.99	3.88	90.90	1.13 ab	0.58	2.53	0.0	4.47	41.11	0.0
DMPP 0.7	1.38	5.03	2.72	96.50	1.64 a	0.76	2.78	0.0	4.42	48.71	0.0
					Depth						
0-20 (cm)	1.52	5.02	6.75	95.46	1.41	0.68	2.43	0.0	4.75	47.63	0.0
20-40 (cm)	1.33	5.04	3.04	89.83	1.04	0.66	2.60	0.0	4.52	42.31	0.0
					F test						
Treatments	0.18	1.36	0.87	0.82	2.50	2.05	0.70	-	1.85	2.14	-
Depth	38.0*	0.21	3.60*	2.60	9.21*	0.11	0.94	-	0.86	7.56*	-
CV (%)	17.9	3.1	167.2	15.7	41.6	32.67	30.42	-	21.73	17.97	-

Means followed by different letters in the column differ significantly by the Tukey test (p <0.05).

Similarly to the soil chemical attributes, no differences were observed between treatments for nutrient contents in the foliar analysis, except for Mg content, where the highest foliar contents were observed with the use of NSF, DMPP 0.7 and DMPP 0.3, respectively (Table 6). According to the criteria of interpretation proposed by Fontes (2000), the average values found in the foliar analyses of N (32.5 g kg^{-1}) and K (20.0 g kg^{-1}) were in the range below appropriate; the values of P (3.3 g kg^{-1}), Ca (25.3 g kg^{-1}), Mn (119.0 mg kg^{-1}) and Zn (15.86 mg kg^{-1}) were in the appropriate range; while Mg (9.2 g kg^{-1}), Cu (362.0 mg kg^{-1}) and Fe (261.0 mg kg^{-1}) were classified as high or above the appropriate range.

Table 6 - Industrial tomato foliar nutrient content as function of the treatments.

Treatments	N	P	K	Ca	Mg	Cu	Fe	Mn	Zn
	----------------------- (g kg^{-1}) -----------------------					----------------- (mg kg^{-1}) -----------------			
NSF	32.2	3.10	18.0	28.0	12.00 a	360.5	453.8	115	14.3
TMG	33.1	3.30	21.4	28.0	8.50 b	383.5	358.3	147	13.2
DMPP 0.3	32.7	3.40	19.2	24.2	9.20 ab	354.2	185.8	131	14.2
DMPP 0.25	34.6	3.60	19.7	19.2	8.50 b	332.5	201.0	102	14.1
DMPP 0.15	30.7	4.40	17.6	23.0	8.20 b	316.5	199.5	112	17.1
DMPP 0.05	31.7	3.50	19.9	24.5	8.00 b	328.5	227.0	86	23.6
DMPP 0.7	33.0	3.20	23.7	30.0	10.00 ab	459.2	202.0	141	14.4
F test	0.45	0.62	1.42	2.05	4.32*	1.29	1.57	2.31	0.97
CV (%)	11.18	14.22	17.52	20.23	14.65	23.58	63.38	24.12	46.59

Means followed by different letters in the column differ significantly by the Tukey test (p<0.05).

Although adequate amounts of these elements were applied to the soil, the leaf contents of N and K were deficient. Ferreira et al. (2006) report that mineral nutrients, such as nitrogen, have direct effect on biochemical or physiological processes, with direct consequences to photosynthesis and translocation of photoassimilates. Sung et al. (2015) disclose that nitrogen and potassium deficiencies cause changes in the composition of xylem-translocated substances, mainly aminoacids (glutamine), organic acids (citrate, malate), soluble sugars (glucose, sucrose, fructose). Such modifications have repercussions on the primary and secondary metabolism of tomato plants.

The leaf contents of micronutrients Cu and Fe presented quantities above the range considered adequate by Fontes (2000). In the commercial cultivation of industrial tomatoes, spraying with micronutrients is a common practice for phytosanitary management. This may have caused a greater accumulation of these nutrients in the leaves without providing toxicity to the plants.

Differences were observed between the yields of the industrial tomato plants, obtained as a function of the applied treatments, being the highest indices obtained using conventional fertilization (PGM), DMPP (0.3), DMPP (0.25) and DMPP (0.15), respectively (Table 7). It is observed, with this result, that the tomato crop is highly dependent on fertilization, since in the treatment with natural soil fertility (NSF), there was a reduction of approximately 73% in relation to the best treatments (PGM; DMPP 0.25; DMPP 0.05 and DMPP 0.3). Also, there are no significant differences between the use of mineral fertilizers considered as conventional in relation to the fertilizers containing nitrification inhibitor for the production of industrial tomato, being, therefore, another option for the producer in the aid of the decision making regarding the type and quantity of inputs to be acquired for crop production.

Table 7 - Productivity, ºBrix, pH, pulp yield and soluble solids (SS) of the industrial tomato as function of the treatments.

Treatments	Productivity (kg ha^{-1})	ºBrix	pH	Pulp yield (kg ha^{-1})	SS (°Brix)
NSF	22,280 d	4.42 a	4.47 a	3,299 d	0.98 d
TMG	86,276 a	4.34 a	4.47 a	12,698 a	3.74 a
DMPP 0,3	75,914 abc	4.37 a	4.50 a	11,259 abc	3.32 abc
DMPP 0,25	85,416 ab	4.23 a	4.46 a	12,262 ab	3.61 ab
DMPP 0,15	83,810 ab	4.32 a	4.46 a	12,319 ab	3.62 ab
DMPP 0,05	60,273 bc	4.31 a	4.42 a	8,837 bc	2.60 bc
DMPP 0,7	55,634 c	4.41 a	4.46 a	8,316 c	2.45 c
F test	17.62	0.39	0.49	16.15*	16.15*

* significant at F test ($p < 0.05$); Means followed by different letters in the column differ significantly by the Tukey test ($p < 0.05$).

The results indicate that adequate DMPP ratios are effective in compensating for the decrease of the standard dose of NPK fertilizer (1,500 kg ha^{-1} of 04-30-16). In the treatments DMPP 0.25 and DMPP 0.3, 1000 kg ha^{-1} and 900 kg ha^{-1} of the formula 04-30-16 were used, respectively. Similar results are described by Hu et al. (2014), who emphasize that fertilizers with nitrification inhibitors can reduce costs associated with the conventional fertilization of several crops.

Tomato plants absorb most of the N in the form of ammonium (NH_4^+) or nitrate (NO_3^-) ions (Castro et al., 2005). With the use of fertilizers with advanced technology for the stabilization of N, there is an improvement in the efficiency of nitrogen fertilization and reduction of losses. Consequently, it provides qualitative and quantitative increases in production.

The combination of fertilizers with 3,4-dimethylpyrazole phosphate (DMPP) can provide varied effects in different crops. Soratto et al. (2012) observed productivity gains of 9.6% in maize plants due to the use of Entec®. Liu et al. (2013) report that nitrification inhibitors increase the yield of maize and wheat plants due to greater efficiency in the availability of nitrogen. This also has environmental consequences due to the reduction in N_2O emissions.

High content of DMPP 0.7 caused yield losses, with decreases of 137% in yield compared to conventional fertilization (Table 7). High doses impair microbial activity in soils with different textures (Tindaon et al., 2012). Such an aspect may cause imbalance of other nutrients and, consequently, in the mineral nutrition of plants. In addition, Dong et al. (2013) and Abalos et al. (2014) emphasize that the efficiency of nitrification inhibitors depends on environmental factors (precipitation, temperature), edaphic factors (pH, texture) and factors related to management (non-irrigated, irrigated). Therefore, it is suggested that studies involving the use of nitrification inhibitors be conducted associated to joint observations of edaphic, environmental, management and phytotechnical factors.

The distinct combinations between fertilizers and nitrification inhibitors did not alter the soluble solids content and the pH of tomato fruits (Table 8). These two attributes are fundamental in the processing of fruits aiming the production of tomato products. Most of the genotypes available for the industrial tomato market present soluble solids values ranging from 4.2 to 6.0 °Brix (Melo & Vilela, 2005; Schwarz et al., 2013). Notwithstanding, it should be stressed that the accumulation of soluble solids in fruits is also influenced by environmental and management factors (Chattopadhyay et al., 2013; Iglesias et al., 2015; Sánchez-González et al., 2015).

Giordano et al. (2000) state that the soluble solids content is one of the main characteristics to determine the quality of the raw material, since it conditions the pulp yield of the processed tomato. This attribute is directly related to industrial income. Koetz et al. (2013) describe that some industries use a reward system considering the soluble solids content, hence the higher the average value of ºBrix, the higher the value paid, because the higher the soluble solids content (ºBrix), the higher the industrial yield and the lower the energy expenditure in the pulp concentration process. In practical terms, it is estimated that for each increase of 1 ºBrix in the raw material, there is a 20% increase in the industrial yield (Melo, 2012).

The pH values present in the fruits were found at the appropriate ranges for processing (3.7 - 4.5) (Silva & Giordano, 2000) (Table 8). It is essential that tomato fruits for industrial processing present low pH because this avoids the proliferation of microorganisms and consequently reduces the period of sterilization of raw material (Monteiro et al., 2008).

The pulp and total soluble solids yield were affected by the presence of nitrification inhibitors (Table 8). These variables are directly related to plant yield. Thus, the highest pulp and total soluble solids yields were found in the treatments that provided the highest productivities: conventional fertilization (PGM), DMPP (0.3), DMPP (0.25) and DMPP (0.15)

Conclusions

The use of fertilizers with nitrification inhibitor (DMPP) does not increase the yield nor the quality of industrial tomato fruit in relation to the use of conventional fertilizers (PGM), but it can be an alternative in the cultivation of industrial tomato.

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