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REGULAR ARTICLE

Advances on apple production under semiarid climate: N fertigation

João Marcos de Sousa Miranda[1], Italo Herbert Lucena Cavalcante[2]*, Inez Vilar de Morais Oliveira[3], Paulo Roberto Coelho Lopes[3]

[1]Federal University of Piaui, Campus "Profa. Cinobelina Elvas", Bom Jesus, Piaui, Brazil; [2]Federal University of São Francisco Valley, Campus of Agricultural Sciences, Petrolina, Pernambuco, Brazil; [3]Brazilian Agricultural Research Corporation, Embrapa Semiarido, Petrolina, Pernambuco, Brazil

ABSTRACT

The fertilizing management for apple tree is essential, especially for nitrogen, one of the most important nutrients affecting fruit yield. Thus, an experiment was conducted in 2012 and 2013 to evaluate the fruit production, yield and leaf chlorophyll of 'Princesa' and 'Eva' apples as a function of nitrogen fertigation under Brazilian semiarid conditions. The experimental design consisted of randomised blocks, with treatments distributed in a factorial arrangement 2 x 4, corresponding to apple cultivars (Eva and Princesa); and nitrogen doses (160, 120, 80 and 40 kg of N ha^{-1}), with four replications and three plants. Calcium nitrate was used as nitrogen source (15.5% of N) with applications twice a week during 40 days, reaching 12 fertilizing performances through irrigation water. The following variables were evaluated: i) fruit production per plant (kg $plant^{-1}$); ii) fruit yield (t ha^{-1}); iii) number of fruits per plant; iv) leaf chlorophyll meter readings (index); and v) leaf nitrogen concentration (g kg^{-1}). Princesa apple cultivar if compared to 'Eva' presents a better fruit production performance under Brazilian semiarid. Furthermore, nitrogen doses fertilized through irrigation water have no effect on fruit production of Eva and Princesa apple cultivars during the first production cycle.

Keywords: Fruit production; *Malus domestica*; Yield

INTRODUCTION

Brazil is the third main worldwide producer of apples (Fao, 2014) with more than 42 ton millions produced, nowadays concentrated in regions with warm climate, although the potential for production under different climates.

The apple tree is native to temperate climate zones where most commercial cultivars satisfy their required chilling temperature, expressed as hours at less than 7ºC (Tromp, 2005). Thus, to produce temperate fruit crops, such as apple, in tropical areas it is necessary to overcome plant dormancy and choose low chilling requirement cultivars, such as 'Anna' (Njuguna et al., 2004) and 'Princesa' apples.

This way research projects have been performed aiming to grow apples under different conditions from those required by this crop such as Ashebir et al. (2010) in northern Ethiopia, Njuguna et al. (2004) in Kenya and Liu et al. (2008) in China. In Brazil, apple crop has been studied in São Paulo State Northeast (Chagas et al., 2012) and in Brazilian Semiarid (Lopes et al., 2012; Lopes et al., 2013; Oliveira et al., 2013). Such publications concluded that it is possible to obtain apple yield under semiarid conditions for the pollinator cultivar, although, additional studies especially for technical and fertilizing management are necessary to generate an apple production system that is reliable under semiarid conditions.

The fertilizing management for apple tree is essential, especially for nitrogen, one of the most important mineral nutrient affecting fruit yield and the red coloration in apples (De Angelis et al., 2011). Specifically for apples N is the nutrient with a particularly strong negative impact on the yield and fruit quality, especially regarding to the fruit flesh firmness, delayed degradation of chlorophylls in the epidermis and soluble solids content (Sadar et al., 2013). In addition, annual N fertilizing is needed to ensure high levels of production year after year, and these fertilizations can be performed in different times of the year by different

***Corresponding author:**
Italo Herbert Lucena Cavalcante, Federal University of São Francisco Valley, Campus of Agricultural Sciences, Petrolina, Pernambuco, Brazil. E-mail: italo.cavalcante@univasf.edu.br

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methods (foliar or soil applications). De Angelis et al. (2011) reported that the time and method of nitrogen fertilizer application can affect both plant growth and production of the following year and it can also affect the different forms of storage and nitrogen mobilization in the tree.

The present work aimed at evaluating the fruit production, yield and leaf chlorophyll of 'Princesa' and 'Eva' apples as a function nitrogen fertigation under Brazilian semiarid conditions.

MATERIALS AND METHODS

Plant material and growth conditions

Princesa and Eva apple (*Malus domestica*) trees propagated by grafting (with 'M9 interstock and Maruba rootstock) and transplanted in 2010 were used in this study.

The study was conducted in 2012 and 2013 on an experimental orchard located in Campo Doro farm, in Petrolina (09°21' S and 40º34' W; at an altitude of 375 m above sea level), Pernambuco State, Brazil.

The climate of this region is classified as Bswh (Köeppen), which corresponds to a semiarid region. During the execution of the experiments the precipitation was 94 mm, the temperature range was between 24.3ºC and 29.4ºC, and air humidity between 48.8% and 64.9%, while the average radiation was 535 ly/day and the average sunshine hours was 7.9 hours/day.

The physical and chemical characteristics of the soil (Oxisol) where the experiment was performed are shown in Table 1.

Before the execution of the experiment leaf samples were taken to access the plant nutritional status (Table 2). According to recommendations of Nachtigall et al. (2004), four leaves per plant were taken from the middle part of the canopy at each cardinal point from 25 plants. Leaves were chemically analysed after washing and rinsing with distilled water and drying at 70ºC for 48 h using the methodology described by Malavolta et al. (1997).

After hand defoliation (July 2012), the apple trees were pruned and treated with 0.08% hydrogen cyanamide and 3.0% mineral oil (Assist®) and 3.0% of color fix (Hi-Light®) following the recommendation of Lopes et al. (2012). Fruit thinning also was performed when fruit measured nearly 2.0 cm in diameter, keeping one or two fruits per floral bunch.

The orchard conduction system was set up with a central leader, and it was composed of Eva and Princesa (pollinator cultivar) apple cultivars. The spacing between the rows was 4.0 m, and the spacing between the trees was 1.25 m. The trees were drip-irrigated each day with ten self-regulated emitters per tree with a flow of 2 L hour^{-1} based on daily evapotranspiration registers recorded by the Embrapa Meteorological Station and corrected according to the apple culture coefficient (Kc).

The nitrogen source used was calcium nitrate (15.5% of N), applied twice a week, during 40 days, reaching 12 fertilizings through irrigation water. The first N fertilizing was performed at 40 days after breaking dormancy. All plants were also fertilized with potassium sulphate (50% of K_2O), triple superphosphate (45% of P_2O_5), magnesium sulphate (15% of Mg), boric acid (17% of B) through irrigation water, according to instructions

Table 1: Chemical and physical characteristics of the soil (0-20 cm and 20-40 soil depths) where the experiment was carried out

Soil Characteristic	Soil Depth	
	0 – 20 cm	20 – 40 cm
pH (in water)	6.9	6.8
	$cmol_c dm^{-3}$	
Ca^{2+}	3.2	2.5
Mg^{2+}	1.8	1.0
Ca+ Mg	5.0	3.50
Al^{3+}	0.05	0.05
$H+Al^{3+}$	2.8	2.47
K+	0.20	0.16
Na	0.04	0.04
CEC	8.04	6.17
P –Melich (mg dm^{-3})	29.77	25.66
OM (%)	0.6	0.44
	g kg^{-1}	
Clay	7.8	47.4
Silt	80.5	53.5
Sand	911.7	925.0

OM=Organic matter; CEC=cationic exchangable capacity [Ca^{2+} + Mg^{2+} + Na^+ + K^+ + (H^+ + Al^{3+})]; P, K: Melich 1; H+Al: calcium acetate (extractor) 0.5M, pH 7; Al, Ca, Mg: KCl 1 M extractor; CEC: Cationic exchangable capacity

Table 2: Leaf nutrient concentrations of Eva and Princesa apple cultivars before the execution of the experiment

Nutrient	Apple cultivar	
	Eva	Princesa
	g kg^{-1}	
N	23.2	29.5
P	1.10	1.65
K	14.94	18.01
Ca	16.60	16.65
Mg	4.20	4.85
	mg kg^{-1}	
B	38.46	37.02
Cu	90.00	73.00
Fe	306.00	346.00
Mn	123.00	187.00
Zn	90.00	73.00

of Sanhueza (2003). Zinc (Coda Zinco®, 10.4% of Zn), magnesium (Coda Mg®, 6.6% de Mg) and iron (Codamin Br®, 2.0% of Fe; 1.0% de Zn; and 10% of amino acid) were leaf applied.

Other cultural treats of the orchard were performed according to the recommendations of EPAGRI (2006).

Treatments and experimental design

The experimental design was randomized blocks with treatments distributed in a factorial arrangement (4 × 2) referring to nitrogen doses (160, 120, 80 e 40 kg of N ha^{-1}) and apple cultivars (Eva and Princesa), with four replications and three plants in each parcel. Nitrogen doses were defined according to Ernani and Dias (1999).

Data gathered and statistical analysis

The following fruit variables were also recorded: i) accumulated number of fruits per plant; iii) fruit production per plant, which was measured using a Filizola® CF15 brand precision scale (0.5 g precision) and expressed in kilograms/plant (kg/plant); and iii) fruit yield, which was obtained by multiplying the fruit production per plant by the total number of plants in one hectare.

During fruit production the total leaf chlorophyll was measured using a chlorophyll meter (Falker®, Brazil) in four leaves per plant from the middle part of the canopy at each cardinal point within the canopy of each replication (plant), following the methodology described by El-Hendawy et al. (2005). Readings were taken in the middle, apex and basis of the leaf, avoiding necrotic areas by the attack of pests and disease. Therefore, each repetition consisted of an average from twelve leaf chlorophyll readings.

The same leaves were collected immediately after performing leaf chlorophyll readings, and chemically analyzed. After washing and rinsing with distilled water, the leaves were dried at 70ºC for 48 h. Total N concentrations were analyzed using the Kjeldahl method.

Statistical analyses included analysis of variance (ANOVA), mean separation of apple cultivars using Tukey test and regression analysis of nitrogen doses, using combined data. All calculations were performed using the Sigmaplot software, and terms were considered significant at $p < 0.01$.

RESULTS AND DISCUSSION

As can be seen in Table 3 nitrogen levels significantly affected total leaf cholrophyll (CHLO) and leaf nitrogen concentration (Leaf N), while fruit production, fruit yield and Leaf N were influenced by apple cultivars. In addition, no significant interactions between N levels and apple cultivars were registered for all variables recorded in the study.

Table 3: Fruit production, fruit yield, number of fruits per plant (NFP), total leaf cholrophyll (CHLO) and leaf nitrogen concentration (Leaf N) of 'Princesa' and 'Eva' apples as a function nitrogen fertigation

Variation source	Fruit production	Fruit yield	NFP	CHLO	Leaf N
	kg $plant^{-1}$	t ha^{-1}	-	-	g kg^{-1}
N levels ("F" value)	0.46^{ns}	0.35^{ns}	0.08^{ns}	3.43*	6.53**
Apple cultivars ("F" value)	7.79*	7.09*	2.04^{ns}	0.39^{ns}	8.08**
Eva	11.2b	22.49b	109.68a	61.69a	22.33a
Princesa	13.8a	27.61a	122.18a	61.08a	20.72b
MSD	1.939	4.007	18.21	2.04	1.18
Interaction (N x cv.)	0.19^{ns}	0.13^{ns}	0.03^{ns}	1.40^{ns}	0.92^{ns}
V.C.	21.61	21.76	21.37	4.51	7.44

cv. = Apple cultivar; VC = Variation coefficient; MSD = Minimum significant difference; **Significant at p<0.01 probability error; *Significant at p<0.05 probability error; ns: Non- significant; Data followed by different letters in columns are significantly different according to Tukey test (p<0.01)

Fruit production (kg $plant^{-1}$) was nearly 18% higher for 'Princesa' apple cultivar in relation to 'Eva' ones (Table 3), result which was not previously expected because most apple cultivars require crosspollination using a compatible cultivar to obtain desirable set fruit, and in commercial orchards 'Princesa' has been used for cross-pollination and not for yield, but under semiarid climate the 'Princesa' has shown potential to be grown as a production cultivar. The average fruit productions contained in Table 3 are higher than 6.62 kg $plant^{-1}$ (Princesa cv.) reported by Lopes et al. (2013) and 5.57 kg $plant^{-1}$ (Eva cv.) registered by Lopes et al. (2012) both under Brazilian semiarid climate and higher than 4.0 kg $plant^{-1}$ recorded by Alshebir et al. (2010) who cultivated apples under tropical mountain climate conditions in northern Ethiopia; and compatible to the average values of 13.2 kg $plant^{-1}$ (Princesa cv.) and 14.1 kg $plant^{-1}$ (Eva cv.) refereed by Chagas et al. (2012), in study under tropical climate of São Paulo State, Brazil.

Following the same tendency of the fruit production (kg $plant^{-1}$), fruit yield was also significantly higher (18%) for 'Princesa' cv. Both apple cultivars studied presented fruit yield, in average, higher than those quoted in the scientific literature by Lopes et al. (2012) and Lopes et al. (2013) who reported 10.3 t ha^{-1} and 12.73 t ha^{-1}, respectively for 'Eva' and 'Princesa', under semiarid climate. Moreover, the present yield results are compatible to 29.3 t ha^{-1} ('Princesa') and lower than 31.3 t ha^{-1} ('Eva') obtained by Chagas et al. (2012). It detaches that Chagas et al. (2012) were recorded in the second fruit harvest, traditionally higher than the first one, when data of Table 3 were collected.

When compared to apples produced under temperate climate the average yield values of the present study were superior to those reported by Naor et al. (2008) for 15-year-old Smoothie apples grown in Israel (13.1 t ha^{-1}), Nava and Dechen (2009) for Fuji apples in Brazil (16.1 t ha^{-1}) and superior to the range reported by Di Vaio et al. (2009) for Annurca Rossa del Sud apples in Italy (7.4 - 25.1t ha^{-1}).

Accordingly, due to the importance of new producing areas around the world, especially for apples, Basannagari and Kala (2013) studied the climate change and apple farming and concluded that it is important to understand the variations in the patterns of climate change and also to identify management practices and alternatives for farmers in order to cope up the vagaries of changing climate, trying to contribute for fruit production sustainability.

It is important to note that apple trees take four to five years to produce their first fruit (Ferree and Warrington, 2003). In the present study, the trees were transplanted in 2010, so the fruit production was anticipated in two or three years. Moreover, it is common that the first harvest presents a low yield, but it is strongly recommended the evaluation of this variable because yield is one of the most important characteristics of apple crops.

The Princesa apples plants of the present study produced more fruits than those evaluated by Lopes et al. (2013) and Chagas et al. (2012), while Eva apples promoted a number of fruits higher than Lopes et al. (2012) but lower than Chagas et al. (2012).

Fruit production (kg $plant^{-1}$), fruit yield and number of fruits per plant were not affected by nitrogen (N) fertilizing through fertigation that is in agreement with Nava and Dechen (2009) who identified no effect of N fertilizing during the first evaluation year and concluded that it had been caused by the buds that originated the fruits of the first harvest had already been differentiated in the previous year. Accordingly, both apple cultivars studied were adequately N supplied before the beginning of the experiment, whether compared to adequate range statement reported by Nachtigall et al. (2004). According to Nava (2007) apple trees are able to store a large N amount as protein and reuse it in later cycles.

It is important to infer that the lack of N fertilizing effect on fruit yield could be associated with some characteristics such as low N requirement of apple tree (Ernani and Dias, 1999), good conditions for N release from soil organic matter, and poor conditions for N leaching.

In a general form, it observes in the scientific literature a huge disagreement about the effect of N fertilizing on apple yield. In Brazil, Ernani et al. (2000) found no effect of N doses and fertilizing times on apple fruit yield and, explained this result by the high N mineralization rate contained on soil organic matter. On the other way, in experiment performed on a shallow and stony soil Nava and Dechen (2009) obtained a positive result, and Nava et al. (2007) concluded that increasing N doses promoted higher fruit mass, fruit yield and number of fruits per plant, maybe caused by a better bud nutrition.

Leaf chlorophyll meter reading presented a quadratic adjustment of the data with a minimum fit of 0.93, with a calculated peak at 120 kg of N ha^{-1} (Fig. 1a), followed by a consecutive decay. This result could be explained by Cavalcante et al. (2012) who argue that nitrogen is the core component of chlorophyll molecule as the structural component in porphyrin ring, and thus its content in the leaf is directly proportional to chlorophyll content, although there is a maximum of sufficiency when this pigment is decreased.

Nitrogen foliar concentrations of apple trees significantly increased with N fertilizing doses enhancement (Fig. 1b) that could be caused by the low soil organic matter where the experiment was performed (Table 3), associated to the N demand of apple tree. In addition, N is the second nutrient more demanded by apple tree (Nachtigall and Dechen, 2006). All average values of Fig. 1B from 80 to 160 kg of N ha^{-1} are compatible to 21.5 g kg^{-1} reported by Nava et al. (2007) and only apple plants fertilized with 40 kg of N ha^{-1} reached the stated adequate range of supply described by Nachtigall et al. (2004).

In the present work, however no significant effects of N fertilizing on fruit production and yield have being registered, there was increasing on leaf N concentration and total leaf chlorophyll meter reading. According to Nava et al. (2007), this effect could stimulate the plant photosynthetic hate, carbohydrate synthesis, leaf specific weight, total plant mass production and carbon allocation on different plant organs, thus exerting a positive effect on bud nutrition.

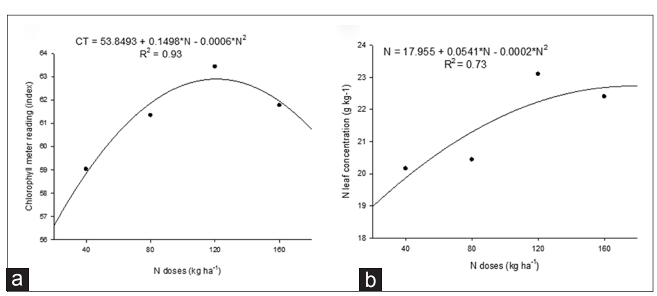

Fig 1. Total chlorophyll meter readings (a) and nitrogen leaf concentration (b) of apple as a function of nitrogen doses.

CONCLUSIONS

Thus, the results of this study indicated that Princesa apple cultivar if compared to 'Eva' presents a better fruit production performance under in Brazilian semiarid. Furthermore, nitrogen doses fertilized through irrigation water have no effect on fruit production of Eva and Princesa apple cultivars during the first production cycle.

Author contributions

All authors contributed equally in this work and article.

REFERENCES

Ashebir, D., T. Deckers, J. Nyssen, W. Bihon, A. Tsegay, H. Tekie, J. Poesen, M. Haile, F. Wondumagegneheu, D. Raes, M. Behailu and J. Decker. 2010. Growing apple (*Malus domestica*) under tropical mountain climate conditions in Northern Ethiopia. Exp. Agric. 46: 53-65.

Basannagari, B. and C. P. Kala. 2013. Climate change and apple farming in Indian Himalayas: A study pf local perceptions and responses. PloS One. 8: e77976.

Cavalcante, Í. H. L., M. S. Cunha, M. Z. Beckmann-Cavalcante, J. A. Osajima and J. S. N. Sousa. 2012. Relationship between chlorophyll meter readings and leaf nitrogen concentration in custard apple. Philipp. J. Crop. Sci. 37: 88-92.

Chagas, E. A., P. C. Chagas, R. Pio, J. E. Bettiol Neto, J. Sanches, S. A. Carmo, P. Cia, M. Pasqual and A. S. Carvalho. 2012. Produção e atributos de qualidade de cultivares de macieira nas condições subtropicais da região Leste Paulista. Cienc. Rural. 42: 1764-1769.

De Angelis, V., E. Sánchez and J. Tognetti. 2011. Timing of nitrogen fertilization influences color and anthocyanin content of apple (*Malus domestica* borkh. cv 'Royal Gala') fruits. Int. J. Fruit. Sci. 11: 364-375.

Di Vaio, C., C. Cirillo, M. Buccheri and F. Limongelli. 2005. Effect of interstock (M.9 and M.27) on vegetative growth and yield of apple trees (cv "Annurca"). Sci. Hortic-Amterdan. 119: 270-274.

El-Hendawy, S., Y. Hu, and U. Schimidhalter. 2005. Growth, ion content, gas exchange, and water relations of wheat genotypes differing in salt tolerances. Aust. J. Agric. Res. 56: 123-134.

Ernani, P. R., J. Dias. 1999. Soil nitrogen application in the spring did not increase apple yield. Cienc. Rural. 29: 645-649.

Ernani, P. R., D. A. Rogeri, M. M. Proença and J. Dias. 2008. Addition of nitrogen had no effect on yield an quality of apples in an high density orchard carrying a dwarf rootstock. Rev. Bras. Frutic. 30: 1113-1118.

EPAGRI. 2006. A Cultura da Macieira. 1st ed. Pallotti, Florianópolis, SC.

FAO: Statistical Database. Food and Agriculture Organization, Rome. Available from: http://www.faostat.org.br/. [Last cited on 2015 Jan 20].

Ferree, D. C. and I. J. Warrington. 2003. Apples: Botany, Production, and Uses. CABI Publishing, Wallingford, UK.

Liu, C., M. Han and L. Zhang. 2008. The effects of fertilizer application at early summer on growth, yield and quality of Fuji apple in Weibei Highland. Agric. Res. Arid. Areas. 26: 124-137.

Lopes, P. R. C., I. V. M. Oliveira, R. R. S. Silva and Í. H. L. Cavalcante. 2013. Growing Princesa apples under semiarid conditions in northeastern Brazil. Acta. Sci. Agron. 35: 93-99.

Lopes, P. R. C., I. V. M. Oliveira, R. R. S. Silva, Í. H. L. Cavalcante. 2012. Phenological characterization, effective frutification and fruit production of apples 'Eva' in semiarid climate in Northeastern Brazil. Rev.Bras. Frutic. 34: 1277-1283.

Malavolta, E., G. C. Vitti and A. S. Oliveira. 1997. Evaluation of plant nutritional status: principles and uses. 2nd. ed. Brazilian Potassium and Phosphate Association, Piracicaba, SP.

Nachtigall, G. R., C. Basso and C. J. S. Freire. 2004. Nutrição e adubação de pomares. In: Nachtigall, G. R., Ed. Maçã: Produção. Embrapa Uva e Vinho, RS. Pp. 66-77.

aor, A., S. Naschitz, M. Peres and Y. Gal. 2008. Responses of apple fruit size to tree water status and crop load. Tree Physiol. 28: 1255-1261.

Nava, G. and A. R. Dechen. 2009. Long-term annual fertilization with nitrogen and potassium affect yield and mineral composition of 'Fuji' apple. Sci. Agric. 66: 377-385.

Nava, G., N. J. Nuernberg, A. J. Pereira and A. R. Dechen. 2007. Adubação de crescimento de macieira cv. Catarina sobre porta-enxerto marubakaido em São Joaquim-SC. Rev. Bras. Frutic. 29: 359-363.

Nava, G. 2007. Nutrição e rendimento da macieira em respostas às adubações nitrogenada e potássica. D. Sc. Thesis. University of São Paulo, Piracicaba.

Njuguna, J. K., S. W. Leonard and E. M. Teddy. 2004. Temperate fruits production in the tropics: A review on apples in Kenya. Hort. Sci. 39: 841.

Oliveira, I. V. M., P. R. C. Lopes, R. R. S. Silva-Matos and Í. H. L. Cavalcante. 2013. Fenologia da macieira, cv. Condessa no vale de São Francisco. Rev. Ciênc. Agrárias. 36: 23-30.

Sadar, N., S. Tojnko, T. Kraner-Sumenjak, M. Lers, A. Vogrin, M. Lesnik and T. Unuk. 2013. Effects of fertigation on pigment pattern and fruit quality of cv. 'Gala' Apples. Erwerbs-Obstbau. 55: 11-18.

Sanhueza, R. M. V. 2003. Produção integrada de maçãs no Brasil. Brasília: Embrapa; Available from: Available from: http://www.sistemasdeproducao.cnptia.embrapa.br/FontesHTML/Maca/ProducaoIntegrada.[Last cited on 2015 Jan 20].

Tromp, J. 2005. Dormancy. In: Tromp, J., A. D. Webster and S. J. Wertheim (Eds.). Fundamentals of Temperate Zone Tree Fruit Production. Backhuys Publishers, BV, Leiden, Pp. 65-73.