



Acta Scientiarum. Agronomy

ISSN: 1679-9275

ISSN: 1807-8621

Editora da Universidade Estadual de Maringá - EDUEM

Souza, Jackson Mirellys Azevêdo; Silva, Marcelo de Souza; Ferraz, Rafael Augusto; Modesto, Joyce Helena; Ferreira, Rafael Bibiano; Bolfarini, Ana Carolina Batista; Tecchio, Marco Antonio; Leonel, Sarita
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Acta Scientiarum. Agronomy, vol. 43, e50519, 2021, January-December
Editora da Universidade Estadual de Maringá - EDUEM

DOI: <https://doi.org/10.4025/actasciagron.v43i1.50519>

Available in: <https://www.redalyc.org/articulo.oa?id=303067924036>

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The use of hydrogen cyanamide or nitrogen fertilizer increases vegetative and productive performance of fig cv. Roxo de Valinhos

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ABSTRACT. Some plants do not demand a lot of chilling hours, but methods to overcome dormancy promote more vigorous and productive plant. This study aimed to assess hydrogen cyanamide and nitrogen fertilizer with different concentration to growth and production in 'Roxo de Valinhos' fig tree. Two crop cycles (2015/2016 and 2016/2017) was performed in São Manuel city, São Paulo State, Brazil. Phenological and productive data was evaluated in a 2 x 5 factorial (Product x Concentration), organized in randomized complete block design, with three trees by plot. The factor products had as level hydrogen cyanamide and nitrogen fertilizer and the factor concentrations was constituted by 0, 1, 2, 3, and 4%. Furthermore, the following data was evaluated: number of days for budbreak, number of buds per plant, harvest period, branch length and diameter, leaf number, leaf area, number of fruits per plant, fruit mass, production and yield. Results indicated that both products anticipated the sprouting and promoted a higher number of buds overcome the dormancy. Plant production was higher in both cycles when the products were used (2.1 and 2.7, respectively). At last, hydrogen cyanamide showed better outcomes due to the higher number of fruits and production.

Keywords: *Ficus carica* L.; phenology; plant growth regulator; sprouting; overcome dormancy; yield.

Received on October 23, 2019.
Accepted on January 23, 2020.

Introduction

The fig tree (*Ficus carica* L.) is among the most important grown fruits in the world. In 2016, Brazil was the world's eighth largest producer of fig, with 26.9 thousand tons. However, Turkey is the main producer in the world, with more than 305 thousand tons (Faostat, 2018). Among fig varieties, 'Roxo de Valinhos' is the most used in Brazil, besides, it is easily adapted to severe pruning due to its rusticity, vigour and yield when compared to other varieties (Dalastra et al., 2009).

Severe pruning or winter pruning of the fig tree is a cultural technique commonly performed in Brazilian orchards, which allows the management of plants with reduced size, consequently, higher density. This technique aims to renewal of productive branch therefore the fruits are produced in the branches of the current season. Thus, the previous crop branches are pruned to 2-3 buds, thus allowing the growth of new branches, which are conducted in nine average number of branches per plant (Leonel & Sampaio, 2011).

Fruit production in the fig cultivars may occur twice a year, the first crop is called Breda and occurs in branches of one-year-old, while the main crop occurs in branches of the current season (Flaishman, Rover, & Stover, 2008). However, in Brazil there is no harvest of breda due to drastic pruning, with only the harvest of the main crop. The production of the main crop is highly correlated with the length and duration of the shoot growth phase in the current season (Gaaliche, Lauri, & Costes, 2011).

Although the fig trees come from the Mediterranean climate, they grow from cold to semi-arid climate. The dormancy period of the fig tree is short because it presents a low or no requirement of cold in winter (Oukabli & Mekaoui, 2012).

Though the fig tree can be grown in regions with little winter cold, the development of buds can be erratic, which hinders the production (Flaishman et al., 2008). As Erez (1987), when deciduous plants grown in warm regions receive insufficient cooling to overcome endodormancy, there is a drop in the percentage of

germination. Although the fig tree presents a low requirement of cold and mild endodormity, the use of plant regulators or other products in this field can promote greater uniformity and better performance of the plants, due to less erratism.

There are several products to promote the overcome dormancy. However, the hydrogen cyanamide has stood out due to its expressive outcomes. There is paucity in literature on use these products in fig crops (i.e. Roxo de Valinhos cultivar) in Brazil. Norberto, Chalfun, Pasqual, Veiga, and Mota (2001) observed that hydrogen cyanamide (2%) associated with May pruning and irrigation promoted early harvests and higher yields. Leonel, Tecchio, and C  ser (2015) found that the application of hydrogen cyanamide 2% promoted sprouting anticipation, and when use with garlic extract, it also promoted productive period concentration.

The use of hydrogen cyanamide has been studied in several countries, but with other fig cultivars. In Israel, the use of 3% hydrogen cyanamide was effective in breaking the buds and scheduling fruit maturation of 'Nazareth' (Yablowitz, Nir, & Erez, 1998). Differently, in South Africa, hydrogen cyanamide and mineral oil (2% ECH) budding reduced in 'Bourjasotte Noire' and 'Damme Col Noire', while in 'Noire Caromb' was effective (Theron, Gerber, & Willem, 2011). While Gaaliche, Ghrab, and Mimoun (2016) report that the use of hydrogen cyanamide is an effective technique allowing higher growth and yield in fig 'Zidi' in Tunisia, producing crucial evidence that highlights the importance of this type of study with the cultivation of the fig tree culture in Brazil.

Although hydrogen cyanamide allows better performances to overcome dormancy, there is still a need to evaluate less toxic synthetic substances. Nitrogen fertilizer is an alternative product, that has been evaluated in some studies, such as Segantini, Leonel, Ripardo, Tecchio, and Souza (2015) and Hawerth, Petri, Leite, and Herter (2010) that reported similar results to those obtained with hydrogen cyanamide for blackberry and apple tree crops, respectively.

Although the need to overcome dormancy in figs is lower, plant regulators can improve vigour; balance vegetative growth; and provide a greater and more uniform production. In Brazil, overcoming dormancy is a technique that has not been much used by fig producers due to its low chilling requirement, but there are positive outcomes, with regards to crop growth and yield. Although most producers have used it after winter pruning, there is no set recommendation on the amount they should use. Therefore, the current study aimed to evaluate the use of hydrogenated cyanamide and nitrogen fertilizer on the vegetative and productive performance of 'Roxo de Valinhos' fig tree.

Material and methods

Experimental area characterization and implantation

The experiment was carried out at the S  o Manuel Experimental Farm that belongs to School of Agriculture (FCA UNESP), located at 22   44' 28" S, 48   34' 37" W and an altitude of 740 m above sea level. According to the K  ppen classification, the climate of the area is type *Cfa*, that is, hot temperate climate (mesothermic), with concentrated rains from November to April (summer) and average annual rainfall of 1,376.70 mm, besides the mean temperature of the hottest month exceeds 22  C (Cunha & Martins, 2009).

The area accumulated 0,0 chill hours (CH) $\geq 7.2^{\circ}\text{C}$ and 58.6 HF $\geq 13^{\circ}\text{C}$ from 1 April until 31 July, 2015 (first season). While in 2016, in the same period, the accumulation of CH was 7.4 $\geq 7.2^{\circ}\text{C}$ and 473.7 $\geq 13^{\circ}\text{C}$ (second season). Other climatic data of the experiment period are shown in Figure 1.

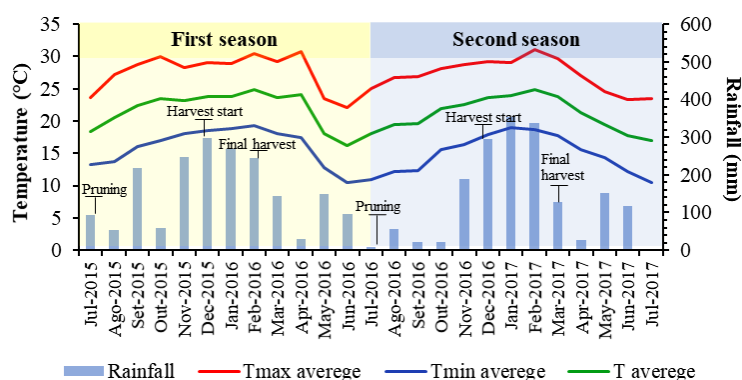


Figure 1. Climatic data of the first and second crop cycle, between July 2015 and July 2017. S  o Manuel, S  o Paulo State, Brazil, 2019.

The fig trees were three years old in 2015 and were planted at 3 m spacing between rows and 2 m between plants. Figs were evaluated in two seasons, i.e. 2015/2016 and 2016/2017. Severe pruning was performed during winter (July), in which nine productive branches were conducted in each cycle. Also, topdress fertilization was performed according to soil analysis and crop recommendations, according to Raij, Andrade, Cantarella, and Quaggio (2001).

Product application

The products used were hydrogen cyanamide (Dormex®) and nitrogen fertilizer (Erger®) associated with calcium nitrate. The commercial product Dormex® contains 520 g L⁻¹ of hydrogen cyanamide and is classified as a systemic regulator of the chemical group of carbimide (hazard class I). While nitrogen fertilizer (Erger®) is composed of 6.1% of urea nitrogen, 5.8% of nitric nitrogen, 3.1% of ammoniacal nitrogen, and 4.7% of calcium oxide (CaO), mono-and-selected polysaccharides and diterpenes, it is available as soluble concentrate at low risk (Valagro, 2013).

Both product concentrations were of 0, 1, 2, 3, and 4%, hydrogen cyanamide was only diluted in water and nitrogen fertilizer in water with 4% calcium nitrate. All applications were performed in the morning of the same day, immediately after winter pruning (i.e. 29/07/2015 and 29/07/2016), then the evaluations were started (Figure 2).

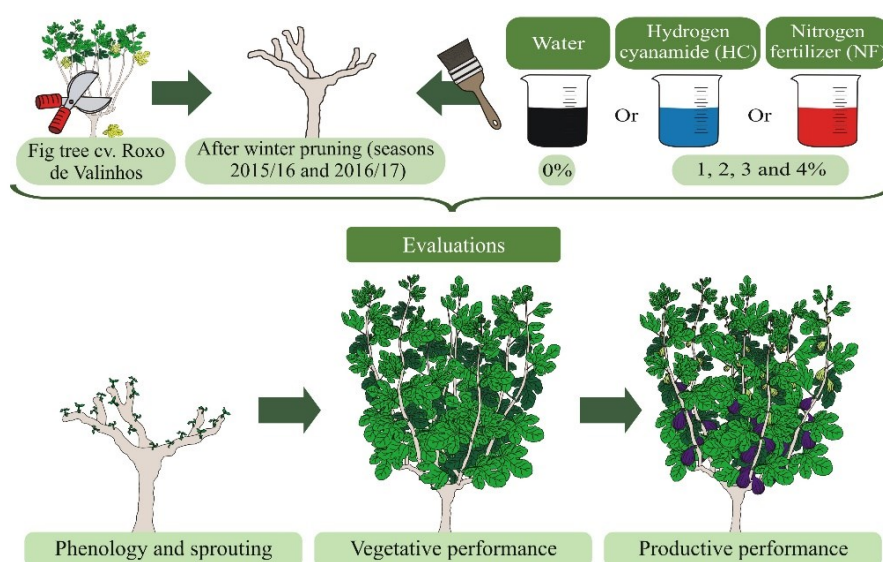


Figure 2. Representative sequence of pruning, product application and evaluations carried out in 'Roxo de Valinhos' fig plants. São Manuel, São Paulo State, Brazil, 2019.

Experimental design

For assessing data, a 2 x 5 factorial organized in randomized complete block design was used. The first factor is about products (hydrogen cyanamide and nitrogen fertilizer) and the second one is their concentrations (0, 1, 2, 3, and 4%). Therefore, four blocks were set with three useful plants per treatment, totalling 120 plants.

Phenological cycle assessments and harvest period

All plants were evaluated for number of days between pruning and beginning of sprouting; and number of days between pruning and beginning of harvesting. It was also evaluated how long harvest period was for each treatment and for each year (counted from the beginning until the end of harvesting).

Evaluations of plants vegetative performance

With regards bud sprouting, numbers of emitted buds were counted at 30 days after pruning (DAP) in each plant. For the other evaluations three branches per plant plants were used to evaluate vegetative performance; therefore, brunch length and diameter, measured using graded tape and digital calliper; leaf number, counted individually; and leaf area, through non-destructive methodology proposed by Souza, Silva,

Leonel, Souza, and Tanaka (2014) in which three leaf lengths were measured using a graduated ruler, from which, by means of an equation, the leaf area was obtained in cm^2 , and all leaves area was added to obtain the plant leaf area. These evaluations were performed at the end of each season, that is, 240 days after pruning.

Evaluations of plants productive performance

The following evaluations was carried out: number of fruits per plant, counted from the beginning until the end of harvesting period; fruit mass, weighed in a digital scale, expressed in grams; and yield is given by weight (kilograms per hectares).

Statistical analysis

Before performing analysis of variance, data was submitted to the normality test. When significant, data referring to products (hydrogen cyanamide and nitrogen fertilizer) were submitted to Tukey test for means comparison, while data referring to concentrations were analyzed through regression at 0.1, 1.0, and 5.0% probability. Furthermore, log transformation (x) was applied to the data of number of days for sprouting and harvesting, length and diameter of the branches, leaf area, leaf and fruit number. All analyzes used the Computer Program System for Analysis of Variance (Sisvar, version 5.6) (Ferreira, 2011).

Principal component analysis (PCA) was performed to verify the correlation matrix of the main variables with Minitab 18 statistical software.

Results and discussion

Phenological cycle assessments and harvest period

With regards to the number of days to bud sprouting, results were only significant on both seasons' concentrations. Since number of days decreased linearly as a result of the increase in product concentrations during the first cycle, while there was a quadratic decrease to the concentration of 3% in the second cycle (Figure 3A and B). Such result is related to the climatic variability between productive cycles, which have a direct impact on products effects. In the second cycle, there were smaller peaks of minimum temperature, in other words no need for higher doses; consequently, a quadratic effect was observed.

However, no significant effect was observed on number of days for beginning of harvest for all factors, with the means were of 133.66 and 133.25 days in the first and second cycles, respectively (Figure 3C and D). Differently, Leonel et al. (2015) verified that the use of hydrogenated cyanamide (2%) decreased the number of days for beginning of fruit set from 119 to 98 days.

Note that product effect depends not only on the doses used, but also product application mode, adopted management practices and climatic conditions of each area. Leonel et al. (2015) applied the product by spraying, while in this work it was by brushing the branches. The climatic conditions on the plants should be considered during the conduction of the respective experiments. The time of application can explain the difference between the studies, in this work the applications were carried out at the end of July, which allowed a greater accumulation of cold, consequently may have diminished the response of the plants to the products. Already, Leonel et al. (2015), for example, the application performed in early July, when there is less accumulation of cold, so allowed highest response of plants to the product.

Although the result was significant, the difference between number of days to start budbreak in the absence and presence of products did not entail large amplitude, that is, about 2 days in both cycles. The low effect is related to fig tree, that does not require higher chilling hours to overcome dormancy when compared to other crops.

The smallest number of days to start sprouting, obtained in both cycles, with the application of its products occur due to its action as cyanamide interferes in the cells respiratory system and enzymatic processes that control the plants dormancy; particularly inhibiting the enzyme catalase activity that converts hydrogen peroxide into molecular oxygen and H_2O . Since, there is accumulation of hydrogen peroxide in plant metabolism; bud sprouting will be triggered by oxidative stress that, in turn, increases ATP through glycolysis and fermentation (Mohamed, Vadel, Geuns, & Khemira, 2012). While nitrogen fertilizer compounds act together, where mono and polysaccharides increasing cells respiratory process, whereas calcium promotes the activation of enzymes responsible for starch degradation and energy production (Alpi, Pupillo, & Rigano, 2001). Yet different forms of nitrogen are responsible to activate nitrogen metabolism that promotes bud

sprouting uniformly and in advance (Serlin, Sopory, & Roux, 1984). Finally, diterpenes increase gibberellins levels that are involved in cell division and stretching (Taiz, Zeiger, Møller, & Murphy, 2017).

The harvesting period was also not affected by the products and concentrations, so that in the 2015/2016 season it was 79 days, while in the 2016/2017 season it was 102 days (Figure 3E and F). The higher harvest period in the second cycle is due to higher rainfall during the fruit growing season, which indicates more hours with cloudy sky, consequently, lower radiation and slower development, which promoted a higher harvest distribution.

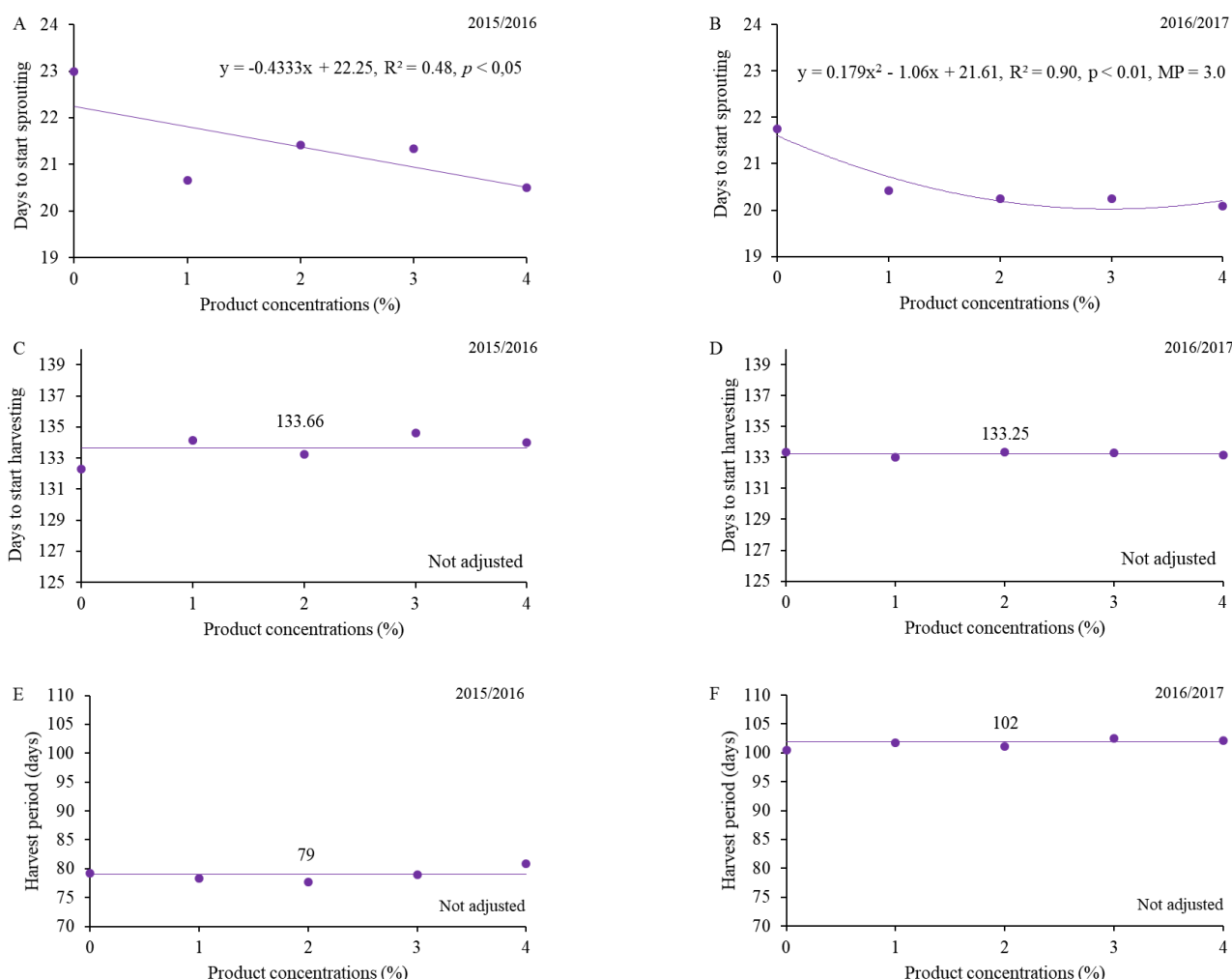


Figure 3. Number of days to budbreak (A, B), beginning of harvest (C, D), and harvest period (E, F) as a function of product concentrations (hydrogenated cyanamide and nitrogen fertilizer) in 'Roxo de Valinhos' fig trees in 2015/2016 and 2016/2017. São Manuel, São Paulo State, Brazil, 2019.

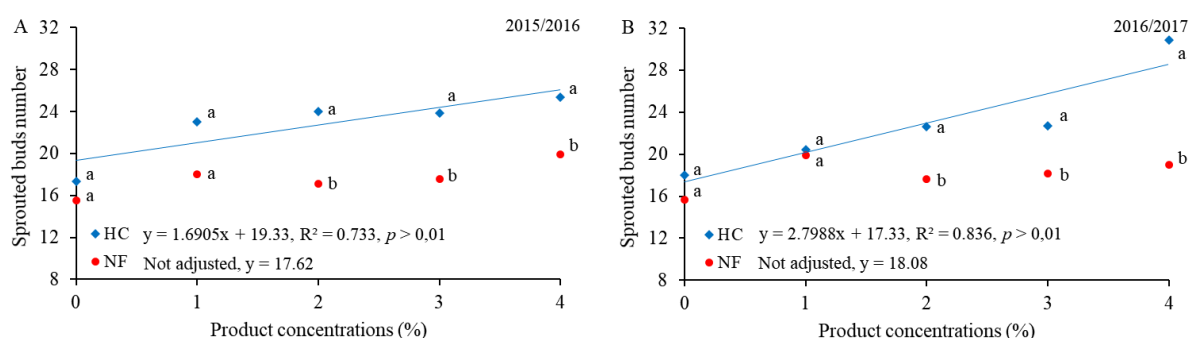
Evaluations of vegetative performance of plants

Regarding the number of sprouted buds issued 30 DAP, there was a significant interaction between products and concentrations in both seasons. There was a linear increase in the number of budbreak with hydrogen cyanamide in both cycles, with highest number of buds obtained with 4% (Figure 3B), providing an increase of 35.0 and 64.6%, respectively. Data from plants treated with nitrogen fertilizer did not fit the models tested (Figure 4A and B).

By comparing the products, hydrogen cyanamide promoted greater budbreak in two seasons evaluated at concentrations of 2, 3, and 4% (Figure 4A and B). In the second season, there have higher average number of sprouted buds. These differences between annual crop cycles can be attributed to climatic factors (Figure 1), notably minimum temperatures recorded, which breaks bud dormancy. It is noteworthy that there was greater accumulation of chilling hours in the run pruning the plants in the second cycle, which contributes to higher sprouted buds.

As in this study, Yablowitz et al. (1998) report higher budding of the ‘Nazareth’ fig tree submitted to 3% hydrogenated cyanamide. In a different way, Theron et al. (2011) verified that the use of hydrogenated cyanamide and mineral oil reduced the initial sprouting of ‘Bourjasotte Noire’ and ‘Damme Noire’ figs, but these products were effective in sprouting ‘Noire de Caromb’ fig tree. As shown, the effect of these products may be different between cultivars of the same species, in addition to the conditions of cold accumulation in the period prior to application. Theron et al. (2011) report that the negative effect of hydrogen cyanamide can be related to the addition of mineral oil, which did not occur in this study.

Regarding the use of nitrogen fertilizer, which has not yet been reported to fig. Segantini et al. (2015), for blackberry ‘Tupy’, verified a higher percentage of budbreak with 4.2% hydrogenated cyanamide, whereas 6.8% nitrogen fertilizer performed corresponding averages. It should be noted that, in general, these products’ effects can vary not only according to the doses, but also of the species and the adopted management practices and weather conditions. However, these authors showed that higher doses is still necessary to obtain better outcomes with this product, which can elucidate the absence of effect of the nitrogen fertilizer on the bud of the fig tree in this work, since the highest dose used was 4%.



The same letters between products do not differ by Tukey test at the 5% probability.

Figure 4. Number of budbreak as a function of the concentrations of hydrogen cyanamide (HC) and nitrogen fertilizer foliar (NF) in ‘Roxo Valinhos’ in the 2015/2016 (A) and 2016/2017 (B) harvests. São Manuel, São Paulo State, Brazil, 2019.

The interaction occurred between products and concentrations of all characteristics in 2015/2016 season (Figure 5 and 6). However, there was interaction between products and concentrations only for branch length and diameter in 2016/2017 season (Figure 5).

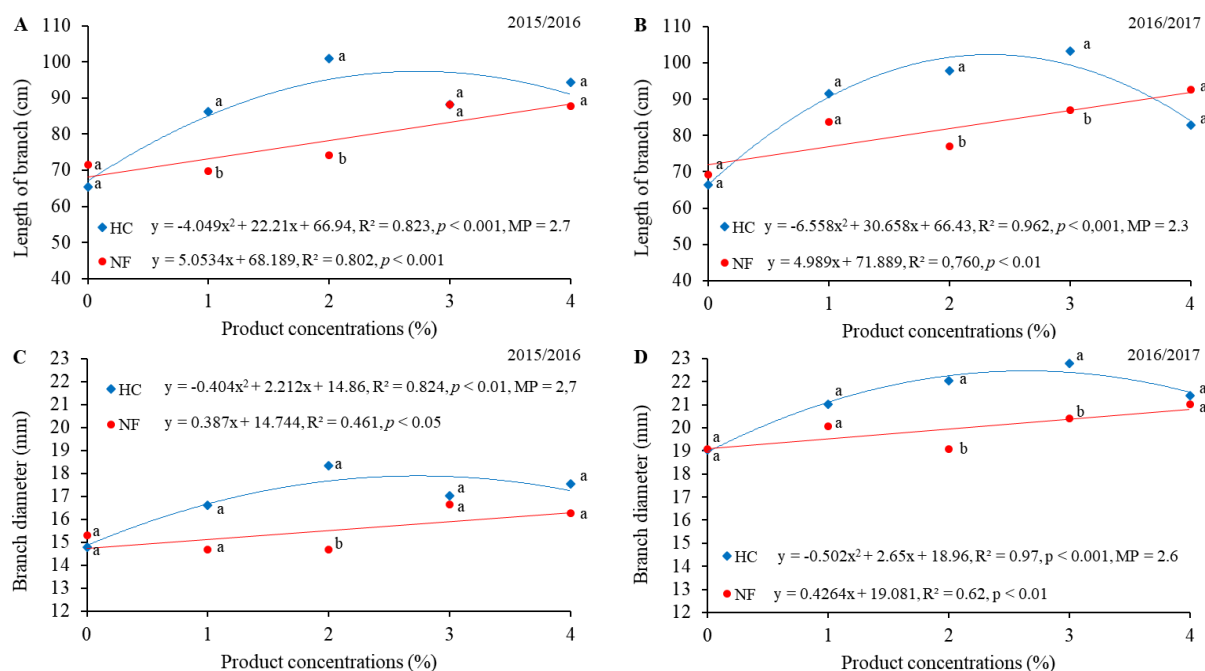
The application of hydrogen cyanamide provided a quadratic adjustment for length and diameter branch in both seasons. In the 2015/2016, the highest averages were obtained with the estimated concentration of 2.7% (Figure 5A and C), which promoted an increase of 48.9% and 21.1%, respectively. Nevertheless, higher length and diameter averages were observed with concentrations of 2.4 and 2.5% in 2016/2017 (Figure 5B and D), that is, an increase of 53.8% and 18.1%, respectively. Although, there was a linear increase in the length and diameter of the branches in both seasons (Figure 5) with 4% nitrogen fertilizer, that is, it increased 22.5% (length) and 6.2% (diameter) in 2015/2016; and 33.7 (length) and 10.3% (diameter) in 2016/2017.

By comparing both products performance, hydrogen cyanamide stood out for branch length and diameter at 1 and 2% in the first season and 2 and 3% in the second (Figure 5). Since chilling requirement was more satisfactory in the second cycle, i.e. higher concentration of hydrogen cyanamide required to reach higher length.

The highest mean length and diameter of the branch with hydrogen cyanamide shows its higher efficiency at budding stage, which allowed more sprouted buds and vigour, since hydrogen cyanamide acts directly on the action of CAT enzyme, triggering oxidative stress that, in turn increases ATP production via glycolysis and fermentation (Mohamed et al., 2012). On the other hand, nitrogen fertilizer depends on a series of factors, considering the isolated effect of each constituent, which can decrease its effectiveness (Segantini et al., 2015). Theron et al. (2011) report higher growth of fig shoots ‘Col de Damme Noire’ and ‘Bourjasotte Noire’ treated with hydrogen cyanamide and mineral oil. Likewise, Gaaliche et al. (2016) also report higher lengths of ‘Zidi’ treated with 1.5% hydrogen cyanamide compared to 1.0% and untreated.

In the case of the fig tree, branch length is of great importance, since it is directly related to leaf number and, consequently, to the number of fruits per plant, since in the axil of each leaf-stalk, fruits are emitted, that is, the bigger the branch is, the greater the number of fruits will be. It is noteworthy that the production of figs in Brazil occurs only in branches of the current season, noting that the

development of the branches is important for the production of the respective crop. According to Gaaliche et al. (2011), the number of reproductive buds is directly related to the length of shoots.



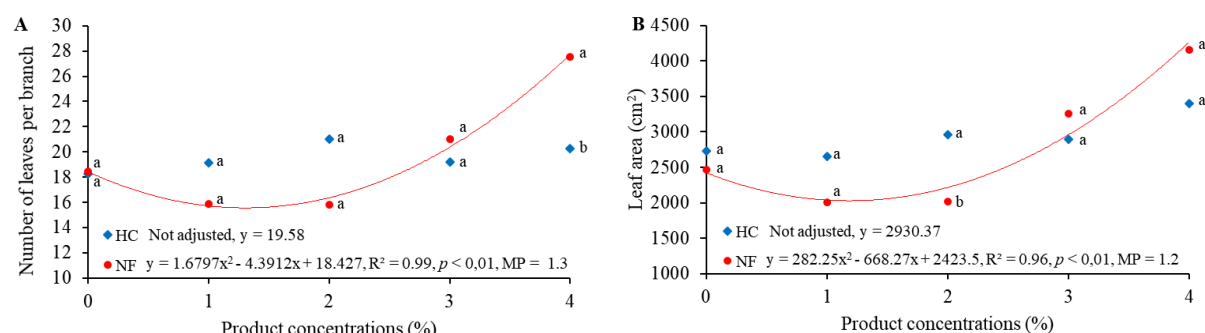
The same letters between products do not differ by Tukey test at the 5% probability.

Figure 5. Branch length (A and B) and diameter (C and D), as a function of the hydrogen cyanamide (HC) and nitrogen fertilizer (NF) concentrations in two cycles of 'Roxo de Valinhos' fig tree. São Manuel, São Paulo State, Brazil, 2019.

Regarding the number of leaves per branch, a quadratic growth was observed in the application of the nitrogen fertilizer from 1.3% to 4% in 2015/2016 season, when it obtained a higher average than hydrogen cyanamide at the same concentration (4%). However, when the hydrogen cyanamide was applied, there was no adjustment of the evaluated models (Figure 6A). This behavior was similar for leaf area in 2015/2016 (Figure 6B). However, the use of 4% nitrogen fertilizer did not promote greater leaf area than hydrogen cyanamide.

The highest mean number of leaves (27.53) of the plants treated with nitrogen fertilizer, in 2015/2016 season, were related to the different nitrogen sources present in the product, besides the calcium nitrate that was also applied. According to Russowski and Nicoloso (2003), nitrogen supply induces the synthesis of cytokinins, and increases the production of new cells, consequently, promotes an increase in the number of leaves. Although it did not result in larger leaf area.

The plants treated with nitrogen fertilizer presented lower averages of length and diameter of branches when compared to those that received hydrogen cyanamide, which are traits directly linked to the number of leaves. This result may have occurred due to the nitrogen sources, which also interfere with leaf maintenance, according to Paciullo, Gomide, and Ribeiro (1998). Thus, leaf maintenance may have kept the highest mean for these traits in plants treated with nitrogen fertilizer.



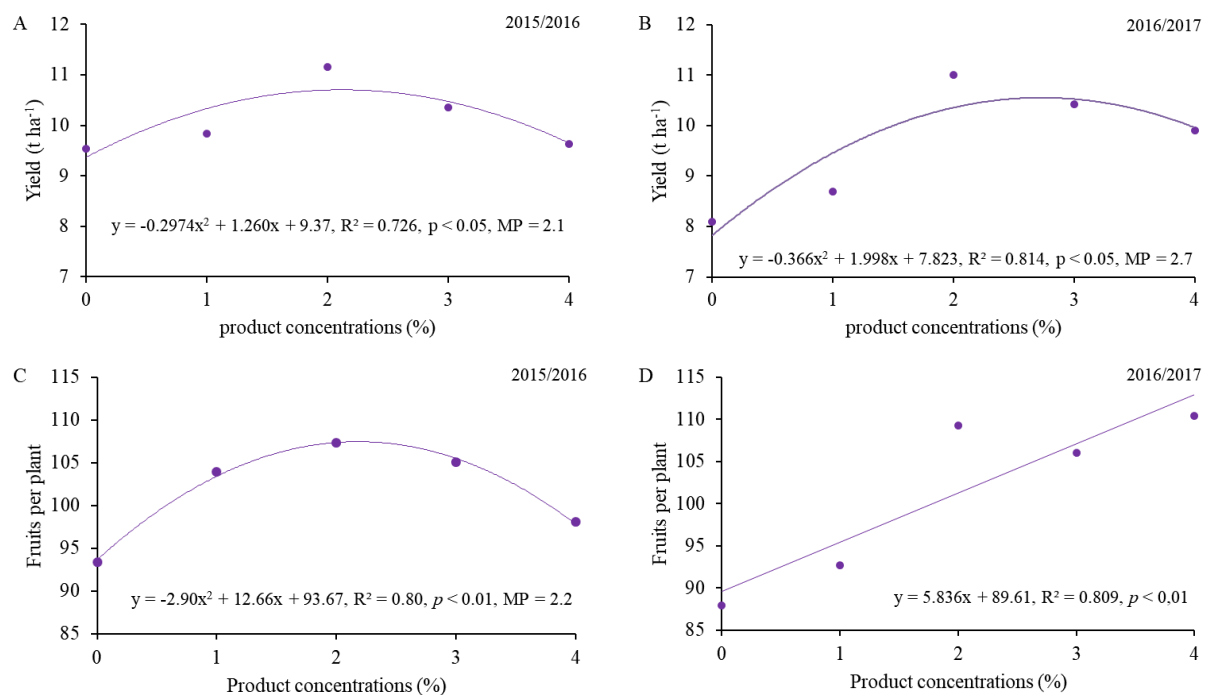
The same letters between products do not differ by Tukey test at 5% probability.

Figure 6. Number of leaves per branch (A) and leaf area (B) of plants as a function of the concentrations of hydrogen cyanamide (HC) and nitrogen fertilizer (NF) of 'Roxo de Valinhos' in the 2015/2016 cycle. São Manuel, São Paulo State, Brazil, 2019.

There was no interaction between products and concentrations for number of leaves per branch and leaf area in 2016/2017, as well as there was no isolated effect of the factors. During this season, the average number of leaves and leaf area were 5.6 and 826 cm², respectively.

Evaluations of plants productive performance

When total number of fruits per plant, fruit fresh mass and yield were evaluated, there was no interaction between products and concentrations in both seasons. However, there was an isolated effect of these factors for the mentioned characteristics in 2015/2016 season, except for fruit fresh mass. In 2016/2017 cycle, a significant effect of the product was only observed for yield; and concentrations for number of fruits and yield. This result indicates that, regardless of the product used, the production data are equally affected by increasing concentrations; therefore, both applications were justified, as they improved production performance of fig tree (Figure 7).



The same letters between products do not differ significantly by Tukey test at 5% probability.

Figure 7. Production (A, B), and number of fruits per plant (C, D) of the fig tree 'Roxo de Valinhos' as a function of product concentrations in 2015/2016 and 2016/2017 cycles, São Manuel, São Paulo State, Brazil, 2019.

The average fruit fresh mass was of 59.56 and 56.94 g in 2015/2016 and 2016/2017 seasons, respectively (Table 1). Similar value (59.50 g) was obtained by Leonel et al. (2015) according to the application of hydrogen cyanamide, which observed that fruits from plants treated with garlic extract were inferior to plants treated with hydrogen cyanamide.

Table 1. Fruit fresh mass, number of fruits per plant, production and yield of 'Roxo de Valinhos' fig tree treated with hydrogen cyanamide and nitrogen fertilizer in the 2015/2016 and 2016/2017 cycles. São Manuel, São Paulo State, Brazil, 2019.

Product	Fruit fresh mass (g)	Fruit number per plant	Yield (t ha ⁻¹)
2015/2016			
Hydrogen cyanamide	60.88 a	106.86 a	10.84 a
Nitrogen fertilizer	58.24 a	96.28 b	9.37 b
Means	59.56	101.57	10.10
LSD	2.99	6.69	0.86
2016/2017			
Hydrogen cyanamide	57.41 a	105.85 a	10.16 a
Nitrogen fertilizer	56.49 a	96.72 a	9.09 b
Means	56.95	101.29	9.62
LSD	3.16	9.58	1.06

Comparing the two products in the 2015/2016 season, the highest of number of fruits per plant and yield were obtained in plants treated with hydrogen cyanamide, with averages of 106.9 fruits and 10.8 t ha⁻¹, corresponding to the increase of 11.0 and 15.2, respectively, when compared to nitrogen fertilizer (Table 1). In 2016/2017 season, only yield (10.2 t ha⁻¹) that received hydrogen cyanamide application were higher, being 12.2% higher than the values obtained with nitrogen fertilizer (9.1 t ha⁻¹) (Table 1).

With regards to concentrations, there was an increase of 12.2% for yield at the concentration of 2.1% of the products used, as well as a 15% increase in the number of fruits with a concentration of 2.2% in the 2015/2016 season when compared to control (0%) (Figure 7A and C). This productive behaviour with quadratic value addition was also observed in 2016/2017 cycle, in which the largest increases in yield (29.8%) were obtained with 2.7% (Figure 7B). Moreover, fruit number increased linearly up to the highest concentration applied in this cycle (Figure 7D).

Although it is not important to use products to overcome dormancy, since fig tree does not demand chill accumulation. The results found in this study showed that the products promoted better plant performance. Moreover, the gains in yield obtained with higher dosages may result in greater financial return to producers due to the higher volume produced in the same area. It is also worth mentioning that the best yield performance is certainly resulting from better performance of vegetative plants treated with their products compared those not treated (0%). For larger branches result in increased fruit number, as fruits are emitted along the branch from leaf axil. While higher leaf area enabled higher photosynthesis rate; which may confer greater vigour to the plants and hence higher production.

The best productive performance of fig tree treated with products to overcome dormancy has been reported, for example, in fig 'Roxo Valinhos' with 2% hydrogen cyanamide (Leonel et al., 2015) and fig 'Bourjasotte Noire', 'Col Damme Noire' and 'Noire Caromb' with 3% hydrogen cyanamide and 6% thidiazuron (Theron et al., 2011). In a study with the fig tree 'Zidi', Gaaliche et al. (2016) reported that 1.5% hydrogen cyanamide promoted increase in length of branches and therefore increased production.

Although the highest average of productive characteristics was observed on plants treated with hydrogen cyanamide, nitrogen fertilizer should not be disregarded in fig crops, since there was a quadratic growth for productive traits average in both seasons, independently of the product. Due to its non-toxicity, nitrogen fertilizer could be indicated as an alternative in which the use of hydrogen cyanamide as a bud sprout inducer is not allowed.

Principal component analysis

The PCA of both fig and vegetative performance explained 67.2% (2015/2016) and 66.6% (2016/2017) of the data variation with the first two components (PC1 + PC2) (Figure 8A and B).

Regarding to PC1 scores in both seasons, we found that products and control were clearly separated. Most of control and nitrogen fertilizer scores were on the left side of PC1, while hydrogen cyanamide stood on the right side. Based on PC1 loadings, the variables that most contributed to this separation were number of days for budbreak, number of buds, diameter and length of the branches. The largest number of days for budbreak is strongly correlated to control plants or plants that received the lowest concentrations of nitrogen fertilizer. It means that the scores on the opposite side negatively correlate with this variable, which reinforces the efficiency of hydrogen cyanamide in reducing the number of days for fig plants to sprout. But hydrogen cyanamide scores strongly correlate with higher number of buds, branch length and diameter, since these traits are paired with productive performance variables in PC1 (Figure 8A and B).

By analysing the PC2 loadings and scores in both seasons, we found that the variables that most contributed to the separation were the number of leaves, leaf area, number of fruits and yield. In the 2015/2016 season, the highest concentrations of nitrogen fertilizer positively correlated with the number of leaves per branch and leaf area, while hydrogen cyanamide positively correlated with the number of fruits and yield in both seasons (Figure 8A and B).

With regards to PCA, it is evident that the use of hydrogen cyanamide is positively correlated with both growth and production variables. It is important to highlight that using higher concentrations of nitrogen fertilizer (3 and 4%), provided an increase in vegetative and productive performance of plants. Also, the scores corresponding to the control plants negatively correlated (opposite side) with the number of fruits and yield in both seasons (Figure 8A and B). Therefore, stating the positive effect of the products on plants, especially hydrogen cyanamide on fig tree 'Roxo de Valinhos'.

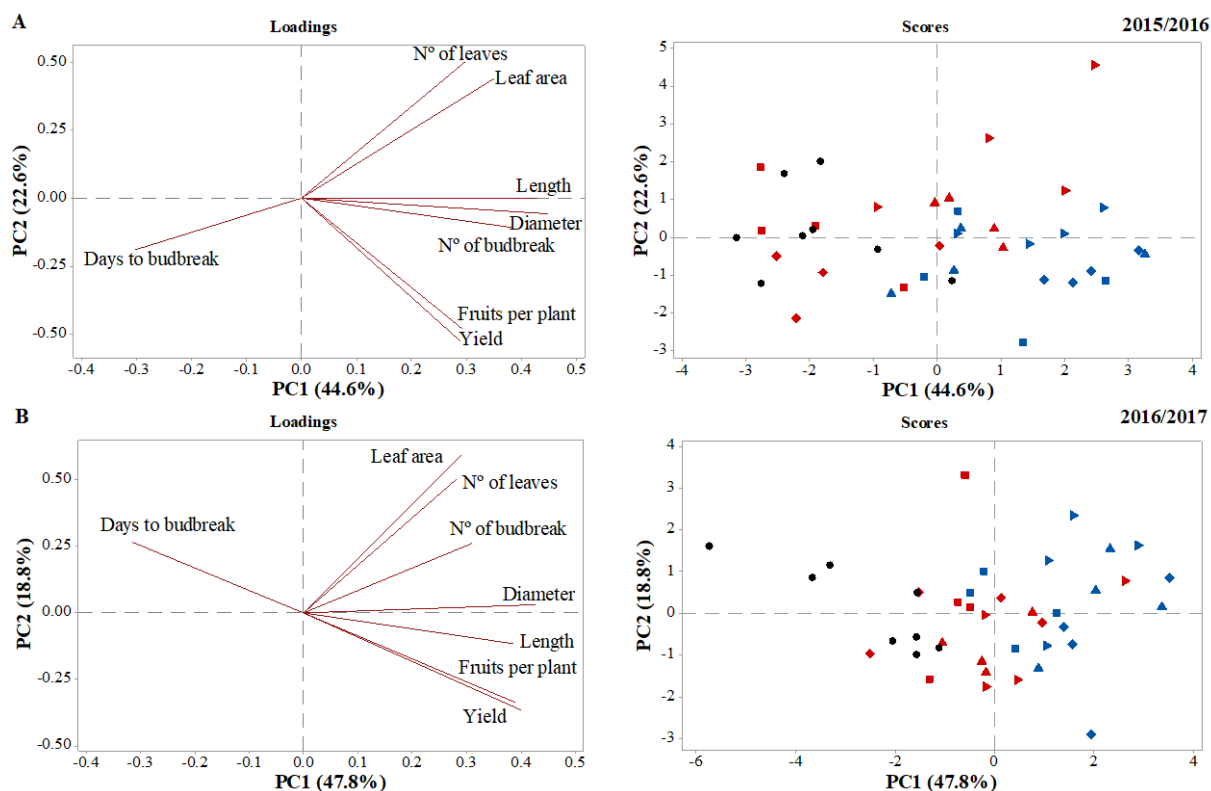


Figure 8. Principal component analysis of the vegetative and productive performance data of the fig tree in the 2015/2016 (A) and 2016/2017 (B) seasons. Left: loadings of variables on PC1 and PC2. Right: observation loadings. Observations were classified by products: control (black), hydrogen cyanamide (blue) and nitrogen fertilizer (red). In addition to the classification by concentration: 1% (■), 2% (◆), 3% (▲), and 4% (►).

Conclusion

The use of hydrogen cyanamide and nitrogen fertilizer anticipates budbreak in the ‘Roxo de Valinhos’ fig tree, as well as better plant vegetative performance at 2-3% hydrogen cyanamide and 4% nitrogen foliar fertilizer. Both products also promote better production performance at 2.1% and 2.7%. Results showed plants with less vigorously vegetative condition in the absence of applications (control); consequently, less productive plants, which was evidenced by principal component analysis. Moreover, this analysis reinforces the positive effect on the vegetative and productive performance of ‘Roxo de Valinhos’ fig tree, mainly hydrogen cyanamide.

Acknowledgements

This work was supported by the National Council for Scientific and Technological Development (CNPq) to scholarship granted for the lead author (#140429/2014-2).

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