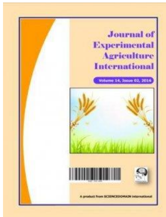

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Production and Quality of Palm Fruits Submitted to Neem Oil

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

The objective of this study was to evaluate the influence of Neem oil on insect management, on production and quality of palm fruits. The experiment was carried out at the Palma Agricultural Center, Federal University of Pelotas. Nine genotypes of palms (*Butia odorata*) were selected, presenting an estimated age of 20 years and production of four bunches. The doses of Neem oil used were: T1 (0.0 mL L^{-1}), T2 (2.0 mL L^{-1}), T3 (4.0 mL L^{-1}) and T4 (6.0 mL L^{-1}). At the beginning of maturation, three samples of 30 fruits each were collected and taken to the pomology laboratory. The experimental design was completely randomized and unifatorial. The means were submitted to analysis of variance and, when significant, were submitted to the Tukey test. The values of mean production cycle, SS/TA ratio, the epidermis colorimetry and number of lesions per bunch reduced in the treatments with Neem oil. The values of mean fruit mass per bunch, mean fruit mass, mean pulp mass, mean juice volume, pulp yield, number of fruits per bunch and effective fruiting increased in T4. The use of Neem oil is effective in the management of flower insects and palm fruits.

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Keywords: Arecáceas; Butia odorata; genotypes; insects.

1. INTRODUCTION

In Brazil, Lorenzi et al. [1] report the presence of several species of palm trees scattered throughout the most diverse points of the territory. Among them, the species derived from the Arecáceas family, such as *Butia catarinensis*, *Butia odorata*, *Butia paraguayensis* and *Butia yatay* are some of the main specimens of this family.

According to the Mapping of Plant Cover and Zoning of the Biotic Environment of the Middle Coast of Rio Grande do Sul for area IV (regions of up to 20 meters high) of the RS Biodiversity Project [2], the estimate of the *Butia* family and associated plant communities is approximately 6,605 ha.

Geymonat & Rocha mention the presence of fruits of the *B. odorata* species in Uruguay, specifically in the Rocha and Treinta y Tres districts [3]. The density of plants is highly variable, with few areas exceeding 100 individuals per hectare. It should be noted that the production of this species can reach more than 50 kg of fruit per plant (adult).

In order to meet the growing demand by the population and industries for new essences and flavors, the palms are an excellent income alternative for the Rio Grande do Sul state agriculture [4]. For Schwartz et al. [5], in the international market, there is an increase in the demand for fruits with new aromatic substances, new flavors and textures. It is in this contextualization that Brazil comes in as a potential supplier of these natural plant resources.

Species of insects have adapted their life cycle to the production cycle of the palm. In the initial flowering period of *B. odorata*, the insect species begin their breeding cycle, at which time flowers and fruits are partially or totally damaged by oviposition, sap sucking, or by the cycle of partial or complete development of insects within the fruits, resulting in the falling and even nullity of fruit production. This is a matter of concern to family farmers and agroindustries in the region, who depend on the production of this native fruit.

According to Araújo Jr. et al. [6], the action of Neem (*Azadiracta indica*) oil, as an insect repellent, food reducer, growth inhibitor, sterility and interference in metamorphosis have been used as an alternative method to combat insects.

Despite the significant damage to the palms (*B. odorata*), caused by insects and diseases, and the importance of the production of its fruits, technical recommendations are scarce for pest and disease management and control, as well as few identified pests.

Based on the above, as well as the fact that, to date, there is practically no research on the behavior of palm (*B. odorata*) fruit under the addition of insect repellent substances, this research aimed to evaluate the influence of Neem oil on insect management, and on the production and quality of palm fruits.

2. MATERIALS AND METHODS

The experiment was conducted at the Professor Antônio Rodrigues Duarte da Silva Didactic Orchard of the Palma Agricultural Center (CAP) owned by the Federal University of Pelotas - UFPel, located in the municipality of Capão do Leão - RS, latitude 31º52'00"S, longitude 52°21'24"W and an altitude of 13.24 meters. The soil of the site presents moderate depth, medium texture in the \`A\` horizon and clayey in the \`B\` horizon, being classified as Red Yellow Argisol according to Santos et al. [7]. The region climate is characterized as subtropical, with hot summers, "Cfa", according to the Köppen classification. This region presents average annual temperature of 17.9°C and average precipitation of 1370 mm year^{-1}. The active germplasm bank presents 132 genotypes derived from palm (*B. odorata)* species, with a spacing of 6 x 3 m, producing 40 t/ha, each plant can reach an average production of 80 kg/plant, an arrangement that simulates a commercial production inexistent in Brazil to date.

The selection of the nine genotypes was based on a draw of plants with a minimum estimated age of 20 years (age estimated by the count of the leaves on the stem) and minimum production of four bunches.

From October 2, 2015 (average period of beginning of flowering), the observation of the nine genotypes destined to the experiment was started, extending until April 25, 2016 (average period of harvesting).

In order to investigate the opening of the peduncular bracts (PB) and consequent exposure of the inflorescences, visits were made every 48 hours, since the opening and breaking of the same can be influenced by different climatic conditions.

As a source of Neem oil, the commercial insecticide NeenMax® (1% Azadirachtin) was used. The concentrations used were: T1 (0.0 mL L^{-1}), T2 (2.0 mL L^{-1}), T3 (4.0 mL L^{-1}) and T4 (6.0 mL L^{-1}). The applications were started in synchrony with the onset of full male flowering (FMF). Intervals of 7 days were set, and extended for six weeks in order to protect the inflorescences until the initial period of development of the fruits.

The first inflorescence of each genotype was received treatment T1 (control). The control only received distilled water. The second inflorescence of each genotype was treated with T2. The third inflorescence of each genotype was treated T3. The fourth inflorescence of each genotype received the T4 treatment.

In the initial maturation period of the bunches (beginning of natural detachment of fruits from the rachillae), three samples were collected (repetitions) composed of 30 fruits from each bunch, totaling 90 evaluated fruits of each of the treatments for each genotype, and taken to the Pomology laboratory (LabAgro) of the Federal University of Pelotas.

The following physicochemical variables were analyzed:

- Mean production cycle (MPC): Determined by the calculation of the number of days from the date of full bloom to the day of harvest and expressed in days.
- Mean fruits mass per bunch (MFMB): Determined by the measurement of the average mass of the total fruits produced in each of the bunches, by digital scale and expressed in grams (kg).
- Mean fruit mass (MFM): Determined by the mean mass of the fruit from samples collected from the bunch (three samples of 30 fruits from each bunch), by digital scale and expressed in grams (g) [8].
- Mean pulp mass (MPM): Determined by the measurement of the average mass of the pulp of the palm fruits, by digital scale and expressed in grams (g).
- Mean mass of the pyrenes (MMPy): Determined by the measurement of the average mass of the pyrenes, intact and separated from the fruit pulp, by digital scale and expressed in grams (g).
- Pulp yield (PY): Represented by the amount of pulp present in 100g of fruits, and expressed in percentage (%).
- Mean juice volume (MJV): Obtained by measuring glass Becker cups of the total juice produced in each sample of 30 fruits, and extracted by a Juice & Co model of the Walita centrifugal extractor, with results expressed in milliliters (ml).
- Soluble solids (SS): Determined from the juice sample of 30 fruits. Measured through refractometry using a Shimadzu refractometer, using a small amount of pure juice from each sample, sufficient to fill the cavity of the apparatus where the light beams are fired obtaining the results expressed in degrees Brix (°Brix) [8].
- Titratable acidity (TA): Determined by neutralization titrations, with the dilution of 10 mL of pure juice in 90 mL of distilled water and titration with 0.1 N NaOH solution until the juice reaches pH 8.2 in percentage of citric acid [8].
- SS/TA ratio (SS/TA): Calculated after obtaining the values resulting from titratable acidity (TA) and Soluble Solids (SS), by the equation SS/TA [8].
- Epidermis Colorimetry (EC): Determined by the measurement of two readings in the equatorial region (opposite) of each fruit, using the Minolta Colorimeter, brand Konica Minolta Chroma Meter CR-400/410, with illuminant D65, opening of 8 mm diameter, calibrated according to manufacturer instructions. The device performs a three-dimensional reading L* a* b*, where L* values correspond to luminosity or brightness, ranging from 100 (white) to 0 (black). With these values, the hue values (h° angle) were calculated, and expressed in degrees by the equation h° = tg - 1.b*/a*.
- Effective fruiting (EF): Determined by the estimated number of female flowers present in each inflorescence, by counting the units present in 15 rachillae subdivided between the basal, median and apical portions of each inflorescence at the beginning of full male flowering (FMF) and compared to the number of fruits

harvested, being expressed in percentage (%).

- Attacked fruits: determines the number of fruits that presented damages (lesions) caused by insects of the *Bruchidae* family, for their proper identification and confirmation, insect samples, found and colleted in the lesioned fruits, were sent to the Entomology Laboratory of the Federal University of Pelotas, were it was confirmed the pest insect *Pachymerus nucleorum* commonly called "larva do coquinho". The visual symptoms in the fruit epidermis were quantified, an example of fruit lesions is shown in Fig. 1. With this, the percentage of fruits attacked (%) was determined, based on the average yield of 725 fruits/plant. An attacked fruit was considered to be that with one or more lesions greater than 5 mm, and the reduction of infestation levels (%) by the use of Neem oil, compared to the control (T1).

The experimental design was completely randomized and uniformed (four treatments), with three replicates of 30 fruits each. The data were analyzed for normality by the Shapiro-Wilk test, and homoscedasticity by the Hartley test. Subsequently, the data were submitted to analysis of variance ($p \leq 0.05$). In the case of significance, treatment means were analyzed by the Tukey test ($p \leq 0.05$), and data that showed significance were submitted to regression analysis, using the statistical program ASSISTAT 7.5.

The linear regression equation can be represented by: "$y = a + bxi + \epsilon$", and quadratic regression equation can be represented by: "$y = a + bxi + cxi^2 + \epsilon$ where: "y" is the dependent variable, or criterion; "a" is the constant, or the intercept between the line and the orthogonal axis; "b and c" are the parameters, standardized coefficient of regression, or weight; “xi" is the independent variable (predictor) and "ϵ" is the error or residual, which refers to the difference between observed and predicted values.

3. RESULTS AND DISCUSSION

The mean production cycle (MPC) showed significant differences between the averages of the treatments. T1 treatment had the longest cycle (87.61 days), while the other treatments presented the lowest indexes and did not differ (T2 = 80.00 days, T3 = 78.17 days and T4 = 76.83 days) (Table 1).

These averages are below the results obtained by Schwartz et al. [5], who obtained an MPC of approximately 90 days in palm (*B. odorata)* fruits. The cited authors emphasize that a longer cycle may be connected to a possible occurrence of a greater number of days with low temperature in that cycle, thus the crop may have required a longer time to reach the thermal sum.

With increasing doses of Neem oil, there was a reduction in MPC values, being slightly more than 10 days lower when the dose of 6.0 mL L^{-1} was used in relation to the zero dose (Fig. 2A). The increase in the number and average mass of the fruits may have required a higher energy expenditure for its development, resulting in the anticipation of the harvest in the fruits under the action of Neem oil. Comiran et al. point out that the importance of the reduction of the productive cycle lies in the fact of making the produce available in the consumer market in advance, before the period of greater supply, resulting in higher selling prices [9].

Fig. 1. Symptoms of damage caused by the *Pachymerus nucleorum* beetles, from the Bruchidae family, commonly called “larva do coquinho”, of palm (*Butia odorata*) fruits, in Southern Brazil. FAEM-UFPel, Capão do Leão - RS, 2016

According to Souza et al. [10], late pruning may lead to a prolonged production cycle of fig trees, since they have more thermic needs, due to the removal of existing blooms. This makes the plant require the redirection of physiological processes once again, for the consequent formation of new productive structure.

In Fig. 2, the mathematical models that describe significant variables ($p \leq 0.05$) analyzed in the study, as well as the respective coefficients of determination (R^2) achieved with the fit of the data are presented.

The mean fruit mass of per bunch (MFMB) showed significant differentiation between the treatments averages (Table 1). Treatment T4 had the highest mean mass (11.18 kg), T3 had an intermediate mass content (8.58 kg), while T2 and the control (T1) had the lowest mean values and did not differ from each other (5.57 kg and 5.58 kg, respectively).

MFMB averages increased significantly as the doses of Neem oil used increased, with an average production estimated to be approximately 6 kg higher when the maximum dose (6.0 mL L^{-1}) was compared to the control (Fig. 2B). These results corroborate with Caproni et al. [11], who, in a research carried out with strawberries, inferred that the higher the amount of Neem oil applied, the higher is the production. Along with the pest insects control of the Bruchidae family, genus *Pachymerus* sp. [12], with the description of *P. necleorum* [13] by the use of Neem oil, which reduces infestation.

The average values of MFMB did not corroborate with the results obtained by Nunes et al. [4], who obtained an average of 3.872 kg of fruits from palms produced in the same active germplasm bank (BAG) as the *B. odorata* species. These averages are far below the current averages when compared to the control. This fact may be related to the estimated age of those genotypes used, as well as to the great variability of existing characteristics in this species of palms.

The mean fruit mass (MFM) presented significant differences between the means of the treatments (Table 1). T4 had the highest mean mass (356.14 g), T3 presented intermediate mass content (308.76 g), while T2 and the control (T1) presented the lowest averages and did not differ from each other (267.17 g and 266.88 g, respectively).

The mean pulp mass (MPM) showed significant differences between the means of the treatments (Table 1). Treatment T4 had the highest mean mass (313.90 g), T3 had intermediate values (266.60 g), while the T2 and the control (T1) had the smallest means and did not differ from each other (224.33 g and 223.32 g, respectively).

With increasing doses of Neem oil applied to palm bunches, there was a substantial increase in the means of MFM (Fig. 2C) and MPM (Fig. 2D), being 89 g and 91 g higher, respectively, with the use of 6 mL L^{-1} in relation to the zero dose. Nunes et al. obtained an average of 308.7 g for MFM and 254.7 g for MPM in palm fruits [4], being below the values found in treatment T4. This increase may be related to the action of Neem oil in reducing the damage caused by insects. These Bruchidae insects drill in the pulp (mesocarp) of *B. odorata* fruit where they deposit their eggs, consequently, generating larvae which feeds on the almonds, causing great losses of production [12-13-14]. The titratable acidity (TA) presented significant differences between the means of the treatments (Table 3).

Table 1. Mean production cycle (MPC in days), mean fruit mass per bunch (MFMB in kg), mean fruit mass (MFM in g) and mean pulp mass (MPM in g) of palm (*Butia odorata*) fruits submitted to Neem oil. FAEM-UFPel, Capão do Leão – RS, 2016

Treatments	Production cycle (days)	Fruit mass per bunch (kg)	Fruit mass (g)	Pulp mass (g)
T1*	87,61 ±1.45a**	5.58 ±1.10c	266.88 ±5.38c	223.32 ±4.25c
T2	80.00 ±2.56b	5.57 ±0.83c	267.17 ±3.16c	224.33 ±3.16c
T3	78.17 ±2.80b	8.58 ±1.02b	308.76 ±3.14b	266.60 ±2.71b
T4	76.83 ±2.77b	11.18 ±1.16a	356.14 ±3.19a	313.90 ±2.95a
M. G.	80.65	7.73	299.74	257.04
C. V. (%)	2.15	14.08	3.48	3.06

** T1 (0.0mL L-1 Neem); T2 (2.0 mL L-1 Neem); T3 (4.0 mL L-1 Neem) and T4 (6.0 mL L-1 Neem);*
*** The mean ± standard deviation of replicates, mean followed by the same letters in the column do not differ by Tukey test at the 5% probability level;*

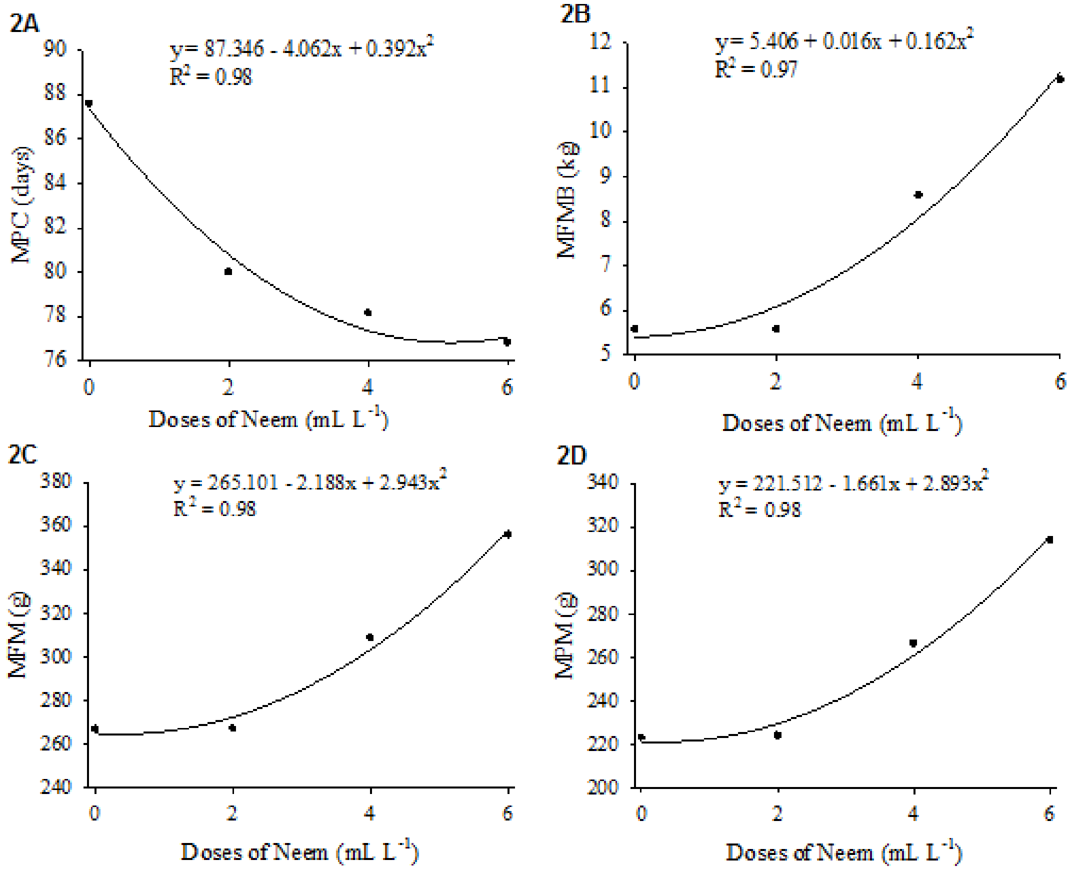

Fig. 2. Regression analysis of significant variables Mean Production Cycle (MPC: 2A), mean fruit mass per bunch (MFMB: 2B), mean fruit mass (MFM: 2C) and mean pulp mass (MPM: 2D) of palm (*Butia odorata*) fruits submitted to Neem oil. FAEM-UFPel, Capão do Leão - RS, 2016

Treatment T2 had the lowest percentage (2.73%), while T4 presented the highest percentage (3.35%). The other treatments presented intermediate values and did not differ from each other (T3 = 3.03% and T1 = 3.11%).

The SS/TA ratio presented significant differences between the means of the treatments (Table 3). T2 treatment had the highest mean (4.88), the control (T1) and T3 had intermediate means and did not differ from each other (4.13 and 4.04, respectively), while T4 presented the lowest mean (3.70) (Fig. 3B).

The mean juice volume (MJV) presented significant differences between the means of the treatments (Table 3). Treatment T4 had the highest mean volume (128.00 mL), T2 and T3 presented intermediate volumes and did not differ from each other (105.67 mL and 101.25 mL, respectively), whereas the control (T1) presented the lowest volume (91.00 mL).

The doses of Neem oil resulted in an increase in MJV, which was estimated to be of 38% for the 6.0 mL L^{-1} dose compared to the zero dose (Fig. 3C). With the reduction of the perforations in the fruits (Table 2), the fruits may have benefited by a possible reduction of energy expenditure for the regeneration of the tissues damaged by the buccal apparatus of the insects, and by the insertion of the ovipositor apparatus.

According to Kerbauy [15], any type of mechanical damage or attack of microorganisms suffered by the plant, generates an increase in the respiratory rate. Such an increase may be related to the regeneration activity of the affected tissue or to the production of defense substances of the plant, since the tissue will have to produce secondary metabolic substances related to the defense, as well as the synthesis of macromolecules related to the construction of new tissues during reconstitution.

Table 2. The percentage of attacked fruits (%) and the reduction of infestation (%) of palm (*Butia odorata*) fruits submitted to Neem oil. FAEM-UFPel, Capão do Leão - RS, 2016

Treatments	Attacked fruits (%)	Infestation reduction (%)
T1*	42.67 ±1.28c**	0
T2	44.27 ±1.03c	0
T3	14.87 ±1.28b	27.79
T4	7.08 ±1.34a	35.59

** T1 (0mL L^{-1} Neem); T2 (2.0 mL L^{-1} Neem); T3 (4.0 mL L^{-1} Neem) and T4 (6.0 mL L^{-1} Neem);*
*** The mean ± standard deviation of replicates, mean followed by the same letters in the column do not differ by Tukey test at the 5% probability level;*

Table 3. Titratable acidity (TA in % citric acid), SS/TA ratio (SS/TA), mean juice volume (MJV in mL) and epidermis colorimetry (EC in °Hue) of palm (*Butia odorata*) fruits submitted to Neem oil. FAEM-UFPel, Capão do Leão - RS, 2016

Treatments	Titratable acidity (%acid citric)	SS/TA ratio	Juice volume (mL)	Epidermis colorimetry (ºHue)
T1*	3.11 ±0.12b**	4.13 ±0.10b	92.71 ±0.53c	71.92 ±0.07a
T2	2.73 ±0.09c	4.88 ±0.14a	105.67 ±0.40b	70.76 ±0.05a
T3	3.03 ±0.08b	4.04 ±0.09b	101.25 ±0.48b	66.37 ±0.09b
T4	3.35 ±0.05a	3.70 ±0.13c	128.00 ±0.35a	65.51 ±0.03b
M. G.	3.06	4.19	106.91	68.64
C. V. (%)	1.05	2.62	2.82	1.17

** T1 (0.0mL L-1 Neem); T2 (2.0 mL L-1 Neem); T3 (4.0 mL L-1 Neem) and T4 (6.0 mL L-1 Neem);*
*** The mean ± standard deviation of replicates, mean followed by the same letters in the column do not differ by Tukey test at the 5% probability level;*

As it can be seen in Table 2, the 4 and 6 mL L^{-1} doses of Neem oil in palm fruits reduced the damage caused by insects (Fig. 1), in the order of 27.79 and 35.59%, respectively. The insecticidal properties of the Neem plant (*Azadirachta indica* A. Juss Meliaceae) come from the Azadirachtin tetranortriterpenoid complex that has the highest toxic activity against insects, and exists in a larger proportion in the seeds, from which the Neem oil is extracted [16-17]. As it can be observed in this experiment, Neem oil controlled the attack of *P. nucleorum*, with a dose higher than 4 mL L^{-1}, besides having systemic activity, efficiency at low concentrations, low toxicity to mammals and less probability of resistance development, since it acts in different places in the organism of the insect [18]. Neem oil can be considered a promising alternative for the control of insects in palm (*B. odorata*) fruits, due to its short residual period [19] and its selectivity to mammals [17].

The reduction of the level of fruit infestation by the insects by use of Neem oil may have benefited the pulp yield due to the greater accumulation of reserve substances in the fruits (Table 2). According to Kerbauy [15], some external variables must be considered, such as climate changes and insect attack, as they provide changes in respiratory rates acting on plant photosynthesis capacity, influencing the accumulation of reserve substances within the fruits, and, therefore, interfering directly in cell division and fruit pulp volume.

Fig. 3 shows the mathematical models that describe significant variables ($p \leq 0.05$) analyzed in the study, as well as the respective coefficients of determination (R^2) achieved with the data adjustment.

The epidermis colorimetry of the fruit (EC) showed significant difference between the means of the treatments (Table 3). Treatment T1 had the highest index (71.92 °Hue), while T4 had the lowest index (65.51 °Hue). T2 and T3 showed intermediate and different values (70.76 °Hue and 66.37 °Hue, respectively).

There was a linear reduction of EC as the Neem oil doses increased, reducing by approximately 6.0 °Hue in the dose of 6.0 mL L^{-1} of Neem oil compared to the control (Fig. 3D). The use of Neem oil interfered with the color indexes of the palm (*B. odorata*) fruits, and this influence may have occurred by the variation in the bioactive compounds that provide the coloration of the fruits as shown in the study of Canuto et al. [20], and Zeraik et al. [18]. The yellow coloration of the fruits is associated with the content of the carotenoid compounds.

The increase of the insect attack on the palm fruits may have favored the greater accumulation of coloration due to the energetic expenditure of the fruits with the production of secondary metabolites related to the healing process in response to insect damage, causing a greater amount of chlorophyll to be degraded and accumulated in the form of bioactive compounds [20-21]. According to Beskow et al. [22], palm (*B. odorata*) fruits are characterized as rich in phenolic substances and carotenoids.

The pulp yield (PY) variable presented significant differences between the means of the treatments (Table 4). Treatment T4 presented the highest yield (87.52%), whereas the control (T1) had the lowest yield (81.95%). The other treatments had intermediate values and did not differ from each other (T3 = 85.67% and T2 = 84.08%).

In Fig. 4, the mathematical models that describe significant variables (p ≤ 0.05) analyzed in the study, as well as the respective coefficients of determination (R²) achieved with the fit of the data are presented.

Increasing doses of Neem oil provided a linear increase in pulp yield (PY). The maximum dose of Neem oil provided an increase of approximately 6.0% RP when compared to the control (Fig. 4A). This increase may have been influenced by the increase of the average pulp mass and the maintenance of the average mass of the pyrenes.

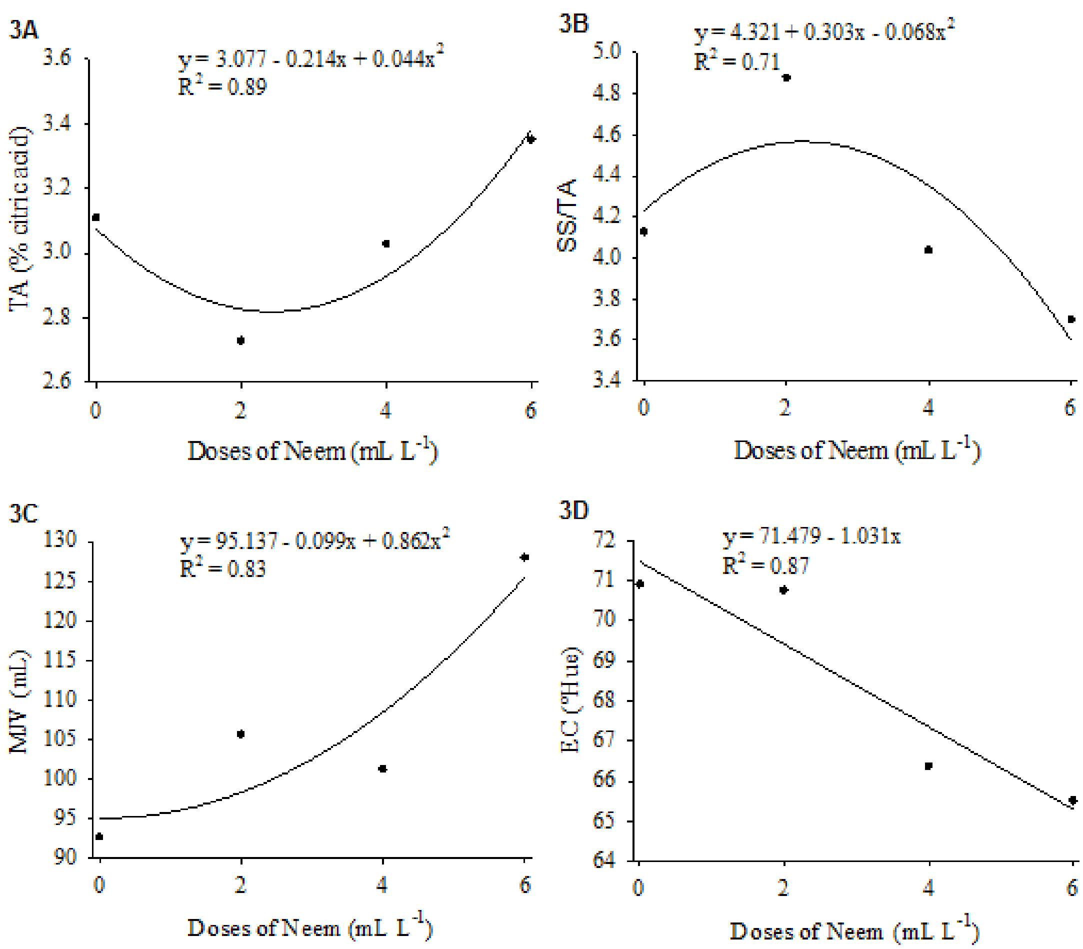

Fig. 3. Regression analysis of significant variables titratable acidity (TA: 3A), SS/TA ratio (SS/TA: 3B), mean juice volume (MJV: 3C) and epidermal colorimetry (EC: 3D) of palm (*Butia odorata*) fruits submitted to Neem oil. FAEM-UFPel, Capão do Leão - RS, 2016

Table 4. Pulp yield (PY in %), number of fruits per bunch (NF/B), number of lesions per bunch (NL/B) and effective fruiting (EF in %) of palm (*Butia odorata*) fruits submitted to Neem oil. FAEM-UFPel, Capão do Leão - RS, 2016

Treatments	Pulp yield	Number of fruits per bunch	Number of lesions per bunch	Effective fruiting
T1*	81.95 ±1.44c**	415.64 ±9.35c	21.39 ±1.99a	32.00 ±2.02c
T2	84.08 ±0.81bc	404.00 ±7.52c	21.74 ±1.81a	32.54 ±2.09c
T3	85.67 ±0.38ab	617.17 ±9.30b	15.48 ±1.53b	46.21 ±2.43b
T4	87.52 ±0.64a	673.67 ±9.71a	9.06 ±1.17c	50.22 ±2.35a
M. G.	84.81	527.62	16.92	40.24
C. V. (%)	1.38	7.72	8.22	13.15

** T1 (0.0mL L-1 Neem); T2 (2.0 mL L-1 Neem); T3 (4.0 mL L-1 Neem) and T4 (6.0 mL L-1 Neem);*
*** The mean ± standard deviation of replicates, mean followed by the same letters in the column do not differ by Tukey test at the 5% probability level;*

The variable number of fruits per bunch (NF/B) showed a significant difference between the means of the treatments (Table 4). Treatment T4 had the highest number (673.67), T3 had intermediate fruit numbers (617.17), while the control (T1) and T2 presented the smallest number of fruits and did not differ from each other (415.64 and 404.00, respectively) (Table 4).

The increase of NF/B was linear; increasing as the doses of Neem oil applied in the palm bunches increased (Fig. 4B). At the maximum dose (6.0 mL L^{-1}), there was an increase of 62.08% in the number of fruits per cluster when compared to the control. Thus, it can be suggested that the repellent action of Neem oil did not interfere in the efficiency of the action of the pollinating fauna, interfering only in the pest insects.

Azevedo et al. [23] infer that the use of products with Azadirachtin is recommended for the management of fruit flies in guava orchards. They point out that the effectiveness of these products is not 100%, but they can be used in the management of *Anastrepha* spp. due to the ease of application and low cost.

Significant increases in the means of NF/B, MFMB, MFM and PY may have been influenced by the decrease in the variable number of lesions per bunch. With the use of the maximum dose of Neem oil (6.0 mL L^{-1}), there was a reduction of the insect attack on the bunches and on the consequent damage or premature falling of female flowers and fruits in the early stages of development. A factor that may have promoted the improvement of the quality of palm fruits.

The number of lesions per bunch (NL/B) showed significant differences between the averages of treatments (Table 4). Treatment T4 had the lowest value (9.06), T3 had an intermediate value (15.48), whereas the control (T1) and T2 presented the highest values and did not differ from each other (21.39 and 21.74, respectively).

The increasing doses of Neem linearly reduced the number of lesions per bunch, with a reduction of 57.64% of the lesions in relation to the zero dose, when the 6.0 mL L^{-1} dose was used (Fig. 4C). This reduction in the number of lesions may have been influenced by the action of Neem oil on the repulsion and food reduction of the insects visiting the inflorescences of *B. odorata*, as reported by Farah et al. [24]. In addition to the fact that the maximum dose of Neem provided the greatest effective fruiting, it can be inferred that the fauna pollinator was not significantly affected.

The effective fruiting (EF) showed a significant difference between the averages of the treatments (Table 4). Treatment T4 had the highest mean (50.22%), T3 had an intermediate value (46.21%), whereas the control (T1) and T2 presented the lowest values and did not differ from each other (32.00% and 32.54%, respectively).

With increasing doses of Neem oil, the effective fruiting of palm fruits was linearly increased, with the maximum dose (6.0 mL L-1) increasing slightly more than 18% when compared to the control (Fig. 4D). This shows that the use of Neem oil repelled insects that cause damage and falling during flowering, preserving the floral development and effective palm (*B. odorata*) fructification. In studies in areas cultivated with coconut trees, Fontes et al. reported an insect pest that causes damage in the flowering period, the floral peduncle borer (*Homalinotus coriaceus*)

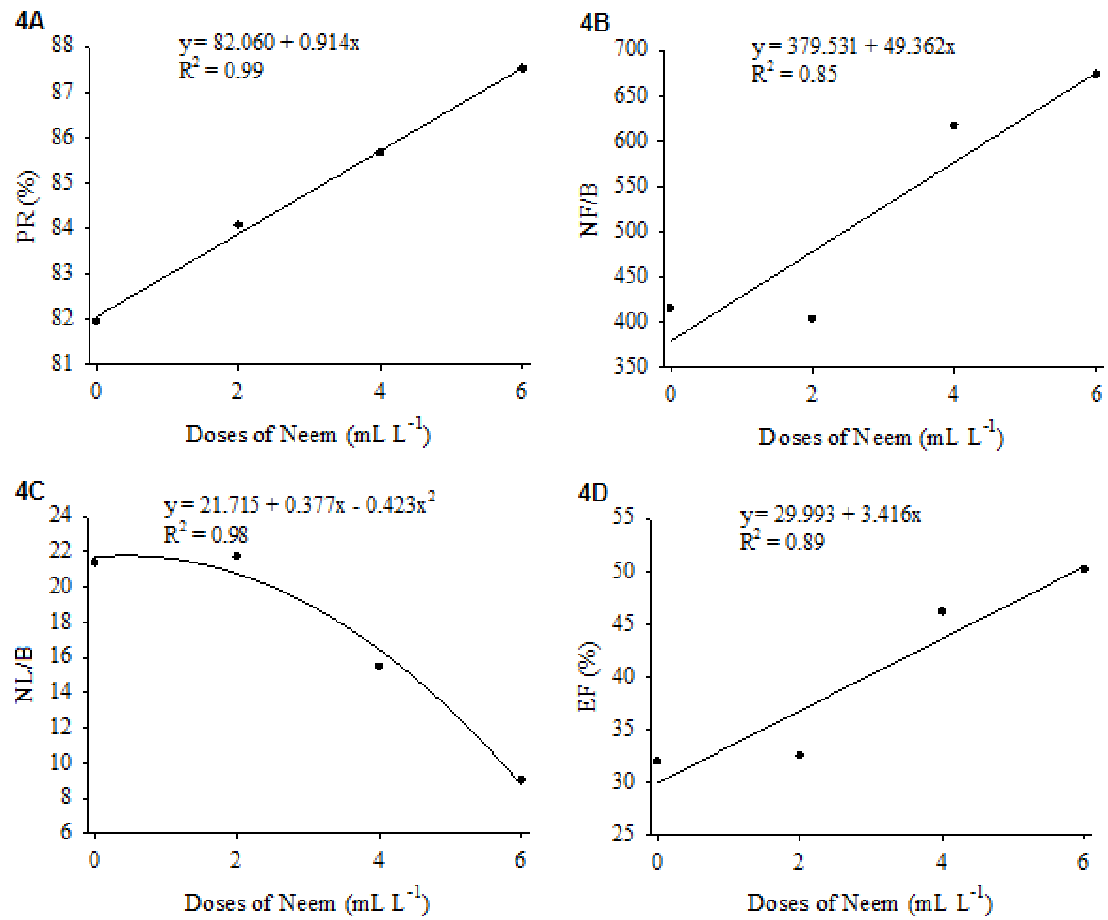

Fig. 4. Regression analysis of significant variables: pulp yield (PR: 4A), number of fruits per bunch (NF/B: 4B), number of lesions per bunch (NL/B: 4C) and effective fruiting (EF: 4D) of palm (*Butia odorata*) fruits submitted to Neem oil. FAEM-UFPel, Capão do Leão - RS, 2016

was responsible for significant damage in production [25].

According to Silveira et al. [26], the action of insects, such as the Irapuá bee (*Trigona spinipes*), is highly detrimental to the fruiting of several fruit trees, due to the damages (holes and scraping) caused in the flowers. They point out that, for the blueberry tree, the reduction of effective fruiting reaches 27%, while the normal fruiting is 60%. For *B. odorata* on the other hand, with the use of a Neem oil dosage of 6 $mL.L^{-1}$, a mean effective fruiting of 50% was presented. Without the application of Neem oil, the fruiting reached only 32%, with the insects present in the experimental field.

The soluble solids (SS) did not show significant differentiation between the averages of the treatments. Treatment T1 presented 12.34 °Brix, T2 presented an index of 12.85 °Brix, T3 presented 12.05 °Brix and T4 had 12.30 °Brix. These averages are slightly below the values reported by Nunes et al. [4], who obtained an average of 14.53 °Brix in for the palm (*B. odorata*). According to Nunes et al. [27], this difference between the averages can be related to the high genetic variability among the individuals of this species.

The Mean mass of the pyrenes (MMPy) did not show significant difference between the averages of the treatments. The control (T1) had 39.22 g, T2 had 40.00 g, T3 with 39.50 g and T4 with 41.45 g. Schwartz et al. [5] obtained averages of 68.1 g of MMPy in palm (*B. odorata*) fruits, being approximately 74% above the averages in the present research.

4. CONCLUSIONS

The application of a Neem oil (NeenMax®) dose of 6.0 mL.L^{-1} promotes an increase in the average fruit weight per bunch, average fruit weight, average pulp weight, average juice volume, pulp yield, number of fruits per bunch, effective fruiting, as well as reducing the number of lesions per bunch, improves palm (*B. odorata*) fruits titratable acidity and mean juice volume, being effective for the management of flower insects.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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