Guava fruit loss caused by rust

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Data de chegada: 11/07/2013. Aceito para publicação em: 11/03/2014w.

10.1590/0100-5405/1904

ABSTRACT

Martins, M.V.V.; Silveira, S.F.; Maffia, L.A. **Guava fruit loss caused by rust.** *Summa Phytopathologica***,** v.40, n.2, p.107-113, 2014.

The aim of this paper was to estimate the loss caused by rust (*Puccinia psidii*) to 'Paluma' guava production in orchards located in Rio de Janeiro State. The disease intensity on the reproductive organs of plants was observed during two chemical control experiments carried out in 2003 and 2004. The loss was estimated based on simple linear regression and the production reduction (fruit number and weight ha^{-1}) on the incidence of diseased buds and fruits. In the first experiment, no relationship was established between incidence of diseased buds and loss since there was a delay in spraying and the incidence of buds showing rust was high (mean of 47%) at the beginning of flowering. In the second experiment (2003-2004), spraying occurred at the beginning of the epidemics and there was a linear relationship between incidence of diseased buds and loss, justifying fungicide intervention at this stage. For the fruiting stage, a significant relationship was found between incidence of diseased fruits and loss in both experiments. In the absence of chemical control, rust reduced fruit production by around 90%.

Additional keywords: *Psidium guajava*, Myrtaceae, *Puccinia psidii*

RESUMO

Martins, M.V.V.; Silveira, S.F.; Maffia, L.A. **Danos em frutos da goiabeira causados pela ferrugem.** *Summa Phytopathologica*, v.40, n.2, p.107-113, 2014.

Objetivou-se estimar os danos causados pela ferrugem (*Puccinia psidii*) à produção da goiabeira 'Paluma' em pomares localizados no estado do Rio de Janeiro. Intensidade de doença foi observada nos órgãos reprodutivos das plantas em dois experimentos de controle químico ocorrido em 2003 e 2004. Estimaram-se os danos através de regressão linear e a redução da produção (número e peso de frutos ha^{-1}) em função da incidência de botões e frutos doentes. No primeiro experimento, não foi obtida relação entre incidência de botões doentes e dano devido ao atraso nas pulverizações e à alta incidência de botões com ferrugem (média de 47%) no início da floração. No segundo experimento (2003-2004) as pulverizações foram realizadas no início da epidemia e houve uma relação linear entre incidência de botões doentes e dano justificando a intervenção com fungicidas neste estádio. Para o estádio de frutos, foi obtida relação significante entre incidência de frutos doentes e dano em ambos os experimentos. Na ausência de controle, a ferrugem reduziu a produção de frutos em torno de 90%.

Palavras-chave adicionais: *Psidium guajava*, Myrtaceae, *Puccinia psidii*

The loss caused by plant diseases is very important to guide study actions and research funding (3, 4). Loss has been estimated for several pathosystems in different experiments (14, 15, 16, 19, 21, 22), especially involving cereal crops and rust diseases (2, 14, 16, 22, 23, 24). However, studies of loss induced by rust disease on tropical fruit trees are scarce, but this has led to a large number of tropical pathosystems such as the Brazilian guava-rust pathosystem.

Brazil is the world's major producer of guava (*Psidium guajava* L.), which supplies local food industries of significant economic importance, especially in the southeastern and northeastern states of the country. Guava fruits are primarily consumed fresh or as sweet, jam, jelly, juice and ice cream; in addition, guava-derived foods are nutritionally important since the fruit shows high contents of sugars, vitamins A, B and C, fiber and minerals such as iron, calcium and phosphorus (28). Most guavas in the market are still produced domestically, and guava crops have great potential to expand, improving the productivity in Brazil and abroad (20). On the other hand, rust is a serious hazard to guava commercial production in Brazil; it is caused by the fungus *Puccinia psidii* Winter and is the most common and disseminated aerial disease affecting Myrtaceae in American countries. When *P. psidii* epidemics affect 'Paluma' cultivar, the most important commercial guava variety in Brazil, frequent fungicide spraying is required (9, 13). However, the effect of rust on guava yield has not been experimentally quantified yet.

P. psidii can infect various Myrtaceae species; it is also very destructive to eucalyptus forest and has recently been introduced in the Australian continent (5, 8, 10, 11). *P. psidii* has some physiological specialization to *P. guajava* since guava isolates are frequently non-virulent to eucalyptus and other hosts (1, 6). This relationship, however, is not absolute to designate *formae speciales* because certain guava isolates can induce mild symptoms in some eucalyptus genotypes and other hosts (1, 12). Chemical control with protective fungicides during flowering and mobile penetrant fungicides during fruiting is highly recommended for environments favorable to rust (17, 18). Humid regions with mild temperatures and long periods of leaf wetness during flowering and initial fruiting stages favor rust epidemics in guavas (26). The fungal rust infects the buds, the flowers and the young fruits of guava plants. In the nursery, the shoots of guava seedlings are severely affected, while in guava orchards the damage is primarily caused by lesions on reproductive organs. Large rust lesions completely jeopardize the quality of mature guava fruits. In addition, the rust lesion is a predisposing factor to decay by secondary infections (rot pathogens) and opportunistic insects in maturing fruits.

According to a study of the chemical control of guava rust (17), systemic fungicide spraying is necessary to ensure guava production under environmental conditions that are favorable to rust. The use of fungicides to obtain disease gradients in experiments focused on estimating losses does not always result in reasonable data, as obtained in the above-mentioned study. The importance of guava rust in Brazil and its potential to cause great losses to crops have evidenced high scientific relevance in analyzing losses based on the data of a previous experiment (17). There is no precedent in the scientific literature. Therefore, the aim of the present study was to determine the relationship between rust intensity and fruit yield for guava crops in Brazil.

MATERIALS AND METHODS

The studies were carried out based on the data from two experiments performed at a commercial orchard of 'Paluma' guava located in São Francisco do Itabapoana, Rio de Janeiro State, Brazil, during two consecutive crop seasons, in 2003 and 2004. The orchard was established in 1998, when 'Paluma' cultivar was planted at 7 x 6 m spacing. The plants reached 2 m height in the two experiments. Cultural practices had been done and pests had been controlled by using insecticide.

A randomized block design was adopted including seven and five treatments and five replicates in the first and second experiments, respectively. One plot consisted of one plant.

In the first experiment, from April to October 2003, the following systemic fungicides were sprayed: [azoxystrobin (100 mgL^{-1}), cyproconazole (150 mgL^{-1}), pyraclostrobin (100 mgL^{-1}), tebuconazole (150 mgL^{-1}) and triadimenol (310 mgL^{-1})] and the protective mancozeb (1600 mgL^{-1}). Control plants were only sprayed with water. Occurrence of rust on buds was determined at the beginning of spraying. Each organic fungicide was sprayed five times alternatively with copper oxychloride (2400 mgL^{-1}) at biweekly intervals after the disease was first detected. However, copper fungicide was sprayed only at the initial fruiting stage, when fruits were smaller than two cm in diameter, to avoid injuries to larger fruits (13, 25). Treatments stopped at the end of the susceptible phase, when fruits reached approximately four cm in diameter (26).

In the second experiment, conducted from September 2003 to May 2004, copper oxychloride at 2400 mgL^{-1} was first sprayed on all plants, except the controls. Copper oxychloride was sprayed twice, on the 3th and the 10th day after the disease onset. According to the obtained data, the average rust incidence on flowers and buds had reached 7% and copper spraying continued until the detection of around 10% flower/bud infection. After the initial copper spraying, the systemic fungicides azoxystrobin (100 mgL^{-1}), tebuconazole (150 mgL^{-1}) and triadimenol (310 mgL^{-1}), as well as the protective fungicide mancozeb (1600 mgL^{-1}), were applied five times. The control was only sprayed with water.

Rust incidence was evaluated every week in the first experiment, and at bi-weekly intervals in the second experiment. Four quadrants (north, south, east and west) of branches of each evaluated tree were marked. The total and the diseased buds and fruits were counted. The presence of one rust pustule on one bud or fruit was enough to consider the organ diseased. The incidence (%) of diseased buds and fruits was considered rust incidence [(number of diseased organs/total number of organs)*100]. The evaluations proceeded until approximately 80 days after the emergence of the first buds. At the end of the cycle (180 days after pruning), healthy fruits were harvested at three-day intervals. Guava yields were estimated based on the total fruit weight and by counting the total number of fruits per plant.

Relationships between disease intensity (diseased buds and fruit incidence) and loss (weight and total number of fruits per hectare) were obtained based on linear regression, using the critical point (CP) and the integral models (AUDPC, by Campbell and Madden, 1990), where "y" and "AUDPC" define the disease intensity (diseased flowers/buds or diseased fruit incidence) and the area under the disease progress curve, respectively. The mean AUDPC was calculated from the original disease incidence data versus time by means of AVACPD software (29). Using the critical point model, the maximum and the final diseased buds and fruit incidence and AUDPC were considered independent variables. The loss (dependent variable) in weight and number of fruits per hectare was estimated based on the difference from the plot with the highest yield, using the formula D = (MP – RP), where D is the yield loss, MP is the yield of the most productive plot (maximum production) and RP is the plot production (actual production). The loss in percentage was estimated according to the formula D(%) = (MP-RP/MP)*100. The obtained value underwent Anova and Tukey's test ($P \leq 0.05$). All statistical analyses were performed by using SAEG 9.1 software (30).

RESULTS

The fungicide treatments used to control rust led to different incidence of diseased buds and fruits (%) in both experiments. Rust incidence during flowering and fruiting directly influenced guava yield. In both experiments, rust was shown to be the main cause of yield loss (Figures 1, 2, 3 and 4). This was confirmed by a mean reduction of 24.324 kg guava fruits per hectare for plots without chemical spraying in the first experiment, which was equivalent to 91% of the average yield with the best treatment. In the second experiment, the mean reduction was 88%, corresponding to 19.627 kg fruits per hectare. There was an equivalent reduction in the number of fruits. Treatment with triadimenol provided the smallest loss caused by guava rust (Tables 1 and 2).

The final incidence of rust disease on fruits and the AUDPC were the only variables showing coefficient of determination (R^2) higher than 0.60 when the loss was estimated for weight and number of fruits per hectare (Figures 1 and 2). However, the maximum rust incidence for buds could not indicate the yield loss (Figures 1 and 2) because an average of 47% buds were already infected before fungicide spraying due to severe rust epidemics at the beginning of flowering and fruiting in the first experiment. In the second experiment, fungicides were applied earlier, and the incidence of diseased buds was low (7%). In the latter experiment, the final incidence of diseased buds, the maximum and the final incidence of diseased fruits and the AUDPC for fruits showed a

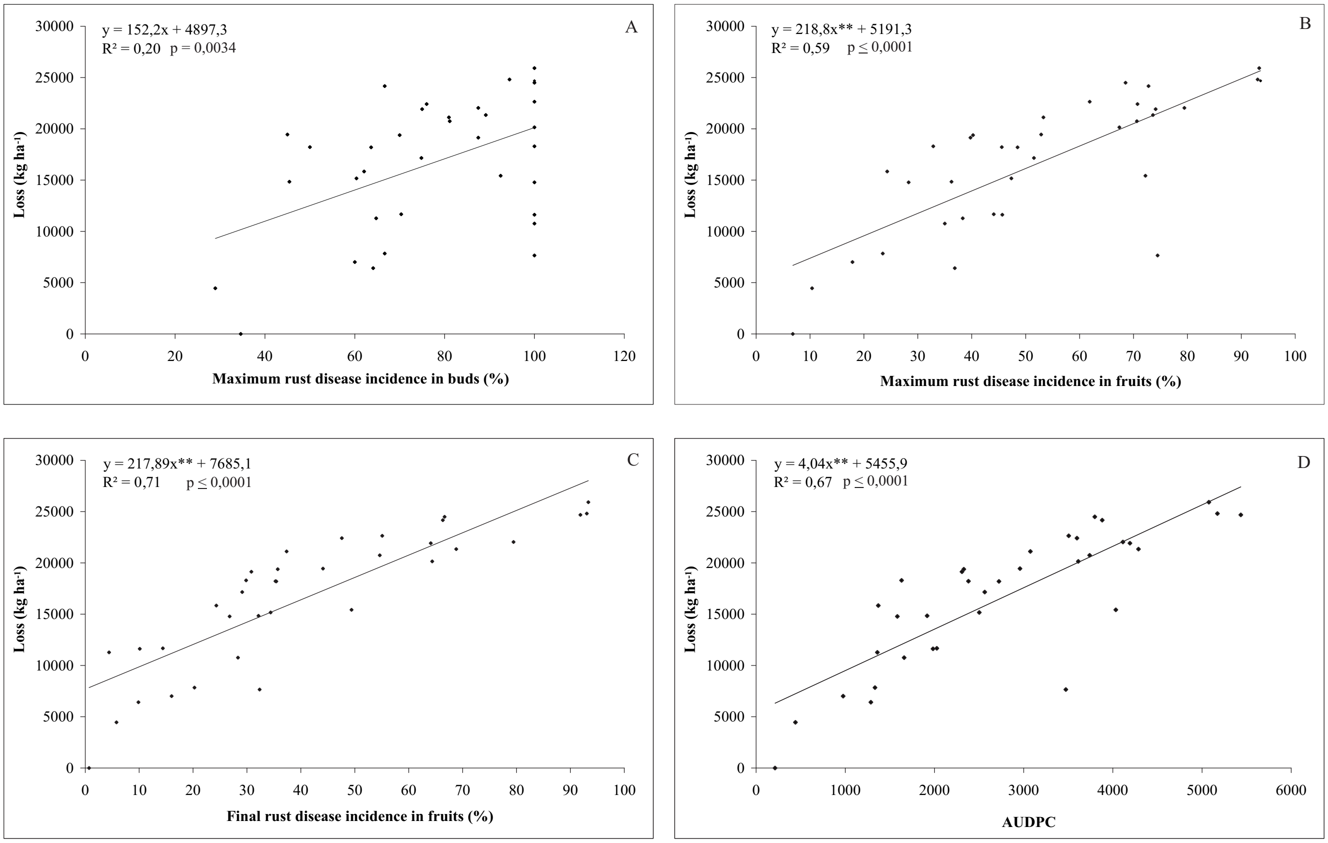

Figure 1. Relationship between guava loss (kg of fruits ha^{-1}) and maximum rust incidence for buds (A), maximum and final rust incidence for fruits (B and C) and AUDPC (D), obtained in 2003.

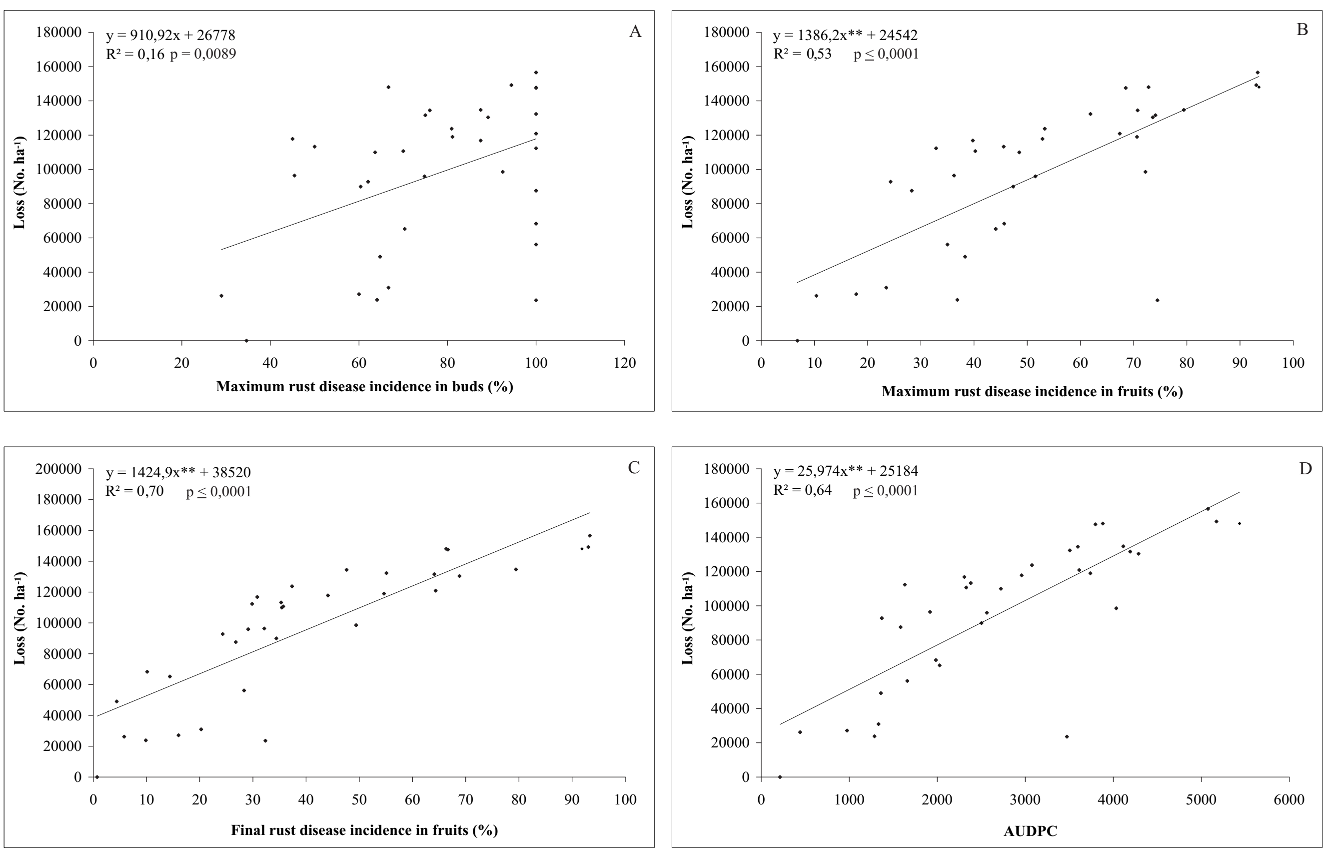

Figure 2. Relationship between guava loss (number of fruits ha^{-1}) and maximum rust incidence for buds (A), maximum and final rust incidence for fruits (B and C) and AUDPC (D), obtained in 2003.

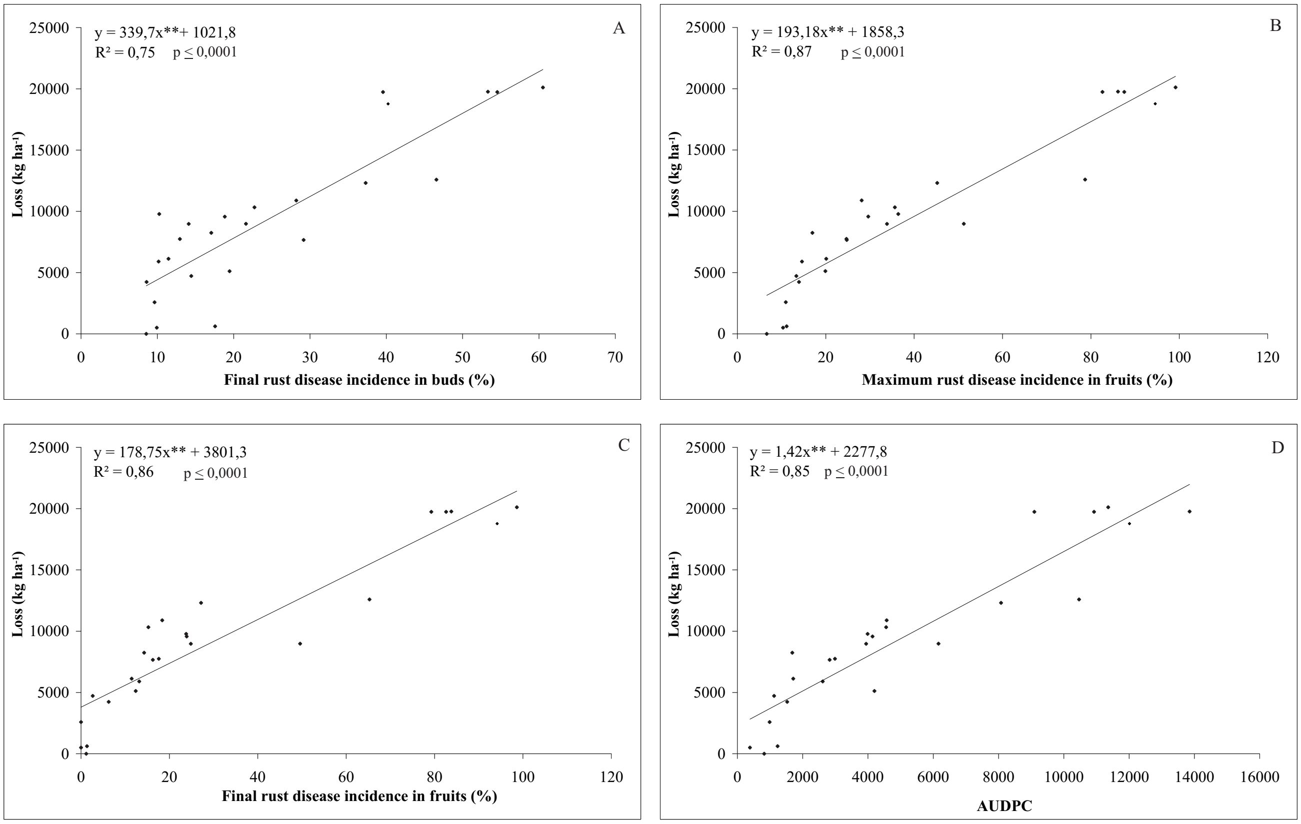

Figure 3. Relationship between guava loss (kg of fruits ha^{-1}) and final rust incidence for buds (A), maximum and final rust incidence for fruits (B and C) and AUDPC (D), obtained in 2003-2004.

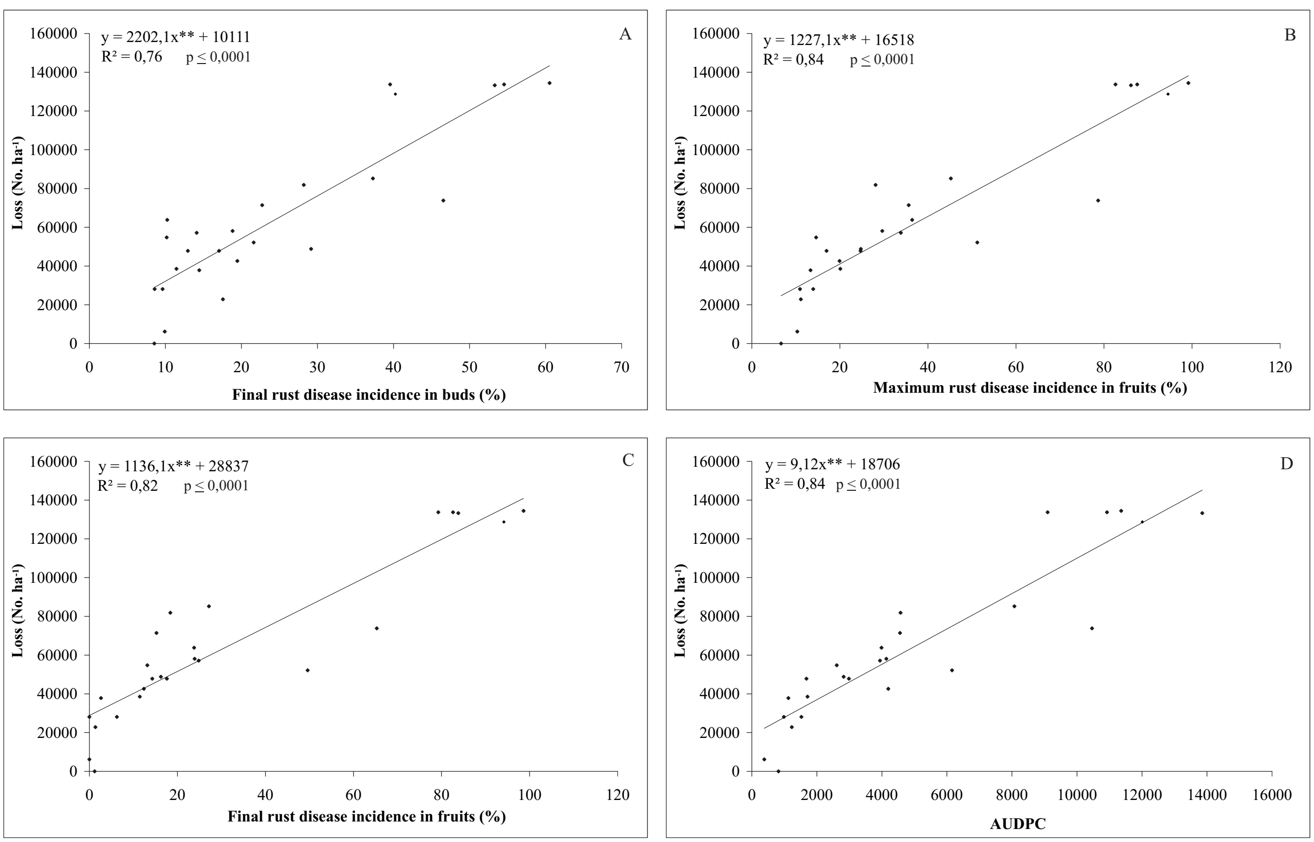

Figure 4. Relationship between guava loss (number of fruits ha^{-1}) and final rust incidence for buds (A), maximum and final rust incidence for fruits (B and C) and AUDPC (D), obtained in 2003-2004.

Table 1. Yield reduction due to rust, expressed as weight (kg) and number of fruits ha^{-1} in 2003.

Weight of fruits				
Treatment	Loss (kg ha^{-1})	Standard error	Loss (%)	Standard error
Triadimenol	7.404 b	4.720	28 b	17.63
Azoxystrobin	14.828 ab	7.163	55 ab	26.76
Cyproconazole	16.121 ab	1.865	60 ab	6.96
Pyraclostrobin	17.264 ab	6.385	65 ab	23.85
Mancozeb	17.721 ab	6.343	66 ab	23.69
Tebuconazole	18.555 a	3.945	69 a	14.74
Control	24.324 a	1.427	91 a	5.33
C.V. (%)	31			
Number of fruits				
Treatment	Loss (no. ha^{-1})	Standard error	Loss (%)	Standard error
Triadimenol	32.320 b	25.273	19 b	15.61
Azoxystrobin	87.822 ab	44.912	54 ab	27.75
Cyproconazole	95.914 ab	9.205	59 ab	5.68
Pyraclostrobin	100.341 ab	44.948	62 ab	27.17
Mancozeb	104.339 a	43.755	64 a	27.03
Tebuconazole	109.766 a	23.315	68 a	14.40
Control	147.322 a	7.904	91 a	4.88
C.V. (%)	35			

Table 2. Yield reduction due to rust, expressed as weight (kg) and number of fruits ha^{-1} in 2003-2004.

Weight of fruits				
Treatment	Loss (kg.ha^{-1})	Standard error	Loss (%)	Standard error
Triadimenol	1.685 c	1.963	7 c	8.8
Tebuconazole	6.804 b	1.639	30 b	7.35
Azoxystrobin	8.910 b	3.200	40 b	14.35
Mancozeb	9.979 b	1.502	45 b	6.73
Control	19.627 a	500	88 a	2.24
C.V.(%)	21			
Number of fruits				
Treatment	Loss (no. ha^{-1})	Standard error	Loss (%)	Standard error
Triadimenol	18.992 c	15.632	12 c	10.26
Tebuconazole	42.221 bc	8.937	28 bc	5.86
Azoxystrobin	60.976 b	8.269	40 b	5.42
Mancozeb	67.164 b	18.147	44 b	11.91
Control	132.804 a	2.301	87 a	1.51
C.V. (%)	20			

direct relationship to yield loss, either for weight or number of fruits per hectare. The reduction in weight and number of fruits per hectare could be explained by all analyzed variables, showing significant loss functions (Figures 3 and 4), and according to the linear regression equations, over 75% of the change in loss was a consequence of the disease (Figures 3 and 4).

There was a 93% correlation between the number of healthy fruits at the end of the susceptibility period and the final guava yield in the first experiment, while in the second experiment this correlation was 97% (Table 3).

DISCUSSION

Single-point and integral models were used to describe the relationship between rust incidence and guava crop production, at a single time and over the whole growth phase, respectively.

Yield loss caused by *P. psidii* has not been experimentally estimated for guava production. The phenology of guava reproductive phases provides practical support to establish a relationship between loss and yield. In the first experiment, there was a high incidence of diseased buds before spraying. Thus, most treatments showed high incidence of diseased organs (buds and fruits), and the maximum incidence of diseased buds did not describe precisely the loss in weight and number of fruits per hectare. Consequently, important loss function was not obtained for the maximum incidence of diseased buds, where R^2 was 0.20 and 0.16 for weight and number of fruits, respectively. Severe epidemics in the bud phase resulted in incidence of highly diseased fruits at the beginning of fruiting (high primary inoculum). Moreover, guava production was impaired by the initial number of infected buds. Before the fruiting phase, rust may affect the yield of a plant when there are infected buds. A significant correlation was obtained between the number of healthy buds and the yield. The greater amount of healthy buds contributes to increased production.

In the first evaluation of the disease in the second experiment, there were 0.5% infected buds. Environmental conditions were favorable to rust infection and from the fifth evaluation (=final incidence of diseased buds), the number of diseased buds remained well distributed

Table 3. Pearson's correlation coefficients between production (kg/plant) and mean number of healthy buds and fruits per guava tree ('Paluma' variety) obtained in 2003 and 2004.

Variables/ year of a field trial	Pearson's correlation	Significance
Maximum number of healthy buds / 2003	0.72	0.033
Final number of healthy buds / 2004	0.97	0.003
Maximum number of healthy fruits / 2003	0.82	0.012
Maximum number of healthy fruits / 2004	0.97	0.003
Final number of healthy fruits /first / 2003	0.93	0.001
Final number of healthy fruits / 2004	0.97	0.002

on the plant, even after two copper oxychloride sprayings and another spraying of systemic fungicides. There was a 97% positive correlation between healthy buds (fifth evaluation) and plant yield. This showed that maintaining the buds healthy is important to predict the harvest and reduce guava yield loss due to rust.

Even though the final incidence of diseased buds reached 25% of the total buds in the second experiment, fungicide application preceded by disease monitoring offered protection to the remaining buds, assuring an economic production of the best treatments. Thus, bud stage (equivalent to the beginning of the sprouting phase) was considered determinant to guava yield, and fungicide protection was considered desirable even when there is great bud fall due to natural abortion or rust itself.

The sprouting phase should be the initial phase to establish preventive rust control by spraying protective fungicides. On the other hand, as buds do not last long on the plant, systemic fungicides must be used, preferably when the first fruits (diseased or not) appear and under favorable conditions for the disease. In cases of delay or negligence in preventive control using protective fungicides, systemic fungicides must be sprayed on the buds, even if they do not last long (17, 18).

The final phase of fruit susceptibility must also receive attention for disease chemical control under favorable environmental conditions. This was observed when the AUDPC was analyzed over the evaluated period. There was a positive linear relationship between the loss expressed as weight and number of fruits per hectare and the AUDPC. The conclusion was that the whole susceptible period between flowering and the emergence of fruits smaller than four centimeters in diameter was also important in limiting guava yield. These findings also indicated that the initial fruiting phases, before the fruit size reaches four cm in diameter, must receive fungicide spraying during rust epidemics. Although the AUDPC showed coefficient of determination higher than 0.84 in the second experiment, bud and fruit phases can be considered critical to establish the economic loss threshold.

Rust loss functions should be used to improve decisions in the disease management. For example, when rust is particularly severe in the initial season (bud), the economic benefit of fungicide application to reduce rust incidence can be evaluated by determining the reduction in rust incidence based on the loss functions.

The single-point model has been employed to study the loss due to several diseases (23, 24). Reis *et al.* (24) have conducted trials to quantify the loss caused by *Cercospora zea-maydis* in corn and have reported that the single-point stage is feasible to predict the loss and calculate the economic loss threshold. For barley (*Hordeum vulgare*), Reis *et al.* (23) have shown that tillering stage reveals the best loss function. In these experiments, single-point stage was important to describe the loss in bud and fruit phases and have been allowed to obtain an increase in loss. The loss coefficient could be used to obtain the economic loss threshold, which should be calculated for every year according to guava valuation, fungicides and control cost.

The economic loss threshold has not been obtained yet for the chemical control of guava rust but has already been established for some pathosystems. Reis *et al*. (22) obtained the economic loss threshold of 12.7% for leaf rust incidence at the elongation stage. In these experiments, the loss equations were obtained under favorable environment for rust and should be used to predict the loss in different guava phases.

The relevance of *P. psidii* in 'Paluma' guava orchards in the north of Rio de Janeiro State has already been reported in epidemiologic research (26). However, the loss functions presented here reflected the importance of the disease in reducing crop yield during the most favorable seasons for the disease. Loss functions demonstrated that there was a linear relationship between buds and/or fruits showing rust and loss increase. Fungal infection in the fruit occurs continuously, the incidence of diseased fruits persists until fruits reach about four cm in diameter (from 70 to 80 days after pruning) (26). Thus, spraying with systemic fungicide has to be prioritized to restrain the emergence of new pustules and to prevent sporulating lesions on the remaining fruits. Considering guava fruit production for direct human consumption, the individual quality of the fruits could be impaired by the existence of a single rust pustule. In this case, loss could be even greater, since a fruit with one pustule can lose its commercial value. Use of the fungicide triadimenol led to lower loss because small rust pustules were extinguished and the lesions were healed (17). In the present study, a fruit with healed lesions was counted as healthy and the loss would then be underestimated.

Even assuming that the maximum fixation index of the guava fruit is 20% during flowering and fruiting phases (7, 27), all buds and fruits must be protected. As far as new control methods or new rust resistant cultivars are developed, fungicides should be used in the susceptible phases to keep as many healthy buds and fruits as possible to ensure the highest guava yield. Thus, the initial flowering phase must be considered critical and the most important phase to prevent rust attack. In this phase, protective spraying can result in better economic profits. Finally, an economic loss threshold of chemical spraying could be established based on the yield estimate at different stages of the year, considering that a high incidence of young diseased buds and fruits is followed by severe yield loss.

ACKNOWLEDGMENTS

The authors thank Rio de Janeiro State Research Aid Foundation (FAPERJ) for the scholarship provided to M. V. V. Martins, and Darcy Ribeiro Rio de Janeiro State University (UENF), which allowed this study to be undertaken. Special thanks to Mr. Luiz Cláudio Macedo Ramos, a kind farmer and owner of the guava orchard where the studies

were conducted; without his help and permission this study could not have been carried out.

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