Urban production of kale (*Brassica oleracea* var. *acephala*) in Brazil: survey of diseases and factors that contribute to their outbreak

Kercio Estevam da Silva[1]; Elida Barbosa Correa[2]; Edvania Abidon Silva[2]; Walter Efrain Pereira[3]; Julio Carlos Pereira da Silva[4]; Flávio Henrique Vasconcelos de Medeiros[1]

[1]Universidade Federal de Lavras. Depto. de Fitopatologia, CEP: 37200-000, Lavras, MG, Brasil; [2]Universidade Estadual da Paraíba, Sítio Imbaúba, Zona Rural, CEP: 58117-000, Lagoa Seca, PB, Brasil; [3]Universidade Federal da Paraíba. Depto. de Fitotecnia, CEP: 58397-000, Areia, PB, Brasil; [4]Universidade Federal de Santa Maria, Dep. de Defesa Fitossanitária, CEP: 97105-900, Santa Maria, RS, Brasil.
Corresponding author: Flávio Henrique Vasconcelos de Medeiros (flaviomedeiros@ufla.br)
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ABSTRACT

Silva, K.E.; Correa, E. B.; Silva, E. A.; Pereira, W. E.; Silva, J.C.P.; Medeiros, F.H.V. Urban production of kale (*Brassica oleracea* var. *acephala*) in Brazil: survey of diseases and factors that contribute to their outbreak. ***Summa Phytopathologica***, v.48, n.1, p.17-24, 2022.

Kale (*Brassica oleracea* var. *acephala*) is mostly produced by urban growers in Brazil, but little is known about the diversity and the management of diseases for sustainable urban agriculture. The present study investigated the occurrence of diseases in the urban cultivation of kale in two regions of Brazil, representing the climate conditions Cwa (Lavras - MG) and Aw (Campina Grande - PB) according to Köppen Geiger classification, as well as the factors that contribute to such occurrence. Growers in each region were visited every week during eight months while a survey was carried out on the diseases and the major crop management practices. In both regions, powdery mildew (*Erysiphe polygoni*) and black rot (*Xanthomonas campestris pv. campestris*) were the prevalent diseases. Relative humidity and high temperature were the environmental factors that contributed to increase the diseases. Management using straw mulch favored powdery mildew reduction and black rot maintenance. Consequently, kale intensive production resulted in higher black rot severity. These results demonstrated the importance of proper recommendations on management practices for urban agriculture with the aim of controlling kale diseases according to the climate conditions in the region.

Keywords: Urban horticulture; *Brassicaceae*; plant disease management; fungal diseases; bacteriosis.

RESUMO

Silva, K.E.; Correa, E. B.; Silva, E. A.; Pereira, W. E.; Silva, J.C.P.; Medeiros, F.H.V. Produção urbana de couve (*Brassica oleracea* var. *acephala*) no Brasil: levantamento de doenças e fatores que contribuem para suas epidemias. ***Summa Phytopathologica***, v.48, n.1, p.17-24, 2022.

A couve (*Brassica oleracea* var. *acephala*) é geralmente produzida por agricultores urbanos no Brasil, mas existem poucos estudos sobre a diversidade e manejo das doenças para produção sustentável em cultivos urbanos. Neste estudo, foi verificada a ocorrência de doenças na couve em cultivos urbanos de duas regiões do Brasil, representando as condições climáticas de Cwa (Lavras MG) e Aw (Campina Grande PB) pela classificação de Köppen Geiger e os fatores que contribuem para a ocorrência das enfermidades. Os produtores foram visitados semanalmente em cada região por oito meses e foi realizado o levantamento das doenças, bem como as principais táticas de manejo aplicadas pelos agricultores de cada município. Em ambas as regiões, o oídio (*Erysiphe polygoni*) e a podridão negra (*Xanthomonas campestris* pv. *campestris*) foram as doenças predominantes. A umidade relativa e alta temperatura foram os fatores ambientais que contribuíram para o aumento das doenças. O manejo com cobertura vegetal contribuiu para diminuir o oídio e para manter a podridão negra. Consequentemente, o cultivo intensivo de couve proporcionou um aumento da severidade da podridão negra. Esses resultados mostram a importância de recomendações adequadas de táticas de manejo utilizadas na agricultura urbana visando o controle de doenças da couve de acordo com as condições climáticas da área.

Palavras-chave: Horticultura urbana; Brassicaceae; Manejo de doenças de plantas; Doenças fúngicas; bacterioses.

Urban agriculture is the production of crops in small areas within a city or in its surroundings (periurban); it is found worldwide for familiar consumption or small-scale trade at local markets (4, 18), exerting social and environmental impacts on local development. Urban agriculture integrates a wide variety of production systems, relying exclusively on family labor and low crop management technologies or third-part labor combined with up-to-date crop management practices (21). In Argentina, Brazil, Cuba and other Latin American countries, governments have national policies and programs to promote urban horticulture (29). The demands for high quality foods in urban agriculture have encouraged the use of sustainable production technologies (9).

There are incentives, but not all crop management practices can be directly deployed from large-scale open-field to the small-scale urban production systems. For example, agrochemicals are not allowed in such systems, requiring identification of the diversity and importance of diseases for the development of sustainable management practices (23). Furthermore, low plant diversity, intensive production without crop rotation and overhead irrigation contribute to the risk of epidemics (8).

According to a preliminary survey, the most important plants used in urban agriculture are lettuce and kale (3). While a vast literature is available about lettuce production, including urban agriculture, little is available about kale. Standing out as an important foliar vegetable, kale (*Brassica oleracea* var. *acephala*) contributes to combat malnutrition, especially due to its high levels of calcium, iron, antioxidants and vitamin; therefore, its cultivation is in expansion (7, 16).

However, foliar diseases are one of the major limiting factors for *Brassicaceae* cultivation in tropical and sub-tropical areas. The genus *Alternaria*, which causes dark leaf spot, is responsible for great yield losses in Brazil and is one of the most important plant pathogens of the *Brassicaceae* family (24). Other fungal diseases such as powdery mildew (*Erysiphe polygoni*) and bacterial diseases such as soft rot (*Pectobacterium carotovorum* subsp. *carotovorum*) or black rot (*Xanthomonas campestris pv. campestris*) are important for kale production in Brazilian regions where the crop is mostly cultivated and consumed (12).

In urban agriculture, growers are not always familiar with the crop management practices or sensitive to early diagnosis of eventual phytosanitary problems. The ideal disease management is based on epidemiological knowledge, usually beginning with a plant disease survey to monitor fluctuation intensities, followed by verification of the efficiency and acceptance of the recommended control practices (27). Thus, identifying the factors that contribute to the occurrence of plant diseases will foster the design of proper management guidelines (1, 25); to the best of our knowledge, studies of the diversity of diseases, the conditions that favor their progress and the importance of management practices have not been proposed for kale cultivation in urban agriculture.

Therefore, kale diseases were surveyed in two urban areas in two regions of Brazil, representing the climate conditions Cwa (Lavras) and Aw (Campina Grande), according to Köppen Geiger (10), during eight months. The severity of dominant diseases in each location was recorded and a relationship of their progress with the climate conditions and the crop management practices was proposed.

MATERIAL AND METHODS

Urban growers and crop management practices

The studies were conducted with two groups of Brazilian urban farmers: in Lavras (Minas Gerais – MG) and Campina Grande (Paraiba – PB).

Growers from Lavras – MG cultivated kale (*Brassica oleracea* var. *acephala*) *Manteiga da Georgia* (Hortivale seeds, vegetable seeds), and *Manteiga* kale (Feltrini seeds) was produced by growers in Campina Grande.

In Lavras, the urban farming area is 7,500m² large and encompasses 24 families with an average of 240-m² plot per household. Their production includes different vegetables, but kale is one of the major crops throughout the year for all growers. The production is intended for the household or neighbors, and an eventual excess is sold to individual buyers and local restaurants (2).

The Community Garden of Santa Rosa in Campina Grande was created through a project intended for elderly people belonging to 10 different families 30 years ago. They share a total area of 10,000 m^2.

Plants were fertilized by adding cattle manure in the soil before each planting cycle. The cover straw consisted of weeds and wasted kale removed from the area onto the soil. Production system, straw use and irrigation system are described in Table 1.

Disease identification and quantification

To quantify the major diseases and identify the factors that may contribute to epidemics, four growers were randomly chosen in each studied location (Lavras and Campina Grande). Each grower had plants randomly chosen and weekly verified for the diversity and the intensity of each studied disease.

The etiology of each disease was determined based on symptoms, morphology of fungi and/or pathogenic ability, and tests of dominant diseases in the producing regions (3). For symptoms of bacterial diseases, isolation and reinoculation were performed (11, 12). Details on the diagnosis of each disease are presented in Table 2.

For each surveyed disease, the severity was evaluated based on a 0-4 scale, where 0 = 0%, 1 = 1% to 25%, 2 = 26% to 50%, 3 = 51% to 75%, and 4 = 76% to 100 %, adapted from Sidhu & Webster (26).

Statistical analyses

Data obtained in the disease severity assessments for kale plants were used to calculate the Area Under the Disease Progress Curve (AUDPC) (25). The data underwent comparisons of means, according to Kruskal-Wallis non-parametric tests at 5% probability. Similarly, non-parametric contrasts were performed between the AUDPC for each disease and each adopted crop management practice, using the

Table 1. Management practices adopted in Lavras - MG and Campina Gande - PB.

Cities	**Growers**	**Irrigation**	**Intensive Production**	**Straw (Kale + weed)**
Lavras	Grower 1 MG	Hose	No	No
	Grower 2 MG	Sprinkling and Hose	Yes	No
	Grower 3 MG	Hose	Yes	Yes
	Grower 4 MG	Watering can	No	Yes
Campina Grande	Grower 1 PB	Watering can	No	Yes
	Grower 2 PB	Hose and Watering can	Yes	Yes
	Grower 3 PB	Watering can	Yes	No
	Grower 4 PB	Hose and Watering can	No	No

Meteorological data were collected for both locations throughout the evaluation period and were correlated to each disease. In Lavras, the whole period included winter, spring and summer (2014) (Figure 1A), while in Campina Grande the collected data were from summer, autumn and winter (2014) (Figure 1B).

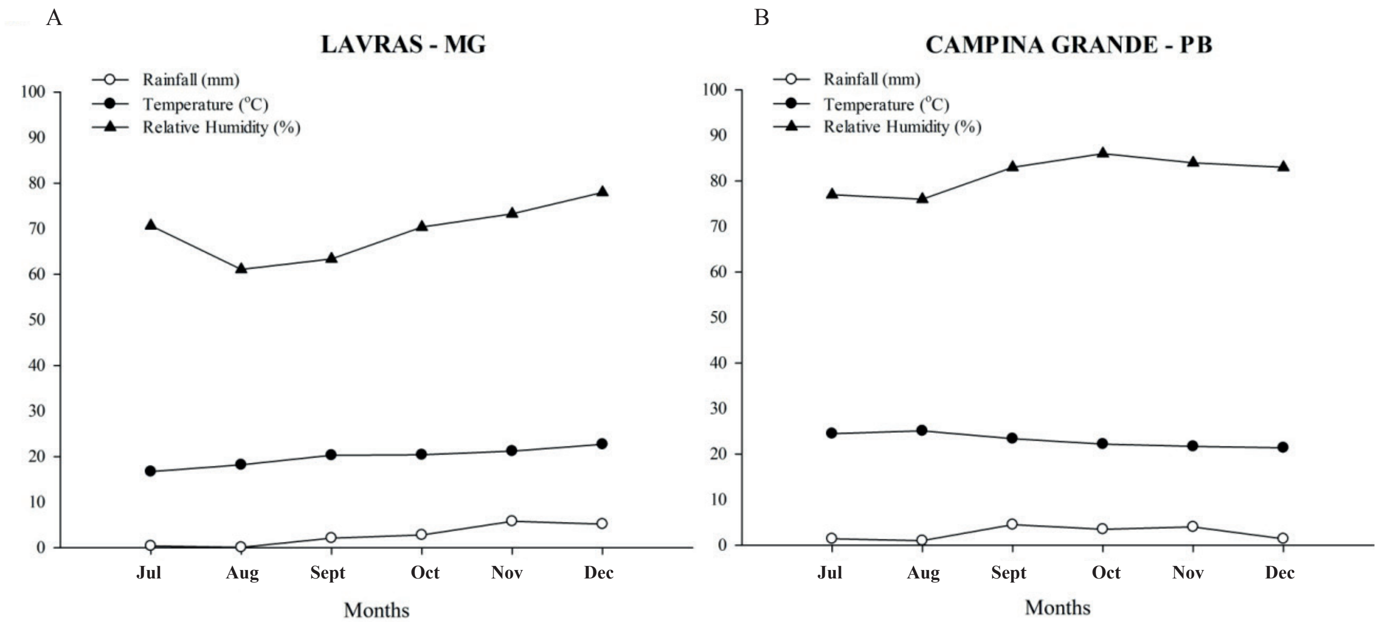

Figure 1: Enviromental conditions troughout the evaluated period, representing (A) Cwa in Lavras - MG and (B) Aw in Campina Grande – PB, based on Köppen Geiger climate conditions (10).

"Statistical Analysis System" program (SAS). Data analyses were demonstrated by box plot graph (box and whisker).

RESULTS AND DISCUSSION

Survey of diseases in Lavras–MG and Campina Grande–PB

During the study period, kale diseases found in Lavras were soft rot (*Pectobacterium carotovorum* subsp. *carotovorum*), *Alternaria* leaf spot (*Alternaria* spp.), black rot (*Xanthomonas campestris pv. campestris*), and powdery mildew (*Erysiphe polygoni*) (Table 2). The former two diseases were sporadic, while the latter two were prevalent throughout the period and were further studied for the conditions that favored epidemics.

In Lavras, the AUDPC for powdery mildew was similar throughout the period for all growers, showing no significant difference ($P = 0.05$) (Figure 2A). However, the effect of season was significant, and the disease severity was higher ($P < 0.01$) in the spring than in the winter (Figure 2B). The optimum temperature for powdery mildew onset is 25ºC together with high relative humidity (12, 22, 30), which are similar to the conditions found at urban gardens in Lavras during the spring and the summer (Figure 1A).

Black rot was another prevalent disease in Lavras and its progress differed among growers ($P < 0.01$). For growers 1, 2 and 4, AUDPC was similarly low, whereas severity progress was highest for grower 3 (Figure 2C). In the spring and in the winter, similar AUDPC was obtained ($P = 0.189$). The conditions reported as most favorable for *X. campestris* pv. *campestris* to penetrate and colonize leaf tissues are temperatures around 28ºC and high moisture on the leaf surface (Figure 2D). However, those environments were not found in Lavras (Figure 1A), even though other regions presenting the same conditions showed high severity (21). Thus, crop management practices seem to be more relevant for black rot since, under the environmental conditions in Brazil, *X. campestris* pv. *campestris* survives for more than 200 days in *Brassica* stubble (12).

During the whole study period, kale diseases found in Campina Grande were black rot (*Xanthomonas campestris pv. campestris*) and powdery mildew (*Erysiphe polygoni*). The severity of powdery mildew differed among growers ($P < 0.01$) and was highest for growers 1 and 4 (Figure 3A). Considering the seasons, severity was lower during the summer ($P < 0.01$), when relative humidity was less than 80% and temperatures were ca. 21ºC. Fungal growth was not favored by those

Table 2: Features of diseases in both surveyed municipalities.

Disease	Diagnostic markers	Conditions that favor epidemic	Location where it occurs
Soft rot (*Pectobacterium carotovorum* subsp. *carotovorum*)	Watering rotten internal tissue with an external dark color and a bad smell	Summer and spring overhead irrigation	Lavras - MG
Alternaria leaf spot (*Alternaria* spp.)	Dark brown circular spots with target-like concentric rings and yellow margin	Spring and winter overhead irrigation	Lavras - MG / Campina Grande -PB
Black rot (*Xanthomonas campestris* pv. *campestris*)	Green spots at first, becoming yellow and then brown. Affected areas are V-shaped	Summer, spring and winter overhead irrigation	Lavras - MG / Campina Grande -PB
Powdery mildew (*Erysiphe polygoni*)	White powdery spots on both surfaces making the leaf tissue under the powdery spot become yellow	Spring and winter overhead irrigation	Lavras - MG / Campina Grande -PB

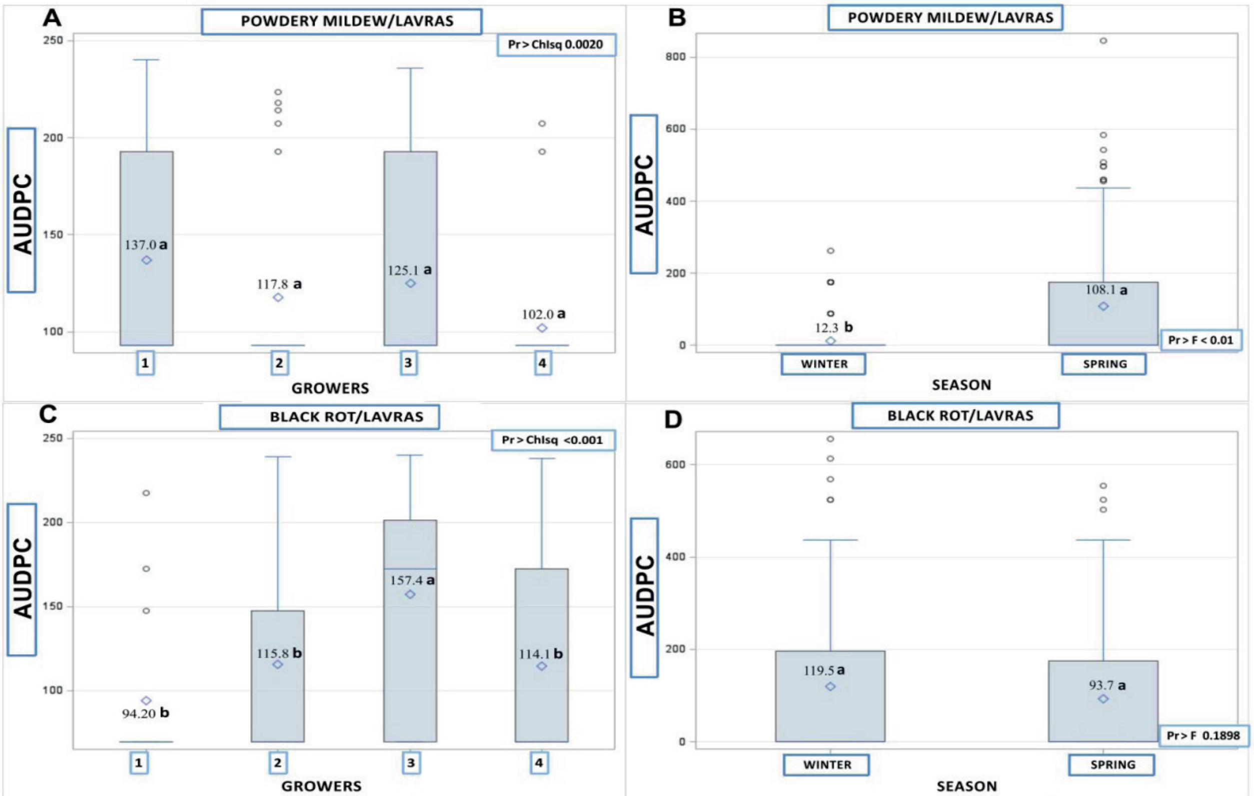

Figure 2: Severity of (a,b) powdery mildew (*Erysiphe polygoni*) and (c, d) black rot (*Xanthomonas campestris pv. campestris*) on kale in Lavras – MG among growers and seasons. Box plots show values of median (rhomb), upper and lower whiskers (bars) and the outliers (circles). Mean values followed by the same letter are not statistically different, according to Kruskal-Wallis test at 5% probability.

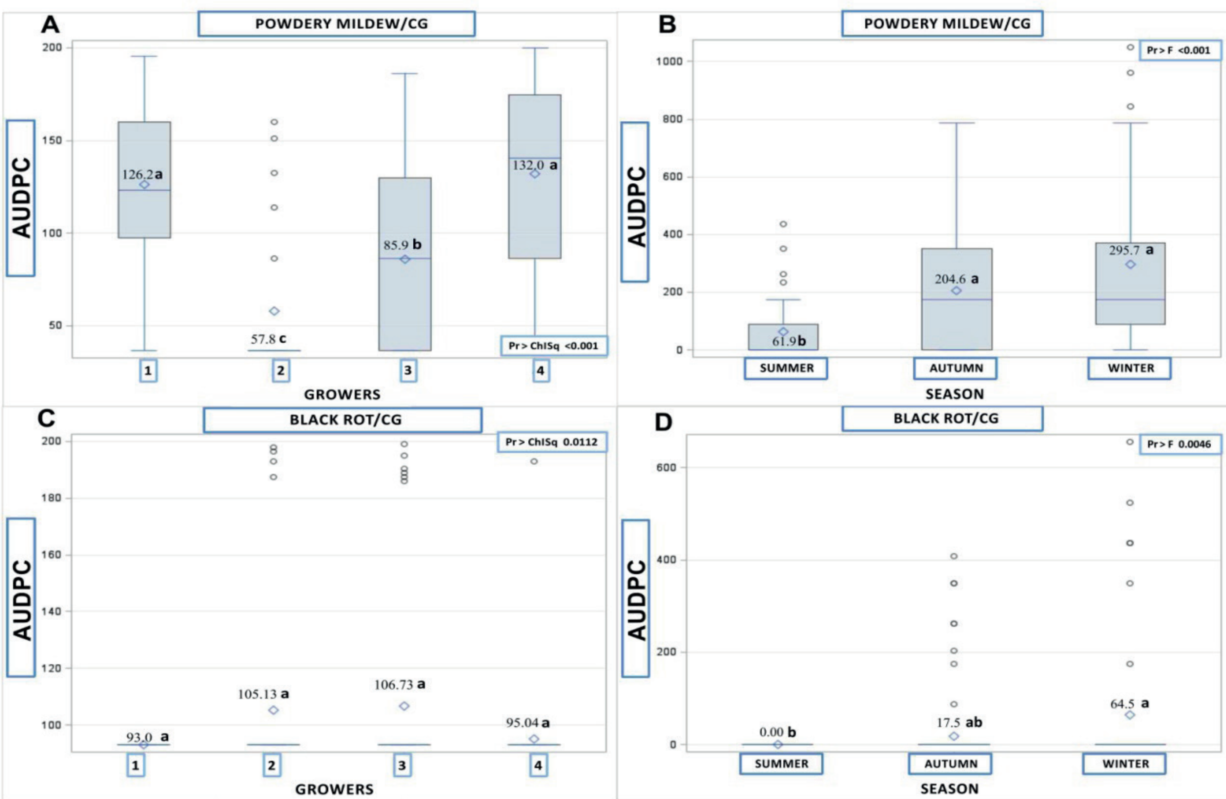

Figure 3: Severity of (a,b) powdery mildew (*Erysiphe polygoni*) and (c, d) black rot (*Xanthomonas campestris pv. campestris*) on kale in Campina Grande – PB among growers and seasons. Box plots show values of median (rhomb), upper and lower whiskers (bars) and the outliers (circles). Mean values followed by the same letter are not statistically different, according to Kruskal-Wallis test at 5% probability.

conditions, especially low humidity, which mostly contributes to the spread of the disease (22) (Figure 3B). In addition, intensive irrigation by the growers throughout the evaluated period may have further increased leaf wetness duration, which was already high due to the rainfall in the winter at that location.

Concerning black rot in Campina Grande, the AUDPC was the same for all growers (P = 0.074) (Figure 3C). However, the disease was lower during the summer (P = 0.030) (Figure 3D), supporting the idea that low humidity is the most important condition to the disease dissemination.

Considering the different disease severity levels based on the AUDPC, the crop management practices adopted in Lavras and Campina Grande (Table 1) may have contributed to the epidemics, and contrasts have determined the triggers for each disease and location. For example, differences could not be found between winter and summer regarding black rot severity in Lavras, whereas the AUDPC was higher for grower 3 than for the other growers (Figures 1 C and D).

Influence of management on the severity of diseases in Lavras-MG and Campina Grande-PB

In Lavras, the use of cover straw influenced the disease severity, decreasing both powdery mildew (P = 0.03) and black rot (P < 0.01) (Figure 4A), while the effect of irrigation did not have a significant difference on powdery mildew (P = 0.63) or black rot (P = 0.10) considering the increase in AUDPC (Figure 4B). The straw covers the soil with dead plant tissue; however, powdery mildew is a biotroph and, under tropical conditions, does not commonly produce cleistothecia, which would act as resting structures (12) while colonized by saprophytic microorganisms that may act as biological control agents, exerting protection for the shoot with microbially active molecular pattern (MAMP)-triggered immunity (6). On the other hand, necrotrophs such as *Xantomonas campestris* pv. *campestris* not only survive but also build up their population in crop residues; the kale straw cover prevents splash dispersal so that the bacterial inoculum hardly reaches the leaf and therefore the infection does not occur (17). Furthermore, the dry winter in Lavras did not favor the bacterial disease, but overhead irrigation supplied the pathogen with the required moisture for dispersal and infection.

Successive cultivation throughout the year in Lavras by harvesting leaves at least once a week led to higher black rot severity progress, compared to less intensive cultivation (P < 0.01). Continuous cultivation and harvesting would imply a lower disease inoculum; however, leaves

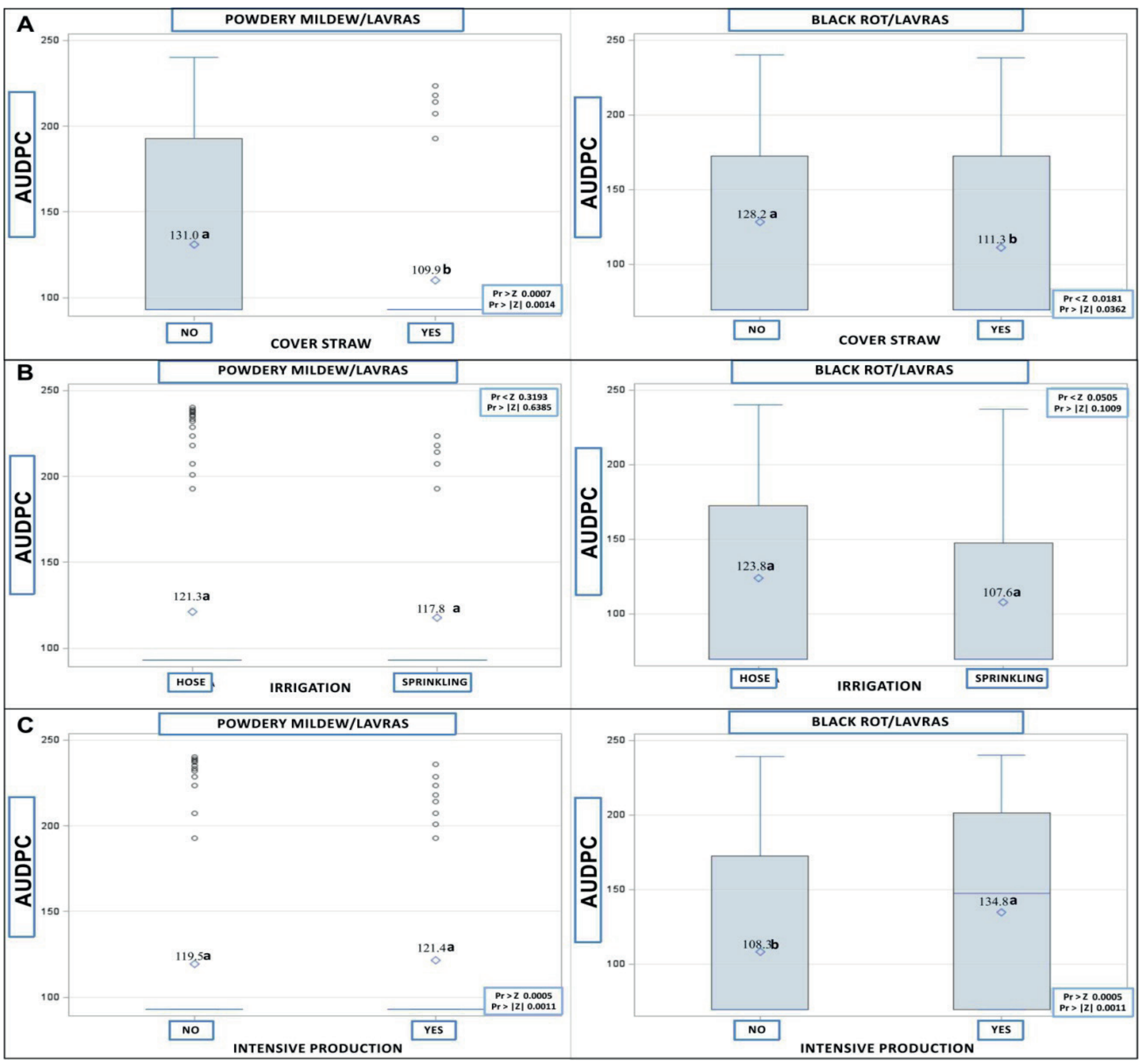

Figure 4: Influence of straw (A), irrigation system (B) and intensive production (C) on powdery mildew (*Erysiphe polygoni*) and (C) black rot (*Xanthomonas campestris pv. campestris*) severity in Lavras – MG. Box plots show values of median (rhomb), upper and lower whiskers (bars) and the outliers (circles). Mean values followed by the same letter are not statistically different, according to Kruskal-Wallis test at 5% probability.

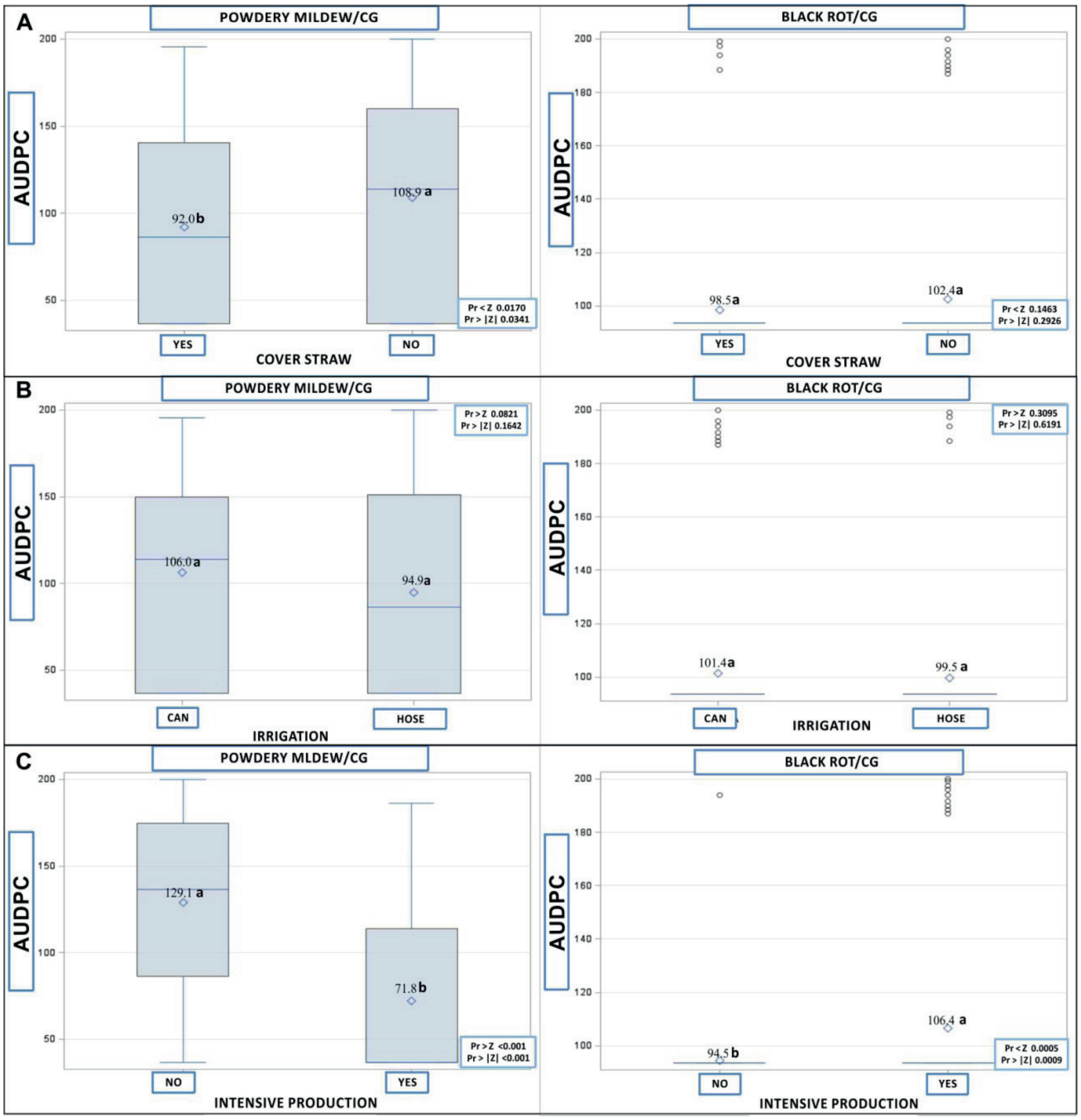

Figure 5: Influence of straw (A), irrigation system (B) and intensive production (C) on powdery mildew (*Erysiphe polygoni*) and (C) black rot (*Xanthomonas campestris pv. campestris*) severity in Campina Grande - PB. Box plots show values of median (rhomb), upper and lower whiskers (bars) and the outliers (circles). Mean values followed by the same letter are not statistically different, according to Kruskal-Wallis test at 5% probability.

showing black rot symptoms are not suitable for commercialization and are left in the field as cover straw, thus contributing to the buildup of inoculum in the field and increasing black rot severity over time and space (8). Under such a condition, bacteria always have a plant tissue to colonize. However, for powdery mildew, the intensive kale production did not contribute to increase the disease outbreak (P = 0.77), since the fungus is biotrophic and only survives in live plant tissue (Figure 4C). Furthermore, intensive kale production with uninterrupted nutrient consumption by the plant and without proper fertilizer supply may interfere in the plant defense mechanisms against powdery mildew (15, 28), which was not the case for the areas of the present study, where cattle manure was applied when necessary. Black rot severity was highest for grower 3, compared to the other growers, in Lavras (Figure 1C); grower 3 had the most intensive kale production in terms of numbers of harvests and successive cultivation within the same site (Table 1), supporting the statement that the adopted crop management practices have greater influence on the importance of diseases than the considered period of the year, i.e., the environmental conditions.

In Campina Grande, powdery mildew severity was lower when cover straw was adopted as a crop management practice (P = 0.03). However, it did not alter black rot severity (P = 0.29) (Figure 5A).

Another variable that differed among growers was their plant watering form. Irrigation by sprinkler or hose (in Lavras) had no difference on the AUDPC for black rot (P = 0.61) and powdery mildew (P = 0.16) (Figure 5B). The lowest powdery mildew severity, even though kale stubble was deposited on the rows, reinforces the hypothesis found for Lavras. Humidity favors the buildup of the saprophytic microbiota that may play a role in plant protection (6).

Similarly, the successive cultivation in Campina Grande increased the AUDPC for kale black rot (P < 0.01), showing that kale stubble probably sustained the bacterium inoculum over time (20). In Campina Grande, using plant straw did not reduce the disease importance, as found for Lavras. On the other hand, powdery mildew severity in Campina Grande was higher under intensive cultivation (P < 0.01), differently from the situation observed in Lavras (Figure 5C). The predominantly dry weather in Campina Grande and the presence of alternative hosts in the surroundings probably contributed to this trend.

Interestingly, the importance of diseases depends not only on the location where urban agriculture occurs but also on the adopted crop management practices (13, 14). Comparing the regions, the dominant climate conditions contributed to the disease prevalence but there were differences among growers, which may be related to their diverse crop management practices. For example, the use of cover crop and kale straw contributed to the lower progress of both powdery mildew and black rot.

Surprisingly, overhead irrigation did not influence the diseases, possibly acting as a buffering strategy to sustain the moisture level necessary for the pathogen even in the dry period, i.e., the condition is always favorable to black rot, a disease that relies on leaf wetness to cause infection. Therefore, drip irrigation should be adopted by all growers, especially in the dry period (5). In addition, a greenhouse or at least a roof-topped production system should be adopted to reduce leaf wetness and the disease pressure, especially in the rainy period.

Finally, considering the profiles of growers, those obtaining the most successful kale production and capable of selling their surplus products tend to scale up their production, which should be stimulated in order to make urban agriculture more attractive to the community. However, kale intensive production has raised black rot severity and, together with the crop management practices that contributed to disease outbreaks in each region, will foster the implementation of changes in kale production in urban areas for the sustainability of such activity to the future generations.

The most important kale diseases for both locations were powdery mildew and black rot. Their relevance depended on the considered season, and their severity was mostly impacted by high moisture and temperature. However, the kale management practices contributed to the progress of the diseases. The use of straw decreased powdery mildew and increased black rot, while kale intensive production raised black rot severity, supporting the importance of kale primary inoculum to the black rot progress.

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