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STUDIES ON SOUR ROT DISEASE IN ACID LIME UNDER IRRIGATED RED SOIL CONDITIONS

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ABSTRACT

Sour rot, caused by *Geotrichum candidum*, is a major postharvest disease in acid lime (*Citrus aurantifolia*), leading to substantial fruit losses under humid tropical conditions. The current study was conducted at the Citrus Research Station (CRS), Petlur, to evaluate the resistance of selected acid lime clones and identify effective fungicides for disease management. Fourteen promising clones were screened for their susceptibility to sour rot, and seven fungicidal treatments were evaluated over three years. Among the clones, the local variety exhibited the least incidence (8.80% PDI), while PS-11 showed the highest (24.00%) followed by acid lime var. 'Balaji' (23.67%). Fungicide trials revealed that Benomyl (0.1%) was most effective, reducing disease incidence to 6.09%, followed by Mancozeb + Carbendazim (0.2%). The results underline the significance of integrating resistant clones with timely fungicidal sprays to manage sour rot effectively and improve fruit marketability.

Keywords: Acid lime, Sour rot, *Geotrichum candidum*, Clone resistance, Fungicidal management, Postharvest disease.

Introduction

Acid lime (*Citrus aurantifolia*) is one of the most economically important citrus fruits grown in tropical and subtropical regions of India (Shyam Singh and Ghosh, 1999). It is valued for its high vitamin C content, refreshing flavor, and extensive use in beverages, culinary applications, and traditional medicine (Shyam Singh and Naqvi, 2001). In Andhra Pradesh and neighboring states, acid lime is a major fruit crop grown under irrigated conditions, often in red soils that offer good drainage and support vigorous tree growth. However, despite its agronomic potential, acid lime cultivation faces considerable challenges due to biotic stresses, particularly postharvest diseases that severely reduce fruit quality and market value (Kavitha and Govinda Rajulu, 2024).

Among the postharvest diseases affecting acid lime, sour rot caused by *Geotrichum candidum* has emerged as a significant constraint, especially under high humidity and warm temperatures (Palou *et al.*, 2001). The disease is characterized by water-soaked lesions, soft fruit rot, and the appearance of white, cottony fungal growth that produces numerous hyaline spores. These spores rapidly spread to adjacent fruits during handling and storage, making the disease highly contagious. Sour rot typically develops after harvest but may initiate in the orchard, especially during the rainy season or when fruits are injured during harvesting and transportation (Droby *et al.*, 2009). In high rainfall zones such as CRS, Petlur, where humidity and temperature remain favorable for fungal proliferation (28–30°C), sour rot can lead to 20–30% annual fruit losses. These losses not only affect the income of growers but also reduce consumer confidence due to poor fruit shelf life. The management of sour rot has traditionally relied on chemical fungicides (Sharma *et al.*, 2009 and Zhu 2006]. Earlier studies have indicated that fungicides like Benomyl, Imazalil, and Etaconazole can reduce disease incidence to a considerable extent. However, the continuous use of a limited set of fungicides may lead to resistance development in pathogens and raise concerns about chemical residues on fruits (Eckert & Eaks, 1989 and Janisiewicz & Korsten, 2002).

Furthermore, most citrus improvement efforts in India have focused on yield and fruit quality traits, with less emphasis on postharvest disease resistance (Prasad, 2015). As a result, many high-yielding varieties remain vulnerable to sour rot and other fungal infections. There is a pressing need to identify and promote acid lime clones that possess natural resistance or tolerance to sour rot while maintaining desirable agronomic and market traits (Khedkhar *et al.*, 2020, Kumar *et al.*, 2017 and Bhatia *et al.*, 2014). Integration of resistant clones with targeted fungicide applications can provide a sustainable, cost-effective solution to minimize losses. The present study was designed to address these gaps through a dual approach: (1) screening elite acid lime clones for their resistance or susceptibility to sour rot under natural infection conditions; and (2) evaluating the effectiveness of different fungicidal treatments when applied prophylactically before harvest. Fourteen clones maintained at CRS, Petlur, were selected for screening, and six fungicidal treatments were tested over a period of three years. The findings are expected to guide farmers in selecting suitable varieties and improve the effectiveness of disease management practices under high rainfall, red soil ecosystems. Ultimately, this integrated approach aims to enhance the productivity, quality, and profitability of acid lime cultivation in the region.

Materials and Methods

Experimental Site and Conditions

The study was conducted from 2013-14 to 2016-17 at Citrus Research Station (CRS), Petlur located in a high rainfall zone with red soils under irrigated conditions, ideal for acid lime cultivation. The area experiences a tropical climate conducive to sour rot development, especially during postharvest handling. The trial was laid out in established acid lime orchards using fourteen clones previously proven for their horticultural performance. Disease progression was observed under natural field conditions, allowing for accurate assessment of varietal resistance and fungicide efficacy. All cultural operations were performed as per standard agronomic practices for acid lime.

Clone Screening for Sour Rot Resistance

Fourteen acid lime clones were selected from CRS, Petlur, based on their consistent field performance and availability. Each clone was assessed for natural infection of sour rot during the harvest period. Fruits were visually examined for typical sour rot symptoms caused by *Geotrichum candidum*, including soft, watery lesions and fungal sporulation.

The Percent Disease Incidence (PDI) was calculated using the formula:

$$PDI = \frac{\text{Number of infected fruits}}{\text{Total fruits assessed}} \times 100$$

Screening helped to identify resistant clones under natural field conditions, with disease scoring done at commercial maturity.

Fungicide Treatment and Application Protocol

To manage sour rot effectively, seven treatments including six fungicides and one untreated control were tested. The treatments were: T_1-Benomyl (0.1%), T_2 - Carbendazim (0.1%), T_3 - Copper Oxychloride (0.3%), T_4 - Mancozeb (0.25%), T_5 - Mancozeb + Carbendazim (0.2%), T_6 - Hexaconazole (0.2%), and T_7 - Control. Each fungicide was applied as two foliar sprays at monthly intervals prior to harvest. Spraying was performed using a high-volume knapsack sprayer ensuring uniform coverage of fruit surfaces, targeting infection points. Postharvest fruits were evaluated for disease development to assess fungicidal efficacy.

Data Collection and Statistical Analysis

Percent Disease Incidence (PDI) was recorded for both clone screening and fungicide trials. Each treatment included multiple replications, and data from three years were pooled to ensure reliability. The percent reduction in disease over control was calculated to determine the efficacy of each fungicide. Data were analyzed using Analysis of Variance (ANOVA), and treatment means were compared using the Critical Difference (CD) at 5% significance level. Disease severity was expressed in both absolute PDI and angular transformed values for statistical accuracy. Results were tabulated and interpreted in the context of varietal resistance and chemical control.

Results and Discussion

Screening of Acid Lime Clones for Resistance to Sour Rot

The evaluation of 14 acid lime clones revealed significant variations in their susceptibility to sour rot under natural field conditions at CRS, Petlur. The Percent Disease Incidence (PDI) ranged from 8.80% in the Local clone to 24.00% in P.S-11**,** demonstrating considerable genetic diversity in disease response. The Local clone, with a PDI of 8.80%, emerged as the most resistant genotype, followed by Pramalini (10.30%), P.S-35 (11.00%), and P.S-32 (13.00%)**.** These clones showed limited lesion development and slower disease progression even under conducive conditions of high humidity and rainfall. In contrast, P.S-11 (24.00%), Balaji (23.67%), and P.S-21 (21.56%) were highly susceptible, exhibiting faster rot development and extensive spore dissemination (Table 1 & 2).

These results are consistent with earlier findings by Shyam Singh and Naqvi (2001), who reported that sour rot incidence is heavily influenced by cultivar genetics and fruit maturity. Clones with firm rind structure and fewer surface injuries were less prone to infection. The resistance observed in local genotypes may be due to natural selection and long-term adaptation to local edaphic and climatic conditions. The identification of resistant clones is a vital step in developing integrated disease management (IDM) strategies. Resistant varieties reduce the need for chemical intervention, thereby lowering input costs and minimizing the risk of fungicide resistance and chemical residues on fruits.

Evaluation of Fungicides for Sour Rot Management

The trial evaluating six fungicidal treatments showed significant differences in their ability to reduce sour rot incidence when applied as two prophylactic sprays before harvest. The untreated control recorded a high PDI of 30.09%, clearly establishing the disease pressure under field conditions. Among the fungicides tested, Benomyl (0.1%) was the most effective, reducing PDI to 6.09%, which translated to a 79.76% reduction over control. This was followed closely by Mancozeb + Carbendazim (Saaf) at 0.2%, which recorded 7.27% PDI and 75.83% reduction. Carbendazim (0.1%) alone also showed good efficacy, reducing the disease by 72.64% with a PDI of 8.23%**.** Fungicides such as Copper Oxy Chloride (0.3%) and Hexaconazole (0.2%) were less effective, showing PDIs of 15.82% and 14.07%**,** respectively. These results suggest that systemic fungicides, particularly benzimidazoles like Benomyl and Carbendazim, provide better curative and protective action against *Geotrichum candidum*, likely due to their ability to penetrate tissues and inhibit fungal metabolism (Table 1 & 2). The efficacy of Benomyl is in line with earlier studies (Shyam Singh and Ghosh, 1999) which highlighted its strong curative action on postharvest fruit rots. However, due to regulatory concerns and the potential for resistance development, its use should be monitored carefully and rotated with other modes of action. The combination product Mancozeb **+ b**showed better results than either fungicide alone, indicating a synergistic effect and offering a practical strategy to delay resistance buildup. Mancozeb, being a contact fungicide, prevents initial infection, while Carbendazim offers systemic protection.

Integrated Interpretation

The results clearly demonstrate that both varietal resistance and fungicide application are essential components for effective sour rot management in acid lime. The integration of resistant clones like Local, Pramalini, and P.S-35, with timely application of Benomyl or Mancozeb **+** Carbendazim, can significantly minimize disease incidence and improve postharvest fruit quality (Table 1 & 2). This integrated approach not only reduces fruit loss but also enhances market value due to better shelf-life and reduced decay. The findings underscore the need for location-specific IDM packages that combine host resistance, chemical control, and good orchard hygiene practices. The variability in clone response also emphasizes the importance of continuous monitoring and evaluation, as disease pressure and pathogen virulence can vary between seasons and regions.

Conclusion

The study identifies significant variation in sour rot susceptibility among acid lime clones, with the local variety emerging as the most resistant. Benomyl (0.1%) and the combination of Mancozeb + Carbendazim (0.2%) were found to be the most effective fungicides in minimizing disease incidence. The adoption of resistant varieties coupled with timely fungicide application can significantly mitigate postharvest losses due to sour rot, improving the profitability and sustainability of acid lime cultivation in tropical regions.

Table 1 : Screening of acid lime clones for sour rot disease of acid lime

S.No.	Variety	Date of planting	PDI of sour rot
1	P.S-1	26-12-1996	18.45
2	Balaji	26-12-1996	23.67
3	PKM-1	23-03-1998	13.78
4	Pramalini	23-03-1998	10.30
5	P.S-11	23-03-1998	24.00
6	P.S-15	20-02-2000	18.00
7	P.S-16	20-02-2000	16.76
8	P.S-21	20-02-2000	21.56

9	P.S-25	20-02-2000	18.56
10	P.S-27	20-02-2000	16.89
11	P.S-30	20-02-2000	13.50
12	P.S-32	20-02-2000	13.00
13	P.S-35	20-02-2000	11.00
14	Local	20-02-2000	8.80

Table 2 : Evaluation of different fungicides against sour rot disease of acid lime

S.No	Treatments	PDI	Percent reduction over control
1	Benomyl (0.1%)	6.09 (14.27)	79.76
2	Carbendazim (0.1%)	8.23 (16.67)	72.64
3	Copper Oxy Chloride (0.3%)	15.82 (23.42)	47.42
4	Mancozeb (0.25%)	11.72 (20.01)	61.05
5	Mancozeb + Carbendazim(0.2%)	7.27 (15.61)	75.83
6	Hexaconazole (0.2%)	14.07 (22.02)	53.24
7	Control	30.09 (33.34)	-
	CV	4.45	
	CD at 5%	1.62	

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