**Field management of *Fusarium solani* (mart.) sacc causing dry root rot/wilt** **of acid lime (*Citrus aurantifolia* Swingle)**

**Abstract:**

Acid lime (*Citrus aurantifolia* Swingle) is one of the four commercially important citrus fruit crop grown in India among the citrus species. It belongs to the family *Rutaceae* and genus *Citrus aurantifolia* (Swingle). Among many soil borne diseases of acid lime, dry root rot/wilt is considered to be a severe disease caused by *Fusarium solani* which is prevalent in northern Karnataka. *Fusarium* spp. is primarily responsible for causing dry root rot in citrus, which is one of the most serious fungal diseases affecting citrus. Studies on management of wilt disease of acid lime under field conditions of natural infection revealed the efficacy of different fungicides and some bio-agents with organic amendment tested in reducing the disease. Reduction in rotting of roots was highest at 90 days after treatment in trees drenched with carbendazim 50 WP @ 2 g /l (59.45 %). The second highest per cent reduction in rotting of roots was recorded in trees drenched with propiconazole 25 EC @ 2ml /l (53.67 %) which was on par with trees drenched with tebuconazole 250 EC @ 2ml /l (51.96 %). Among neem cake and bio-agent combinations, soil application of neem cake @ 10 kg/plant and FYM enriched with *Trichoderma* @ 30 kg/plant was most effective in reducing the root rot per cent (36.50 %) followed by treatment with neem cake @ 10kg /tree with FYM enriched with *Trichoderma* and *Paecilomyces @* 30 kg /plant (30.14 %).

**Key Words**: Acid lime, dry root-rot/wilt

**Introduction**

Acid lime (*Citrus aurantifolia* Swingle) is one of the four commercially important citrus fruit crop grown in India among the citrus species. It belongs to the family *Rutaceae*. South East Asia is the origin of acid lime. It requires tropical and dry tropical climate, well drained soil with optimum temperature ranging from 20-30°C. The crop is grown in an area of 2,96,000 ha with a production of 33,97,000 t and a productivity of 11.47 t/ ha (Anon., 2018). Diseases cause serious problem to citrus cultivation which can be etiologically grouped under diseases caused by fungi, bacteria, viruses, viroids, phytoplasma and nematode. The crop is affected by many soil borne diseases like root-rot or gummosis, dry root rot and citrus decline.

*Fusarium* is among the most prominent genera in the kingdom fungi, incorporating a broad spectrum of morphologically and phylogenetically diverse fungi. These fungi are mostly soilborne saprophytic organisms, which colonize both living and dead plant tissue as endophytes or epiphytes. *Fusarium* spp. produce a wide range of mycotoxins that contaminate food, thereby reducing its quality and posing a threat to the health of citrus trees ([Mihlali Badiwe](https://pubmed.ncbi.nlm.nih.gov/?term=%22Badiwe%20M%22%5BAuthor%5D) *etal*., 2025). Dry root rot, produced by *Fusarium* species, is one of the worst fungal diseases of citrus and can be a serious issue in many countries (Ploetz *et al.,* 2007). The disease is severe in the areas of north Karnataka caused by *Fusarium solani* (Mart.) Sacc. which was further confirmed from Indian Type Culture Collection (ITCC), IARI, New Delhi. *Fusarium solani* is an opportunistic pathogen and a complex organism that can remain in the soil for a long time and is transmitted by wind, machinery, and water. On susceptible crops, the fungus produces a variety of destructive diseases, including wilt, gradual decline, and fruit rot. Dry root rot has been shown to cause a variety of symptoms, including wilt, gradual decline, fruit rot, and dieback over most citrus cultivars (Kaczmarek *et al*., 2019).

Considering this, present studies were carried out under field condition to know the best effective chemical which would help in managing the disease thereby helping the farming community.

**Material and methods**

For management of wilt of acid lime, experiment was laid out during 2021-22 on 12 years old orchard with wilt incidence at farmer’s field (Pirappa S Metri, Indi taluk, Vijayapur district, Karnataka state) adopting completely randomised block design (CRBD) with nine treatments replicated three times. Each replication comprised of one tree.

Fungicides were applied as a soil drench in rainy season @ 10 l /tree. Second, third drench was given at 15 days interval. For assessing the incidence of rotted roots, all roots from one sq.ft area upto one ft depth were collected from all the four corners of each tree basin. The roots were dried for 48 h and the proportion of healthy and rotted roots were calculated by weighment. The per cent rotting was assessed before imposing treatments (initial rotting %) and 90 days after treatment imposition (final rotting %). The per cent reduction in rotting was calculated by the formula.

|  |  |  |
| --- | --- | --- |
| Per cent reduction in rotting = | Initial rotting (%) - Final rotting (%) | × 100 |
| Initial rotting % |

**List 1 : Treatment details**

|  |  |
| --- | --- |
| **Treatments** | **Details** |
| **T1** | Drenching of carbendazim 50 WP @ 2 g /l of water |
| **T2** | Drenching of hexaconazole 5 SC @ 2 ml/l of water |
| **T3** | Drenching of propiconazole 25 EC @ 2 ml/l of water |
| **T4** | Drenching of hexaconazole 5 % + captan 70 % WP @ 2 g /l of water |
| **T5** | Drenching of tebuconazole 250 EC 2 ml/l of water |
| **T6** | Soil application of neem cake @ 10 kg/plant, FYM enriched with *Trichoderma* @ 30 kg/plant (2 kg of *Trichoderma* enriched with 100 kg of FYM) |
| **T7** | Soil application of neem cake @ 10 kg/plant, FYM enriched with *Paecilomyces* @ 30 kg/plant (2 kg of *Paecilomyces* enriched with 100 kg of FYM) |
| **T8** | Soil application of neem cake @ 10 kg/plant, FYM enriched with *Trichoderma* and *Paecilomyces*@ 30 kg/plant (1kg each in 100 kg of FYM) |
| **T9** | Control (Untreated) |

 **Statistical analysis**

The data obtained was statistically analysed using completely randomized block design (CRBD). Observations of per cent mycelial inhibition and per cent reduction rotting were converted into angular transformation values.

**Results**

Results from the experiment conducted on management of wilt disease of acid lime under field conditions of natural infection revealed the efficacy of different fungicides and some bio-agents with organic amendment tested in reducing the disease Among the different treatments tested, all the treatments significantly reduced the per cent root rotting compared to control. Drenching of carbendazim 50 WP @ 2 g/l was found to be significantly superior over other treatments in reducing the rotting of roots. Reduction in rotting of roots was the highest in trees drenched with carbendazim 50 WP@ 2 g/l (59.45%) followed by drenching of propiconazole 25 EC@ 2 ml/l (53.67%) which was on par with drenching of tebuconazole 250 EC @ 2 ml /l (51.96 %) (Table 1; fig.1).

Among the bio-agents, Soil application of neem cake @ 10 kg/plant and FYM enriched with *Trichoderma harzianum* @ 30 kg/plant was found to be effective in reducing percentage root rotting (36.50) followed by treatment with neem cake at 10 kg /tree with FYM enriched with *Trichoderma* and *Paecilomyces* at 30 kg /plant (30.14 %) (Table 1; fig.1).

**Discussion**

Though many new generation fungicides used in this experiment were found effective under *in-vitro* conditions but surprisingly carbendazim 50 WP was still found effective in reducing per cent root rottig against dry –root rot. In a similar study, Suhag (1976) found that the guava trees affected with root-rot could be regenerated by severe pruning followed by a drench with Benlate or Bavistin (0.2%) using 20-30 g of fungicide dissolved in 40-60 litres of water per tree, depending upon age and canopy of the tree four times in a year in March, June, September and December.

 Results are also in agreement with Jayachandra (1999) who reported that the root-rot affected sweet orange trees drenched with Bavistin (0.2%) followed by either Dithane M-45 @ 0.25 per cent or Daconil @ 0. 2 per cent has recorded the highest percent reduction in rotting of roots *i.e.*, 79.21 and 75.31 per cent respectively, Vijayakumar (2001) also also concluded drenching of fungicides like carbendazim (0.2%) and captafol effective against *F. solani*, causing dry root rot of acid lime.

 Sumana et al. (2012) studied on *Fusarium* wilt and root-knot complex disease of tobacco under field conditions which revealed that, among chemicals propiconozole and carbendazim (0.2 %) controlled the wilt disease to 60.29 per cent and 61.47 per cent respectively and among bio-agents, *T. viride* *and P. fluorescens* controlled the disease to 58.46 per cent and 60.15 per cent respectively. Similarly sodium tetra thiocarbomate and *P. fluorescens* affected 49 per cent and 52 per cent control of root-knot nematode over the check respectively.

Bubici *etal*. (2019) also controlled *Fusarium* wilt in banana by using *Trichoderma sp.* who reported 70 per cent biological control efficiency using the *Trichoderma.* Alamri *et al. (*2019) reported *Trichoderma* mediated control by enhanced growth (height and weight), enhanced levels of photosynthetic pigments and primary metabolites and enhancing plant defense mechanisms in managing root rot in lettuce. Results are in accordance with Hafiz Muhammad Usman *et al*. (2024) who narrated Bio-control agents, such as *Trichoderma species* (*harzianum and viride*), have been used to manage several phytopathogens, including the causal agent of dry root rot, *Fusarium*, to promote eco-friendly practices instead of using harmful chemicals in agriculture.

Additionally, the management of dry root rot disease caused by *Fusarium* *solani* necessitates the optimization of irrigation and fertilization inputs. Along with sanitation practices, regular scouting and monitoring of key pests and diseases play a crucial role in enhancing control methods and minimizing pesticide usage.

**Table 1: Effect of different treatments in reducing percentage root rotting in wilted acid lime orchard at 90 days after treatment**

|  |  |
| --- | --- |
| **Treatments** | **Mean per cent reduction in rotting (%)** |
|
| T1: Drenching of carbendazim 50 WP @ 2 g/l of water | 59.45(50.45) |
| T2: Drenching of hexaconazole 5 SC @ 2 ml/l of water | 48.43(44.10) |
| T3: Drenching of propiconazole 25 EC @ 2 ml /l of water | 53.67(47.10) |
| T4: Drenching of hexaconazole 5% + captan 70% WP @ 2 g/l of water | 44.55(41.87) |
| T5: Drenching of tebuconazole 25 EC @ 2 ml/l of water | 51.96(46.12) |
| T6: Soil application of neem cake @ 10 kg/plant, FYM enriched with *Trichoderma* @ 30 kg/plant (2 kg of *Trichoderma* enriched with 100 kg of FYM) | 36.50(37.17) |
| T7: Soil application of neem cake @ 10 kg/plant, FYM enriched with *Paecilomyces* @ 30 kg/plant (2 kg of *Paecilomyces* enriched with 100 kg of FYM)  | 28.97(32.57) |
| T8: Soil application of neem cake @ 10 kg/plant, FYM enriched with *Trichoderma* and *Paecilomyces*@ 30 kg/plant (1 kg each in 100 kg of FYM) | 30.14(33.30) |
| T9: Control (Untreated) | 0.00(0.00) |
| CD at 5% | 3.20 |
| S.Em± | 1.07 |
| CV(%) | 5.71 |

Figures in parenthesis indicate angular transformed values

**Fig.1: Effect of different treatments in reducing percentage root rotting in wilted acid lime orchard**

**Per cent reduction in rotting**

**Treatments**

**Conclusion**

Studies on management of wilt disease of acid lime under field conditions of natural infection revealed the efficacy of different fungicides and some bio-agents with organic amendment tested in reducing the disease. Reduction in rotting of roots was highest at 90 days after treatment in trees drenched with carbendazim 50 WP @ 2 g /l (59.45 %). The second highest per cent reduction in rotting of roots was recorded in trees drenched with propiconazole 25 EC @ 2ml /l (53.67 %) which was on par with trees drenched with tebuconazole 250 EC @ 2ml /l (51.96 %). Among neem cake and bio agent combinations, soil application of neem cake @ 10 kg/plant and FYM enriched with *Trichoderma* @ 30 kg/plant was most effective in reducing the root rot per cent (36.50 %) followed by treatment with neem cake @ 10kg /tree with FYM enriched with *Trichoderma* and *Paecilomyces @* 30 kg /plant (30.14 %).

**References**

Alamri, S.A., M. Hashem, Y.S. Mostafa, N.A. Nafady and K.A. Abo-Elyousr. 2019. Biological control of root rot in lettuce caused by *Exserohilum rostratum* and *Fusarium oxysporum* via induction of the defense mechanism. Biological Control 128:76-84.

 Anonymous, 2018, Data on area, production, productivity of lime in Karnataka and India. Horticulture Statistics Division, Department of Agriculture, Cooperation and Farmers Welfare

Bubici, G., M. Kaushal, M.I. Prigigallo, C. Gómez-Lama Cabanás and J. Mercado-Blanco. 2019. Biological control agents against *Fusarium* wilt of banana. *Frontiers in microbiology,* 10:445720.

Hafiz Muhammad Usman, Atika Iffat, Qaiser Shakeel, Ayesha Munawar Bhatti, Mohammad Mazharul Karim, Muhammad Irfan Zafar, Rabia Tahir Bajwa, Ifrah Rashid, Judith J. Kiptoo and Talha Shafique, 2024, Insights into *Fusarium* spp., associated with Dry Root Rot of Citrus and its Management

Jayachandra D, 1999, Studies of survey and chemical management of root-rot of sweet orange var. sathgudi (*Citrus sinensis* (L.) Osb. *M. Sc*. *(Agri.)Thesis*, Andhra Pradesh Agricultural University Tirupati, Andhra Pradesh, India.

Kaczmarek, M., S. V. Avery and I. Singleton. 2019. Microbes associated with fresh produce: Sources, types and methods to reduce spoilage and contamination. In Advances in Applied Microbiology 107:29-82. Academic Press

[Mihlali Badiwe](https://pubmed.ncbi.nlm.nih.gov/?term=%22Badiwe%20M%22%5BAuthor%5D), [Régis Oliveira Fialho](https://pubmed.ncbi.nlm.nih.gov/?term=%22Fialho%20RO%22%5BAuthor%5D), [Charles Stevens](https://pubmed.ncbi.nlm.nih.gov/?term=%22Stevens%20C%22%5BAuthor%5D), [Paul-Henri Lombard](https://pubmed.ncbi.nlm.nih.gov/?term=%22Lombard%20PH%22%5BAuthor%5D), [Jan van Niekerk](https://pubmed.ncbi.nlm.nih.gov/?term=%22van%20Niekerk%20J%22%5BAuthor%5D), 2025, *Fusarium* Species Associated with Diseases of Citrus: A Comprehensive Review. J.Fungi, 11(4):263.

Ploetz, R. C. 2007. Diseases of tropical perennial crops: challenging problems in diverse environments. Plant Disease 91:644-663.

Suhag L S, 1976, Observations on guava decline III Haryana and its control. *Pesticides,* 10: 42-44.

Sumana K, Ramakrishnan S, Sreenivas S S and Devaki N S, 2012, Field evaluation of promising fungicides and bioagents against *Fusarium* wilt and root knot complex disease in FCV tobacco crop. *Journal of Agriculture technology*, 8(3): 983-991.

Vijayakumar B, 2001, Studies on dry root rot disease of acid lime (*Citrus* *aurantifolia* Swingle) nursery. *M.Sc (Agri.) Thesis*, Acharya N.G. Ranga Agricutlural University Hyderabad, India.