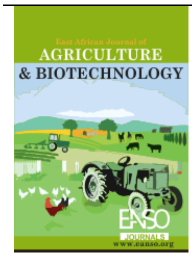

East African Journal of Agriculture and Biotechnology
eajab.eanso.org
Volume 7, Issue 1, 2024
p-ISSN: 2707-4293 | e-ISSN: 2707-4307
Title DOI: https://doi.org/10.37284/2707-4307

EAST AFRICAN NATURE & SCIENCE ORGANIZATION

Original Article

Re-Fining Citrus Leaf and Fruit Spot Disease Control Options in Northern Uganda

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Article DOI : https://doi.org/10.37284/eajab.7.1.1798

Date Published:

05 March 2024

Keywords:

Buck Horning, Chemical Treatment, Pruning, Inoculum, Pathogen Replication.

ABSTRACT

Citrus leaf and fruit spot disease, caused by *Pseudocercospora angolensis* has, since 2010, come about as the most dreadful disease of citrus in Northern Uganda. Over the last few years, feedback from citrus farmers has helped in re-fining management strategies. In the first years of citrus leaf and fruit spot disease outbreak in Northern Uganda, chemical treatment was promoted as part of a control package, in addition to the destruction of heavily diseased plants and buckthorn to remove inoculum. Buck horning and destruction of diseased plants is labour-intensive and time-consuming, especially when many infected citrus trees have to be taken out, or buck horned. Research findings indicate citrus leaf and fruit spot disease fungus can be weakened with fungicide sprays to the extent that even when disease symptoms are present on leaves, it does not automatically lead to infection of fruits. This gave rise to a new control strategy where only infected plants in an orchard are pruned, and all the citrus trees in the orchard are treated with fungicides. The pruning of visibly infected plants in an orchard will lessen the inoculum load, and the fungicide sprays will stop pathogen replication. This method is not labour intensive and takes less time when equated to severe buck horning of all the trees in the orchard. However, pruning and fungicide treatment need to move together with the control of new infections that can happen via unrestricted entry during harvesting.

APA CITATION

Kumakech, A. & Turyagyenda, L. F. (2024). Re-Fining Citrus Leaf and Fruit Spot Disease Control Options in Northern Uganda. *East African Journal of Agriculture and Biotechnology*, *7*(1), 110-116. https://doi.org/10.37284/eajab.7.1.1798

CHICAGO CITATION

Kumakech, Alfred and Laban F. Turyagyenda. 2024. "Re-Fining Citrus Leaf and Fruit Spot Disease Control Options in Northern Uganda". *East African Journal of Agriculture and Biotechnology* 7 (1), 110-116. https://doi.org/10.37284/eajab.7.1.1798.

HARVARD CITATION

Kumakech, A. & Turyagyenda, L. F. (2024) "Re-Fining Citrus Leaf and Fruit Spot Disease Control Options in Northern Uganda", *East African Journal of Agriculture and Biotechnology*, 7(1), pp. 110-116. doi: 10.37284/eajab.7.1.1798.

IEEE CITATION

A. Kumakech, & L. F. Turyagyenda "Re-Fining Citrus Leaf and Fruit Spot Disease Control Options in Northern Uganda", *EAJAB*, vol. 7, no. 1, pp. 110-116, Mar. 2024.

MLA CITATION

Kumakech, Alfred & Laban F. Turyagyenda. "Re-Fining Citrus Leaf and Fruit Spot Disease Control Options in Northern Uganda". *East African Journal of Agriculture and Biotechnology*, Vol. 7, no. 1, Mar. 2024, pp. 110-116, doi:10.37284/eajab.6.1.1798.

Article DOI : https://doi.org/10.37284/eajab.7.1.1798

INTRODUCTION

Citrus is the world's second fruit crop by volume after bananas (FAO, 2006). More than 104 million tons of citrus are produced, and about 15 million tons are traded annually globally (FAO, 2004). In 2011, FAO estimated the world's citrus production to be about 115.6 million tons. Brazil is the top producer of citrus fruits in the world, with an annual production of about 20 million tons, followed by China (19.6 million tons) and the USA (10 million tons) (https://www.worldatlas.com/articles/the-world-s-top-citrus-producing-countries.html).In Africa, the total surface area under citrus production is 1.3 million ha, of which 44,000 ha is in South Africa and 45,00 ha in Ethiopia (Seifu, 2003). Citrus is a very important commodity in tropical Africa as a source of employment, raw material for agro-industries and foreign currency (FAO, 2021). In Uganda, Citrus (Citrus spp.) is an important and widespread fruit crop, where it is produced for domestic consumption and regional markets (Uganda Investment Authority, 2009). Citrus plays a very important role of ensuring food and income security of rural households in Uganda. (Dijkxhoorn et al., 2019).

Citrus production in Uganda is constrained by biotic, abiotic, and socio-economic factors, including pest and disease pressure, declining soil fertility and socio-economic factors. Among these constraints, leaf and fruit spot disease recently emerged as the most important. Damage caused by the disease includes premature dropping of young fruits and leaves, leading to direct yield loss. Additionally, the development of spots on fruits leads to unmarketable fruits, thus reducing income. The ability of the disease to infect all cultivatable species of citrus and bring about yield loss of 50-100 % threatens the livelihood and food security of citrus farmers (CABI, 2009; Kumakech et al., 2014). Overall, leaf and fruit spot disease and low soil fertility are currently regarded as the two most important threats to citrus productivity in Uganda (Kongai et al. 2018).

Caused by the fungus *Pseudocercospora angolensis*, citrus leaf and fruit spot disease was first identified in Africa in 1952 in Mozambique and Angola (De Carvalho and Mendes, 1952), from where it was spread to other parts of Africa (Seif and Hillocks, 1993). Occurrence of *P. angolensis* was reported in Eastern Africa in the 1980s (Seif and Hillocks, 1993), Ethiopia in 1990 (Derso, 1999), Guinea in 1993 (Diallo, 2001), and later in the highlands in Sierra Leone in 2010 (Harling et al., 2010). The disease was identified as a new threat to citrus in northern Uganda in 2010 (Anonymous, 2012). The confirmation of the causal organism was through DNA sequencing at CBS Fungal Biodiversity Centre, Netherlands (Pedro Crous, personal communication).

Infection occurs mainly during the rainy season. It is often spread through infected seedlings, fruits, and conidia. Conidia on leaf and fruit lesions are disseminated by air currents and rain splashes to healthy citrus trees. According to Seif and Hillocks (1993), airborne conidia are disseminated further than water-splashed conidia. Infection and symptom development on citrus leaves and fruit occur at 25 °C and 3 hours of leaf wetness (Seif and Hillocks, 1998). Ndo et al. (2010) reported the disease at altitudes 800-1,800 m). According to Lawson et al. (2017), leaf and fruit spot severity in Guinea, Cameroon and Ghana was greater at higher altitudes characterized by cooler temperatures of between 22–26 °C and humid conditions. Poor management is also observed in orchards across Uganda, which significantly contributes to the spread of disease. The use of infected seedlings from uncertified nurseries led to the disease spreading widely in northern Uganda during the early years of the epidemic.

The disease affects fruits and leaves of citrus species, creating spots and lesions of various sizes (Kuate et al., 1994). Symptoms on leaves appear initially as greenish-yellow patches. The spots are brown or blackish brown, surrounded by a dark brown margin and a yellow halo at maturity. The centres of the brown spots become

Article DOI : https://doi.org/10.37284/eajab.7.1.1798

detached, producing a hole. According to Seif and Hillocks (1993), the leaf spots always coalesce on younger leaves, resulting in necrosis followed by abscission. The lesions become black as they sporulate during wet weather. According to Seif and Hillocks (1993), *P. angolensis* spots on fruits are round to crooked, either distinct or fused. Overgrowth-like lesions surrounded by a yellow mark characterize the commencement of symptoms on young fruits. On mature fruits, lesions are mainly flat, although in some cultivars, the brown centres are slightly sunken and surrounded by raised epicarp (Seif and Hillocks, 1993). Fruit and leaves are very susceptible, and affected fruits ripen prematurely and drop. Symptoms on stems are not common, but when infected, the lesions on stems are dark brown in colour (Seif and Hillocks, 1993).

In the early years of the *P. angolensis* disease outbreak in northern Uganda, its epidemiology was not known. Field indicator survey revealed symptom similarities with citrus canker, a bacterial disease of citrus caused by *Xanthomonas citri* (Ismail et al. 2019). The disease management programme at Ngetta ZARDI recommended the appropriateness of *Xanthomonas citri* management strategies as an emergency intervention option for *P. angolensis* control as problem-specific research was being undertaken. Therefore, during the initial years of the disease, three control strategies were advocated: a) uprooting of severely diseased trees, b) burning of uprooted and chopped plant debris, and c) copper-based fungicide treatment of diseased trees or orchards. The hope was that these strategies, together with awareness creation, would halt the spread of the disease. Instead, there was further spread of the disease. It was later observed the strategies were not practicable due to high associated costs. Further studies were conducted to gather more information on the epidemiology and fine-tune control options.

This article presents a synopsis of research initiative regarding the development of effective control strategy for *P. angolensis*. The management options presented in this article aims to revive and sustain citrus production.

DISCUSSION

In spite of the significance of citrus leaf and fruit spot disease in Africa, elaborate information about the disease including management options is still lacking. There is therefore, the need to package research information on control options for further technology re-fining and development of effective control strategy. The threat posed by *P. angolensis* pathogen to the citrus industry world-wide, calls for experience sharing and research collaboration at national, regional and International levels. A number of control options including cultural and chemical options have been evaluated for *P. angolensis* management in Uganda.

Efforts have been made to manage citrus leaf and fruit spot disease in Africa (Kumakech et al. 2014; Eshetu et al. 1999). Such efforts have led to the recommendation of a number of control methods such as botanical control, sanitation measures, chemical control and plant host resistance (Mohammed, 2007; Kaute et al. 2006; Eshetu et al.1999). In Uganda, further studies were conducted to understand the disease better and design effective management options for *P. angolensis.* The research efforts are discussed in the sections below;

Mechanical destruction of severely diseased trees

The initial strategy recommended for the control of citrus leaf and fruit spot spread in Northern Uganda included the removal of all severely diseased trees. Removal of diseased citrus reduced *P. angolensis* pressure in experimental orchards. Although the strategy was effective, it was labour intensive. It requires resources to be pulled from other household activities. Worse still, after the destruction of diseased trees, more of the remaining trees also become severely infected, and farmers must continue to remove diseased trees. This approach becomes expensive for resource constrained farmers when many diseased trees have to be uprooted. As a result,

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citrus farmers in northern Uganda did not fully adopt this practice. The strategy is however, is still useful for reducing inoculum pressure in newly infested orchards.

Chemical treatment of infected trees using fungicides

An alternative to the destruction of diseased trees was fungicide spray. In the context of *P. angolensis* control elsewhere, a fungicide based on copper was recommended (Mohammed, 2007; Kaute et al. 2006; Eshetu et al. 1999). Fungicides based on copper significantly reduced disease severity but did not eradicate the disease from infected orchards in Uganda. Ngetta ZARDI in 2015 studied the efficacy of non-copper-based fungicides (Winner 50WP, Orius, and Mancozeb) for the treatment of infected trees. It found that Winner and Orius were able to reduce disease severity significantly (Table 1). The efficacy of fungicide application may however, depend on the application regime. A study by Kumakech (unpublished) found a lack of efficacy when the fungicides are applied once or twice and not repeated at fruit set. Adoption by citrus farmers has been poor, mainly due to limited access to fungicides in rural areas, the high cost of fungicides, and the lack of willingness to spray physically asymptomatic plants that later develop the disease. Yet, proactive application of fungicides can keep citrus trees free of infection from foliar diseases including leaf and fruit spot disease. Deliberate effort must therefore, be made to educate citrus farmers on how to effectively treat citrus trees with benomyi and tebuconazole fungicides to maintain the health of citrus orchards.

Table 1: Efficacy of non-copper-based fungicides for the treatment of infected trees

Fungicide	Common name	Disease severity rating 3 months after treatment on a scale of 1-5
Benomyi	Bilarben	2
Tebuconazole	Orius	3
Mancozeb	Mancozeb	5

1=0 %; 2= <5 %; 3= 5-20 %; 4 = 21-50 %; and 5= > 51 % of the leaf area affected

Source: (Seif and Hillocks, 1998)

Buck horning of diseased trees

The alternative to the complete destruction/uprooting of diseased trees is severe pruning to remove inoculum (*Figure 1*). A study on the effects of rehabilitation methods was initiated by Ngetta ZARDI in 2012. Buck's horning practice during both dry and wet seasons significantly reduced the disease within the experimental plots. The reason behind diseased plant parts removal is reduce the inoculum load and reduce disease incidence and severity. Buck horning during the dry season was the most effective, as only less than 2% of all the treated trees were re-infected. On the other hand, 17.5% of trees buck horned during the wet season were re-infected. The re-infection occurred as early as one month after treatment. Over 70% of trees treated emerged with citrus leaf and fruit spot disease symptoms. Buck horning during the dry season was, thus, recommended as a strategy for rehabilitating orchards devasted by leaf and fruit spot disease.

This practice however, was reported by farmers to be labour-intensive, as one person can only severely prune about five trees per day. Worse still, after buckhorn, the emergence of new leaves remains problematic as some can emerge with the infection. Farmers must frequently return to the orchard to apply protective fungicide sprays to ensure complete control of the disease. These challenges limited the adoption of the practice by resource-constrained smallholder farmers. It was however, fully adopted by market oriented citrus farmers. The strategy is useful for rehabilitating orchards devastated by citrus leaf and fruit spot, where mechanical removal of diseased trees may lead to total destruction of the orchard. The strategy must however, be integrated with chemical treatment to stop the reproduction of *P.*

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angolensis pathogen that may survive on infected stems, and can infect new leaves emerging after buck`s horning.

Figure 1: Management of *P. angolensis* using buck horning technology

P. angolensis affected tree | Buck horned | Canopy recovery

Selective diseased tree pruning and fungicide treatment

In spite of the more practicable management options discussed above, orchard health is still not easily maintained, and farmers are not always willing to rogue a single infected tree. Field observations in less intensively managed citrus orchards and research findings indicate rehabilitated orchards can be re-infected. Initial research by Ngetta ZARDI in 2015 revealed that pruning infected plants when symptoms are still limited to a few branches reduced disease spread within the orchard. Subsequent treatment of the pruned trees with fungicide sprays (benomyi and tebuconazole) showed that the disease could be eliminated completely (unpublished report) if further infection from poor sanitation was prevented. Similar observations in farmer fields were made by Ngetta ZARDI in 2016, indicating that rehabilitation of moderately infected orchards can be achieved when single diseased tree pruning is carried out, accompanied by fungicide sprays as part of a package of control options. It is advised to restrict entry to such orchards to prevent re-introduction of the inoculum.

The principal of selective pruning of infected plant parts is that the removal of only the diseased plant parts in an orchard will lessen the disease pressure and will reduce disease incidence and severity to a tolerable level. This method requires less labour and takes a short time to complete. To be effective, the selective diseased parts removal needs to be accompanied with fungicide sprays to weaken the pathogen hidden diseased branches and leaves, and stop further pathogen replication.

Identification of Host-Plant Resistance to Pseudocercospora Leaf and Fruit Disease from Adapted Commercial Cultivars in Uganda

Host-plant resistance provides the most efficient, economical and ecologically sustainable method of managing plant diseases. In an effort to identify resistance to *P. angolensis*, Ngetta ZARDI in 2014 conducted a study to identify variability for citrus leaf and fruit spot resistance from adapted commercial cultivars in Uganda as an initial step in developing integrated disease management strategy. The study identified Kuno as the most tolerant and Tangelo as less susceptible to Pseudocercospora leaf and fruit spot infection, and were recommended for integration into integrated citrus leaf and fruit spot disease management.

The major advantages of host-plant resistance in disease management are compatibility with other crop management practices such as irrigation, fertilizer, etc; environmental safety, ecological suitability and economic viability. Integration of host-plant resistance with other Pseudocercospora leaf and fruit spot disease

Article DOI : https://doi.org/10.37284/eajab.7.1.1798

management practices, such as cultural and chemical control measures is more effective in a sustainable citrus production system.

CONCLUSIONS AND RECOMMENDATIONS

The increasing burden of citrus fruit and leaf spot disease, especially among resource-limited smallholder farmers, calls for innovative, cost-effective and people-centred prevention and management approaches. Management approaches discussed in the current study exhibited different levels of efficacy. None of the strategies was able to eliminate the disease from affected orchards. Furthermore, technology-specific characteristics such as input demand, labour requirements, advantages to existing farmer practices and compatibility with a farmer`s local conditions influence adoption of citrus leaf and fruit spot disease practices. Thus, the perception of farmers' about the attributes of technologies influences adoption.

Control options need to be packaged into integrated disease management strategy to be promoted across affected communities. In addition, farmers need to be sensitized on the importance of applying chemical control options as a preventive measure. Additional research however, is required to re-fine the control options discussed in this paper.

Community awareness is critical for the advancement of technologies for citrus leaf and fruit spot disease, hence the need for awareness creation strategies. Such strategies could include plant clinics, trainer training, posters, leaflets, and brochures, which are all carefully designed to target the levels of literacy in the target community.

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