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Effects of Citrus aurantifolia Linn and *Xylopia aethopica* (Dunal) A. Rich Extracts on Leaf Blight Disease of Taro (*Colocasia esculenta* L. Schott)

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Abstract

Phytophthora colocasiae Raciborski, an Oomycete phytopathogen, has been known for several decades as the causal agent of the most infectious and devastating disease of *Colocasia esculenta* (L.) Schott, known as taro leaf blight (TLB). Investigations were conducted in a screenhouse to determine the effects of fruit extracts of *Citrus aurantifolia* and *Xylopia aethiopica* on the incidence and severity of TLB. The experiment was set up in a completely randomized design with three replicates. Healthy taro seedlings obtained from the National Root Crops Research Institute (NRCRI), Umudike, were planted in plastic pots (5000 cm^3) containing sterilized soil enriched with poultry manure. The plant extracts were applied as foliar spray on taro leaves with a manually operated hand sprayer at 7 weeks after planting and continued at four days intervals for 28 days. Positive check was maintained with the fungicide Ridomil (a.i. mefenoxam) applied at the rate of 0.67 $mg.ml^{-1}$ while zero concentration in distilled water served as negative control. Data were subjected to one-way analysis of variance, and means were separated using F-LSD. Results showed a very high reduction of disease with plant extracts ($P < 0.05$) and Ridomil compared to the control. *Citrus aurantifolia* juice was more efficient in reducing the incidence and severity of TLB compared to *X. aethiopica* extracts and was highly significant ($P<0.05$). The overwhelmingly fungitoxic effects of *C. aurantifolia* and *X. aethiopica* extracts on *P. colocasiae,* as expressed in the reduction of disease, suggests that these extracts can serve as alternative bio-fungicide for the control of TLB. Hence, further studies under field conditions are required to reestablish their efficacy.

Keywords: disease, fungitoxic, plant extracts, *Phytophthora colocasiae before plant extracts*

Introduction

Plant disease epidemics have influenced the course of history in countries where they have had a devastating effect, and continue to be of great importance especially for those people whose day-to-day survival depends on their crops. The *Phytophthora* leaf blight epidemic in Nigeria in 2009 almost wiped out subsistence and large scale cocoyam production (Ugwuja and Chiejina, 2011) within two months of its incidence. Farmers in Southeast Nigeria, where the epidemic started, were alarmed at the swift destruction of their taro crops and the onset of severe scarcity and exorbitant prices of taro commodities in all the markets. Similar situations attributed to the same cocoyam leaf blight were reported in Cameroon's southwest and northwest districts (Mbong et al., 2013) and Ghana (Omane et al., 2012) where farmers could not produce enough cocoyam to eat or sell.

Taro (*Colocasia esculenta* (L.) Schott), known as cocoyam, is one of the oldest tropical crops grown primarily for its edible starchy corms and highly nutritive leaves (Ekanem et al., 2008; Ukpabi et al., 2011) as well as for its ornamental and traditional uses (Manner and Taylor, 2011). It is an important traditional staple food for millions of people in developing countries and is a good source of carbohydrates, wax, and therapeutics. Ethno-botanical evidence suggests that taro originated in South Central Asia, probably in India or the Malaya Peninsula (Onwueme and Charles, 1994). From its center of origin, taro spread eastward to the rest of South East Asia, China, Japan and the Pacific Islands (Manner and Taylor, 2011). From Asia, taro spread westward to Arabia and the Mediterranean region. It arrived on the east coast of Africa over 2,000 years ago. Voyagers took it, first across the continent to West Africa, and

later on slave ships to the Caribbean. Today taro is pan-tropical in its distribution and cultivation due to its wide adaptability, large-scale acceptability and high return per unit area. Taro also thrives well on heavy soils on which flooding and waterlogging can occur.

From time immemorial, taro has been an essential daily diet for many ethnic groups in Nigeria, creating a relatively constant year-round demand as it provides an alternative source of carbohydrates to supplement yams and cassava (Echebiri, 2004; Nwachukwu and Osuji, 2008; Okereke, 2020). The scarcity of this important food crop occasioned by the recurring epidemic of taro leaf blight has tremendously increased costs beyond the reach of most people and overall demand.

Phytophthora colocasiae, an oomycete phytopathogen (CABI, 2020; Otieno, 2020), has been known for several decades as the causal agent of the most infectious and devastating disease of *Colocasiae esculenta* commonly referred to as "taro leaf blight" (Fullerton and Tyson, 2004; Brooks 2005; Brook, 2008; Misra et al., 2008; Misra et al., 2011; Ugwuja and Chiejina, 2011; Omeje et al., 2016; Padmaja et al., 2017). Ugwuja et al. (2020) noted that the swift development of taro leaf blight infections has catastrophic consequences for both small, medium and large-scale production of taro due to the ubiquitous nature of the pathogen and the rapid rate of spread by wind-blown rain. The pathogen is also soil-borne and favored by field flooding conditions (Grade and Joshi, 2003). It is believed to have originated in South East Asia and is widely distributed throughout tropical regions (CMI, 1997). It attacks mainly the foliage, first appearing as small, brown, water-soaked spots that rapidly enlarge to form large, dark brown lesions. The lesions often coalesce to destroy a large portion of the leaf, sometimes with numerous droplets of orange or reddish exudates (Ugwuja et al., 2021). Depending on the aggressiveness of the infection, rapid and complete defoliation of leaves may occur within 14 days against 40 days normal longevity in the absence of disease (Brooks, 2008; Misra et al., 2008; Nath et al., 2015), leading to a strong hindrance of photosynthesis, stunted corms and a yield loss up to 80% (Adomako et al., 2017). Yield losses can also vary from 25-30% in some areas when the infection is mild (Miyasaka et al., 2001; Misra et al., 2011), up to 50% in severe cases (Brunt et al., 2001; Misra, 2008) and over 70% in extremely severe cases (Nelson et al., 2011; Adomako et al., 2017). Leaf yield losses can be up to 95%. The epidemic of taro leaf blight may occur throughout the year during the continuous rainy season over vast weather where night temperatures are 20 – 22°C and daily temperatures of 25 - 28°C with little seasonal variation (Mbong et al., 2013).The pathogen also causes pre-harvest and post-harvest deterioration of corms (Omeje et al., 2016) leading to the depreciation of their market value. Significant depletion in the proximate and phytochemical composition of infected corms has also been reported (Ugwuja et al., 2020).

Several measures of integrated pest management have been adopted to control this disease. These include the use of cultural methods, synthetic chemicals, biological control methods, and natural plant use of natural plant extracts (botanicals). Synthetic chemicals such as sodium ortho-phenyl phenate, borax, captan, thiabendazole, sodium hypochlrorite (bleach), nordox, benomyl and mancozeb have been found to significantly reduce TLB (Mishra et al., 2008). However, the high costs of these chemicals and obvious pollution of non-target organisms have prompted investigations on exploiting pesticides of plant origin to control fungal pathogens. There has been increasing interest in using bio-pesticides to manage many plant diseases due to their relative accessibility and availability at little or no cost. These bio-pesticides are also specific, biodegradable and environmentally friendly. On the other hand, the conventional synthetic chemicals used in managing of plant diseases have continually received criticismsdue to the associated ecological and health hazards (Komarek et al., 2010; Dhaliwal and Koul 2011). Moreover, researchers have shown that a repeated exposure of fungal pathogens to fungicides can lead to resistance in the pathogen (Adomako et al., 2017).

Given the many demerits of synthetic chemicals and the need to boost taro production through a sustainable disease control strategy against taro leaf blight, there should be no limit to the exploration/exploitation of readily available and biodegradable products of nature in our environment. Therefore, this study aimed to evaluate the antifungal potentials of lime, ethanol, and aqueous extracts of *Xylopia aethopica* on taro leaf blight disease under screenhouse conditions.

Materials and Methods

Study Location

The study was carried out in a screenhouse at the National Root Crops Research Institute (NCRI) Umudike, Nigeria (05° 21¹N and 07° 33¹E).

Sources of Materials

Healthy taro corms were obtained from the Research Farm at the NCRI, Umudike, Nigeria. Materials for

plant extracts: *Xylopia aethopica* (locally known as "uda") fruit and lime (*Citrus aurantifolia*) fruit were obtained from the Umuahia town market. The identity of these plant materials was authenticated by the Herbarium Section of the Department of Plant Science and Biotechnology, Michael Okpara University of Agriculture, Umudike.

Soil Preparation

Loam soil used in this work was collected from a fallow field at the NRCRI and sterilized by heating in metallic drums at temperatures above 160ºC for 2 hours to destroy soil-borne pathogens. The sterilized soil was allowed to cool for three days and mixed with dry poultry dung at the rate of 4 g per kg of soil in order to increase the soil fertility status. The enriched soil was transferred into plastic pots (5000 cm^3) in the screen house where the corms were to be planted. Thereafter, the soil was left for 7 days before the corms were planted so that heat generated during the decomposition of the poultry manure does not suffocate the corm (Fokunang et al., 2016).

Experimental Design and Planting

The experiment was a completely randomized design comprising three plant extracts applied in four levels (control, 10%, 20%, 30%). Healthy seedlings of a highly susceptible variety, NCe001 were planted one per plastic pot (5000 cm^3) containing ¾ filled enriched loam soils in July during the 2019 planting seasons. The plants were maintained in a screenhouse and watered twice daily.

Preparation of the Plant Extracts

The aqueous and ethanolic plant extracts were obtained following the soaking method described by Onaebi et al. (2019) with slight modifications.

Preparation of ethanolic extract of Xylopia

Fifty grams of pulverized *Xylopia* fruits were measured into a glass bottle with a lid and soaked with 500 ml of 95 % ethanol. The mixture was stirred thoroughly and allowed to stand for three days. During this time, the mixture was stirred at least twice each day. After the third day, it was filtered into a beaker through four layers of sterile muslin cloth and covered with a perforated foil in order for the ethanol to evaporate and form a paste-like end product.

Preparation of aqueous extract of Xylopia

In preparing the aqueous extract of *Xylopia,* hot distilled water at 40ºC was used in soaking the milled sample of *Xylopia* fruits. The mixture thus obtained was shaken vigorously and allowed to stand for only 24 hours to prevent microbial growth and later on sieved through four layers of sterile muslin cloth. The filtrate was concentrated under a vacuum at 20-40ºC using a rotary evaporator (Model: RE – 52A) supplied by Union Laboratory, England. The crude extracts (stocks) were put into sterile screw-capped bottles, labeled accordingly, and stored in the refrigerator as long as the experiments lasted.

Preparation of the lime extract

Fresh lime fruits were washed, sliced into four pieces, and the juice was squeezed out into a beaker which was later sieved to remove debris and stored.

Reconstitution of crude extracts

One gram portion of each crude extract was mixed with 1 ml of 25% of dimethyl sulfur oxide (DMSO) in a sterile Bijou bottle; DMSO served as a binding agent to make the extract adhere or stick to the foliage surface when it was being sprayed. The mixture was stirred thoroughly and an additional 9 ml of sterile distilled water was added to form 1a 100 mg/ml stock solution of the particular extract. By means of a sterile pipette 10ml of the stock was taken and added to 90 ml of sterile distilled water in a conical flask to form 10%. Another 20 ml of the stock was added to 80 ml of sterile water to form 20%, and the last concentration 30%, was formed by adding 30 ml of stock to 70 ml of the sterile water.

Fungal cultures

The inoculum used in this study was obtained from previously isolated stock cultures of *Phytophthora colocasiae* maintained in the Phytopathology laboratory of NCRI, Umudike.

Inoculation

Inoculation of taro plants was done artificially with inocula obtained from a 7-day-old actively growing cultures of *P. colocasiae.* The cultures were grown on Cornmeal Agar (21 g of Cornmeal in 1 liter of distilled water, autoclaved under pressure at 121°C for 15 minutes) and incubated at room temperature for seven days. Thereafter spore suspension was made by pouring 10 ml of sterile distilled water to each culture plate and carefully dislodging the spore with sterile Carmel's -hair brush and chilling at 10°C for 30 minutes to allow zoospore release (Brooks, 2008). The spore suspension was diluted and two drops were applied to the third-oldest leaves of the taro plant to cause infection.

Application of Treatment

The plant extract treatments were applied when the first symptoms of TLB were observed on the inoculated plants as foliage and petioles spray with a manually operated hand sprayer at seven weeks after planting (7 WAP) and continued at four days intervals for up to 28 days. Application of treatment was carried out early in the morning or evening to avoid the effect of wind which might drift extracts from their intended targets. Distilled water was sprayed on the leaves and petioles of control plants.

Disease Monitoring

The crops were closely monitored for initiation of disease symptoms. TLB incidence and severity were measured on the leaves of treated plants starting from the day the first symptom was noticed and continued consecutively at 4-day intervals for 28 days.

Disease incidence

Percent blight incidence was worked out according to the expression of Ganie *et al.* (2013).

Disease incidence was calculated based on the total number of infected plants per total number of observed plants.

$$PBI = \frac{TNIP}{TNP} X100\%$$

Where PBI = Percentage blight incidence
TNIP = Total number of infected plants per treatment
TNP = Total number of plants per treatment

Disease severity

A six-point numerical scale (0, 1, 2, 3, 4, 5) adopted from Ganie et al. (2013) was used for the assessment of disease severity. These numerical values denote the percent (%) leaf area infected as follows: 0 = No disease (0%), 2 = 1-10%, 3 = 11- 25%, 4 = 26 - 50%, 5 = 51- 75 %, 6 = > 76 %.

Percent disease Intensity (PDI) was calculated following the formula given by Ganie et al. (2013):

$$PDI = \frac{\Sigma (n_i \times v_i) \times 100}{n \times S}$$

Where, Σ = Summation; n_i = number of leaves in each category; v_i = score of leaves observed, and *S* = maximum score.

Statistical Analysis

Data obtained from the experiment were subjected to one-way analysis of variance, and treatment means were separated at 5% level of significance.

Results

Effect of Citrus aurantifolia Extracts on TLB Leaf Blight Incidence

Plants treated with extracts of *C. aurantifolia* had significantly lower ($P < 0.05$) incidence than that treated with distilled water, the negative control (Table 1). Disease incidence gradually reduced as the concentration of *Citrus* juice extract increased. No disease was recorded on the plants treated with Ridomil, the standard fungicide and *C. aurantifolia* extract at 30% concentration, while the highest disease incidence 38.9% was obtained with the distilled water (zero strength of the extract). There was a remarkable reduction in disease incidence from the 12 DAI (day after infection) to the 24th day reaching zero levels at 20 and 30% concentrations.

Effect of Citrus aurantifolia Extract on TLB Severity

Table 2 shows the effect *C. aurantifolia* extract on percent leaf blight severity days after infection. Mean disease severity varied amongst the concentrations and assessment periods and was statistically ($P<0.05$) significant. No disease was equally observed on the plants treated with the *C. aurantifolia* extract at 30 % concentration as it was with the incidence while the

Table 1. Effect of *Citrus aurantifolia* extract on TLB incidence (%)

	Time (DAI)					
Concentration (%)	4	8	12	16	20	24
0	38.9	36.1	16.7	16.1	11.1	10.0
10	33.3	25.0	20.2	10.0	6.7	3.3
20	33.3	19.4	0.0	0.0	0.0	0.0
30	16.7	6.1	0.0	0.0	0.0	0.0
$LSD_{0.05}$ (Treatment):	9.21*					
$LSD_{0.05}$ (Time):	11.28**					
$LSD_{0.05}$ (Interaction):	22.57^{NS}					

highest severities (16.0) was observed on the plants treated with the distilled water. Disease severity equally decreased with increasing concentration and time as was observed earlier.

Effect of Aqueous Extract of Xylopia aethopica on TLB Incidence

The effect of aqueous extract of *Xylopia aethopica* revealed less incidence on application of high concentration (30%) than others comparing favourably with that of Ridomil (Table 3). The results showed that taro plants treated with distilled water (control) expressed significantly (P<0.05) higher disease ranging from 66.7% to 44.4% as time increased compared to the ones that received the *Xylopia* extract treatments at 10, 20 and 30% which had disease incidence range of 16.7- 0.0%. Reduction of disease with time observed with *Xylopia* extract was not as remarkable as that of the *Citrus* extract which had 0.0% incidences from the 12^{th} -24^{th} DAI under 20 and 30% concentrations.

Effect of Aqueous Extract of Xylopia on TLB Severity

Results showed that Plants treated with aqueous extract of *X. aethopica* recorded zero (0%) disease at 30 and 20% concentrations from 16- 24 DAI and 24 DAI, respectively. This result was compared favourably with that of the Ridomil but significantly differed (P< 0.05) from the ones obtained from plants treated with distilled water and extract at 10% concentration (Table 4).

Effect of Ethanol Extract of Xylopia aethopica on TLB Incidence

Results presented in Table 5 showed that ethanol extract of *Xylopia aethopica* significantly (P< 0.05) reduced the incidence of TLB compared to the control and also had a better effect than the aqueous extract in reducing disease. Similarly, in a dosage dependent pattern, disease declined as the concentration of the extract increased. There was a drastic reduction of disease amongst concentrations 10-30 % of the extract from the 12-24 DAI and a complete elimination of disease (zero incidence) at 30% concentration from12-24 DAI. This suggests that 30% concentration is the most efficient and the best concentration for the ethanol extract.

Effect of Ethanol Extract of Xylopia aethopica on TLB Severity

Ethanol extract of *Xylopia aethopica* significantly (P < 0.05) reduced disease severity compared to the control and also had a better effect than the aqueous extract in reducing disease (Table 6). Similarly, in a dosage-dependent manner, the disease was drastically eliminated to zero values as the

Table 2. Effect of *Citrus aurantifolia* juice extract on TLB severity (%)

	Time (DAI)					
Concentration (%)	4	8	12	16	20	24
0	16.0	14.9	11.0	10.1	10.6	11.6
10	9.5	5.2	0.4	0.2	0.0	0.0
20	9.0	0.7	0.0	0.0	0.0	0.0
30	2.7	0.1	0.0	0.0	0.0	0.0
$LSD_{0.05}$ (Treatment):	2.89 **					
$LSD_{0.05}$ (Time):	3.53**					
$LSD_{0.05}$ (Interaction):	7.07^{NS}					

Table 3. Effect of aqueous extract of *Xylopia aethiopica* on TLB incidence (%)

	Time (DAI)					
Concentration (%)	4	8	12	16	20	24
0	66.7	41.7	48.9	50.0	55.6	44.4
10	19.4	19.1	18.3	11.7	8.3	3.3
20	16.7	14.4	8.3	6.7	5.0	1.7
30	16.7	12.0	6.7	3.3	3.3	0.0
$LSD_{0.05}$ (Treatment):	9.92 **					
$LSD_{0.05}$ (Time):	12.14 ^{NS}					
$LSD_{0.05}$ (Interaction):	24.29 ^{NS}					

Table 4. Effect of aqueous extract of *Xylopia aethiopica* on TLB severity (%)

	Time (DAI)					
Concentration (%)	4	8	12	16	20	24
0	12.0	6.3	9.2	9.9	5.8	5.8
10	0.4	1.7	1.0	0.3	0.3	0.1
20	3.8	2.0	1.0	0.2	0.1	0.0
30	0.1	0.1	0.1	0.0	0.0	0.0
$LSD_{0.05}$ (Treatment):	2.4** (**) highly significant					
$LSD_{0.05}$ (Time):	2.94**					
$LSD_{0.05}$ (Interaction):	5.88^{NS}					

Table 5. Effect of ethanol extract of *Xylopia aethopica* on TLB incidence (%)

	Time (DAI)					
Concentration (%)	4	8	12	16	20	24
0	33.3	25.0	44 .4	44.4	38.9	41.7
10	20.1	19.4	13.3	6.7	5.0	5.0
20	16.7	11.1	5.0	5.0	5.0	5.0
30	8.3	11.1	0.0	0.0	0.0	0.0
$LSD_{0.05}$ (Treatment):	10.03 **					
$LSD_{0.05}$ (Time):	12.28 ^{NS}					
$LSD_{0.05}$ (Interaction):	24.57 ^{NS}					

concentration of the extract increased at 20 and 30 % on day 12 DAI and 12- 24 DAI, respectively. This suggests that 30% concentration is the most efficient and the best concentration for the ethanol extract.

Discussion

In several laboratory and field trials, botanical-based antifungal products are effective in the control of pathogenic fungi (Ahmed, 1998; Carabet et al., 2005; Sealy et al., 2007; Shakywar et al., 2007; Shakywa et al., 2012; Jimoh et al., 2013; Balamurugam, 2014; Sesan et al., 2017). Findings from the present study have also demonstrated the ability of extracts from the test plants to control an Oomycete pathogenic fungus, *Phytophthora colocasiae* through vivid reduction of incidence and severity of *Phytophthora* leaf blight under screen house conditions. The disease was markedly reduced in the extract treated plants than in control. This reflects the ability of the extracts to reduce the amount of inocula (infective propagules) which would have caused more infection within the screen house. Moreover, the character exhibited by the plant extracts also reflects their direct fungistatic or fungicidal effect on the causal pathogen *Phytophthora colocasiae* likely due to the antifungal principles reported to be present in them (Fleischer 2003; Nata'ala et al., 2018; Oikeh et al., 2015; Aibinu et al., 2007). The results are comparable to those previously obtained by earlier workers who studied the effects of these plant species on pathogenic organisms in different experiments (Balamurugam, 2014; Okigbo and Nmeka, 2005; Amadioha and Obi, 1998; Aibinu et al., 2007).

Table 6. Effect of Ethanol extract of *Xylopia aethopica* on TLB severity (%)

	Time (DAI)					
Concentration (%)	4	8	12	16	20	24
0	30.6	26.5	22.3	21.3	19.7	20.5
10	0.4	1.6	1.7	0.8	0.4	0.2
20	2.4	2.7	0.2	0.0	0.0	0.0
30	2.4	0.1	0.0	0.0	0.0	0.0
$LSD_{0.05}$ (Treatment):	4.6**					
$LSD_{0.05}$ (Time):	5.6**					
$LSD_{0.05}$ (Interaction):	11.3^{NS}					

The results illustrated in the tables show that disease incidence and severity decreased with increasing concentration of extracts indicating that the antifungal capacity of the extracts is dependent on the amount of active principle in each given concentration of crude extract. This corroborates the findings of many workers (Sagar et al., 2007; Balamurugam, 2014; Tegang et al., 2018) who reported marked concentration-dependent inhibition of phytopathogenic fungi in different studies.

Although the extracts exhibited effective control of TLB, *C. aurantifolia* extract was the most efficient in reducing disease given the lowest (zero) percentage of disease at a 30% concentration. This suggests that 30% concentration is the absolute fungicidal dose. The differential capacity of the extracts to reduce disease could be attributed to differences in their quantitative and qualitative phytochemical composition as opined by Edeoga et al. (2005). Plants of different species vary in the type and amount of bioactive principles and their biological activities are bound to be different. The observed variation in the performance of the extracts could also be attributed to the type of solvent used for extraction (Okwu, 2006).

The antifungal activity of *C. aurantifolia* could be ascribed to some components such as limonene and geranial which were reported to have antimicrobial activity. Two studies by Pasqua et al. (2006 and 2007) reported that limonene, the major component in citrus essential oil, had high antimicrobial activity against pathogens when applied separately. This result agrees with the results of Tchameni et al. (2017) who reported the highest inhibition of sporangia production (72.84%) by lime oil at 400 ppm.

Although the aqueous and ethanol extracts of *Xylopia aethiopica* showed a significant reduction of disease they were not as efficient as that of *C. aurantifolia* in the present study. However, there are reports of the overwhelming potency of *X. aethiopica* against many pathogenic fungi and bacteria in different studies (Amadioha and Obi, 1998; Fleischer, 2003; Okigbo and Nmeka, 2005; Fleischer et al., 2008, Nweze and Onyishi, 2010; Tegang et al., 2018). Amadioha and Obi 1998 reported that hot water and oil extracts of *Xylopia aethiopica* significantly reduced spore germinatsion and growth of *Colletotricum lindemuthianum in vitro.* Test with cowpea (*Vigna unguiculata*) indicated that the extracts applied before or after infection of plant with *C. lindemuthianum* were also effective in reducing the size of pathogen induced lesions greater than that of Benomyl.

Conclusion

Our present study indicated that fruit juice of *C. aurantifolia*, aqueous and ethanol extracts of *X. aethiopica* significantly exhibited antifungal potency in controlling leaf blight disease of *C. esculenta* caused by *P. colocasiae*. The results revealed that among the extracts used, an aqueous extract of *C. aurantifolia* (lime juice) was the best alternative for biocontrol of taro leaf blight. This finding is the first report of these extracts in controlling *Phytophthora* leaf blight disease of *colocasia.* However, the mechanism of action of these extracts still needs further investigation in both *in-vitro* and field trials. Having observed the efficacy of *Citrus aurantifolia* aqueous extract as well as aqueous and ethanol extracts of *Xylopia aethiopica* on the reduction of *Phytophthora* leaf blight disease of taro, we therefore, recommend that farmers should adopt these extracts because of their bio-friendly and availability status. Further research should be carried out in this area to isolate the specific antifungal fractions of these extracts and make them available in commercial quantities.

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References

Adomako, J., Kwoseh, C. and Moses, E. (2017). Metalaxyl sensitivity and aggressiveness of *Phytophthora colocasiae* isolates associated with taro leaf blight disease. *Journal of Plant Pathology* **99**, 205-21.

Aibinu, I., Adenipekun, T., Adelowotan, T., Ogunsanya, T., and Odugbemi, T. (2007). Evaluation of the antimicrobial properties of different parts of *C. aurantifolia* (lime fruit) as used locally. *African Journal of Traditional, Complementary and Alternative Medicine* **4**, 185-190.

Amadioha, A.C., and Obi, I. (1998). Fungitoxic activity of extracts from *Azadirachtaindica* and *Xylopia aethiopica* on *Colletotrichum lindemuthianum* in cowpea. *Journal of Spices, Herbs and Medicinal Plants* **6**, 33-40.

Awuah, R.T. (1989). Fungitoxic effects of extracts from some West African plants. *Annals of Applied Biology* **115**, 451- 453.

Balamurugan, S. (2014). *In vitro* antifungal activity of *Citrus aurantifolia* Linn plant extracts against phytopathogenic fungi *Macrophomina phaseolina. International Letters of Natural Sciences* **13**, 70.

Brooks, F.E. (2005).Taro leaf blight. The plant health instructor. American Phyto- pathological Society. http://www.apsnet.org/edcenter/intropp/lessons/ fungi/Oomycetes/Pages/TaroLeafBlight.aspx [January 2, 2019].

Brooks, F.E. (2008) Detached-leaf bioassay for evaluating taro resistance to *Phythophthora colocasiae. Plant Diseases* **92**,126-131.

Brunt, J., Hunter, D. and Delp, C. (2001) "A Bibliography of Taro Leaf Blight". Secretariat of the Pacific Community (SPC)/AusAID Taro Genetic Resources: Conservation and Utilization. Noumea, New Caledonia, 93pp.

CABI (2020). *Phytophthora colocasiae* (taro leaf blight). www.cabi.org. [August 18, 2021].

CMI [Commonwealth Mycology Institute]. (1997). "Distribution Maps of Plant Diseases, Map No. 466 *Phytophthora colocasiae*". 3rd Ed. pp. 56. Commonwealth Agricultural Bureau. Wallingford. Oxfordshire.

Danny, H., Kirifi P. and Semisi, S. (2008). "The Impact of Taro Leaf Blight in the Pacific Islands with Special Reference to Samoa". pp. 75-78.

Dhaliwal, G.S. and Koul, O. (2011). "Biopesticides and Pest management". Kalyani Publishers, Ludhiana, New Delhi. 455 p.

Edeoga, H.O., Okwu, D.E., and Mbaebie, B.O. (2005). Phytochemical constituent of some Nigerian medicinal plants. *African Journal of Biotechnology* **4**, 685- 688.

Ekanem, A.M. and Osuji, J.O. (2006). Mitotic index studies on edible coco yams (*Xanthosoma* and *Colocasia* species). *African Journal of Biotechnology* **5**, 846-849.

Fleischer, T.C., Mensah, M.L.K., Mensah A.Y., Komlaga, G., Gbedema, S. Y. and Skalta, H. (2008). Antimicrobial activity of essential oils of *Xylopia aethopica*. *African Journal of Traditional*, *Complementary and Alternative Medicine* **5**, 391-393.

Fleischer, T. C. (2003). *Xylopia aethiopica* (Dunal) A. Rich.: a chemical biological perspective. *Journal of Science and Technology* **23**, 24 – 31.

Fullerton, R. A. and Tyson, J. L. (2004). The biology of *Phytophthora colocasiae* and implication for its management and control *In* Third Taro Symposium, New Zealand, pp. 107-111.

Ganie, S. A., Ghani, M.Y., Nissar, Q., Jabeen, N., Anjum, O., Ahanger, F. A. and Ayaz, A. (2013). Status and symptomatology of early blight (*Alternaria solani*) of potato (*Solanum tuberosum* L.) in Kashmir valley. *Academic Journal* **8**, 5104-5115.

Grade, U.A. and Joshi, M.S. (2003). Influence of weather factors on the incidence of leaf blight of *Colocasiae*. *Annals of Plant Protection Science* **11**, 168-170.

Komarek, M., Cadkova, E., Chrastny, V., Bordas, F. and Bollinger, J.C. (2010). Contamination of vineyard soils with fungicides: a review of environmental and toxicological aspects. *Environmental International* **36**, 136-151.

Manner, H.I. and Taylor, M. (2011) (revised). "Farm and Forestry Production and Marketing Profile for taro (*Colocasia esculenta*)". Permanent Agriculture Resources (PAR), Holualoa, Hawaii. pp 34.

Mbong, G.A., Fokunang, C.N., Lum, A.F., Bambot, M.B., and Tembe, E.A. (2013). An overview of *Phytophthora colocasiae* of cocoyams: a potential economic disease of food security in Cameroon. *Discourse Journal of Agriculture and Food* **1**, 140-145.

Misra, R. S., Mishra, A.K., Sharma, K., Jeeva, M. L. and Hegde, V. (2011). Characterization of *Phytophthora colocasiae* isolates associated with leaf blight of taro in India. *Archives of Phytopathology and Plant Protection* **44**, 581-591.

Misra, R.S., Sharma, K. and Mishra, A.K. (2008). *Phytophthora* leaf blight of taro (*Colocasia esculenta*) - a review. *The Asian and Australian Journal of Plant Science and Biotechnology* **2**, 55-63.

Miyasaka, S.C., McCulloch, C.O. and Nelson, S.C. (2012). Taro germplasm evaluated for resistance to taro leaf blight. *HortTechnology* **22**, 838-849.

Nata'ala., M.K. Dalhat, M.H., Omoye, B.S., Isah, A.A., Kabiru, S. I. Bashiru, I. and Umar, F.A. (2018). Phytochemical screening and antibacterial activities of *Citrus sinensis* (L.) Osbeck (orange) and *Citrus aurantifolia* (Cristm) Swingle (lime) stem on bacteria associated dental carries. *Journal of Advances in Microbiology* **8**, 1-9.

Nath, V.S, Senthil, M., Hedge, V.M., Jeeva, M.L., Misra, R.S., Veena, S.S. and Raj, M. (2013). Molecular evidence supports hyper-variability in *Phytophthora colocasiae* associated with leaf blight of taro. *European Journal of Plant Pathology* **136**, 483-494.

Nelson, S., Brooks, F. and Teves, G. (2011). Taro leaf blight in Hawaii. *Plant Diseases Bulletin* PD-71. University of Hawaii Manoa, HI, USA.

Nweze, E.I. and Onyishi, M.C. (2010). In-vitro antimicrobial activity of ethanolic and methanolic extract fruit extract of *Xylopia aethiopica* and its combination on disc antibiotics against clinical isolates of bacteria and fungi. *Journal of Rural and Tropical Public Health* **9**, 1-6.

Nwosu, M.O., Okafor, J.I. (1995) Preliminary studies on the antifungal activities of some medicinal plants against *Basidiobolus* and some other pathogenic fungi. *Mycoses* **38**, 191–195.

Okereke, N.R. (2020). Taro leaf blight: threat to taro (*Colocasiae esculenta* L. Schott) production. *Nigeria Agricultural Journal* **51**, 281-286.

Okigbo, R.N. and Nmeka, I. A. (2005). Control of yam tuber rot with leaf extracts of *Xylopia aethiopica* and *Zingibe rofficinale. African Journal of Biotechnology* **4**, 804-807**.**

Otekunrin, O.A., Sawicka, B., Adeyonu, A.G., Otekunrin, O.A. and Racho, N. L. (2021). Cocoyam [*Colocasia esculenta* (L.) Schott]: Exploring the production, health and trade potentials in sub-Saharan Africa*. Sustainability* **13**, 44-83.

Otieno, C.A. (2020). Taro leaf blight (*Phytophthora colocasiae*) disease pathogenicity on selected taro (*Colocasia esculenta*) in Maseno, Kenya. *Open Access Library Journal* e6393. https://doi.org/10.4236/oalib.1106393

Omane, E., Oduro, K.A., Cornelius, E.W., Opoku, I.Y, Akrofi, A.Y, Sharma, K., Kumar, P.L. and Bandyopadhyay, R. (2012). First report of leaf blight of taro (*Colocasia esculenta*) caused by *Phytophthora colocasiae* in Ghana. *Plant Disease* **96**, 292-293.

Okwu, D.E. and Josiah, C. (2006). Evaluation of the chemical composition of two Nigerian medicinal plants. *African Journal of Biotechnology* **5**, 357-336.

Pasqua, R., Hoskin ,N., Bett, G. and Mauriello, G. (2006).Changes in membrane fatty acids composition of microbial cell induced by addiction of thymol, carvacrol, limonene, cinnamaldehyde and eugenol in the growing media. *Journal of Agriculture and Food Chemistry* **54**, 2745-2749.

Pasqua, R., Bett, G., Hoskin, N., Edwards, M., Ercolini, D., and Mauriello, G. (2007). Membrane toxicity of antimicrobial compounds from essential oils. *Journal of Agriculture and Food Chemistry* **55**, 4863-4870.

Rios, J.L. and Recio, M.C. (2005). Medicinal plant and antimicrobial activity. *Journal of Ethnopharmacology* **100**, 80.

Sagar, S.D., Kulkarmi, S. and Hedge, Y. R. (2007). Management of rhizome rots of ginger by botanicals. *International Journal of Plant Science* **2**,155-158.

Sealy, R., Evans, M.R. and Rothrock, Craig (2007). The effect of garlic extracts and root substrate on soil borne fungal pathogen. *HortTechnology* **17**, 169-173.

Sesan, T.E., Enache, E., Locomi, B.M., Oancea, F., Lacomi, C. and Oprea, M. (2017). *In-vitro* antifungal activity of some plant extracts against *Fusarium oxysporum* in blackcurrant (*Ribesnigrum*L.).*Acta Scientiarum Polonorum Hortorum Cultus* **16**, 167-176.

Shakywar, R.C., Pathak, S.P., Kumar, S. and Singh, A.K. (2012). Evaluation of fungicides and plant extracts (botanicals) against *Phytophthora colocasiae* Raciborski causing leaf blight of taro. *Journal of Plant Disease Science* **7**, 197-200.

Tegang A.S., Beumo, T.M.N., Dongmo, P.M J., and Ngoune, L.T. (2018). Essential oil of *Xylopia aethiopica* from Cameroon: Chemical composition, antiradical and in-vitro antifungal activity against some mycotoxigenic fungi. *Journal of King Saud University - Science* **30**, 466-471.

Tehameni, S.N., Mbiakeu, S.N., Sameza, M. L., Jazet, P.M.D and Tchoumbougnang, N.C.(2017). Using *Citrus aurantifolia* essential oil for the potential biocontrol of *Colocasia esculenta* (taro) leaf blight caused by *Phytophthora colocasiae*. *Environmental Science Pollution Research* DOI://doi.org/10.1007/S11356-017-0506-0.

Ugwuja, F.N., Onyeka, T.J., Chiejina, N.V. and Ugwuoke, K. I. (2020). Effect of *Phytophthora* leaf blight disease of taro (*Colocasia esculenta* (L.) Schott on proximate and phytochemical constituents of infected taro corms. *Nigerian Agricultural Journal* **51**,142-150.

Ugwuja, F.N., Oti, C.P., Onaebi, C.N. and Oti, V. O. (2021). Comparative antifungal potency of some botanical-fungicides obtained with different extraction solvents against taro leaf blight (*Phytophthora colocasiae)* in south east Nigeria. *Nigerian Agricultural Journal* **52**, 247-25.

Ugwuja, F. N. and Chiejina, N.V. (2011). Preliminary investigation of the causes of leaf rots of cocoyam in Nsukka zone of Nigeria. *Nigerian Journal of Plant Protection* **25**, 203-213.

Ukpabi, U.J., Chijioke, U. and Mbanaso, E. N. A. (2013). Feasibility of producing acceptable carotene and energy rich taro crisps with deep palm-oil frying in Nigeria. *Pakistan Journal of Nutrition* **12**, 811-814.