



# Pathological Assessment of Fungi from Diseased Crops Grown with Contaminated Irrigation Water in Some Selected Local Government Areas of Sokoto State

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## ABSTRACT

Crop production in Sokoto State is heavily dependent on irrigation, but contaminated irrigation water often introduces pathogenic fungi and heavy metals which compromise crop health. This study investigated the presence of fungal pathogens in crops grown with contaminated irrigation water used in three Local Government Area of Sokoto State which include Kware, Wamakko, and Tambuwal. The Physicochemical analysis shows that the pH of the water is neutral with 7.18, 7.15 and 7.04 from TBW, KW and WMK respectively. The electrical conductivity recorded highest from KW with 1688, then 1685 from WMK and the least was from TBW, dissolve oxygen was higher in TBW and lest recorded was from WMK, the result of BOD recorded highest from WMK with 23.3 followed by 22.9 from TBW and 22.1 from KW, Ca, Mg and Cl were also analyzed with highest ca from TBW WITH 84.0 followed by KW with 68.0 then the least was 30.0 from WMK. Heavy metal analyses were Iron which recorded highest from WMK with 10.5 and lowest from KW with 5.1, copper recorded highest from TBW with 6.4 followed by WMK with 5.5 and KW was the least with 4.3, lead concentration was very minimal across all the sample sites with 0.9, 0.8 and 0.4 from KW, WMK and TBW respectively. Zinc recorded higher from TBW with 13.0 and the least was 8.1 from WMK, chromium concentration was recorded from KW with 4.3 and WMK was the least with 2.3. Isolation of fungi from the irrigation water samples shows that both water and diseased crops. Pathogens identified included *Aspergillus niger*, (10%) *Rhizopus stolonifera* (10%), *Mucor hiemalis* (6.66%), *Candida tropicalis* (6.66%), *Penicillium* (3.33%), *Cladosporium* (3.33%), *Trichoderma*, *fusarium* (10%), and *Aspergillus flavus* (10%). Pathogenicity tests confirmed their role in crop spoilage. Results revealed high contamination levels, linking irrigation water to the prevalence of fungal diseases in crops, all the fungal isolated detected from the water samples were also isolated from the diseased crops. The study concludes that irrigation water is a major vector for fungal pathogens and heavy metal stress, threatening agricultural productivity and food safety. Recommendations were made on water treatment, farm sanitation, crop rotation, and policy interventions.

**Keywords:** Irrigation, Fungi, Crop, Pathogens, Water, Contamination.

## 1.0 INTRODUCTION

Crop production remains the backbone of agricultural sustainability in Nigeria, particularly in the northern regions where farming is not only a source of livelihood but also a major contributor to food security. However, crop production is constantly threatened by various biotic and abiotic stresses, of which fungal pathogens are among the most devastating. Globally, fungi are responsible for more than 30% of emerging plant diseases, leading to significant yield losses, reduction in crop quality, and economic setbacks for farmers (Agrios, 2018). The problem becomes more pronounced in semi-arid regions such as Sokoto State, where water scarcity forces farmers to rely heavily on surface and underground irrigation systems. Unfortunately, the use of contaminated irrigation water provides a potential pathway for the introduction and spread of fungal pathogens in crop fields (Agrios, 2018).

Agriculture in Sokoto State is largely subsistence-based, yet it plays a critical role in the livelihoods of

rural communities. Farmers rely heavily on irrigation to produce crops throughout the year, especially during the long dry season characteristic of the Sudan and Sahel savannah zones. Irrigation agriculture has enabled the cultivation of water-demanding crops such as tomato, pepper, and onion in regions where rainfall is highly erratic. However, while irrigation has improved crop availability, it has inadvertently introduced new challenges related to water quality and plant health.

In Nigeria, irrigation agriculture has grown rapidly in response to the increasing demand for vegetables, cereals, and cash crops. Sokoto State is one of the hubs of irrigation farming, particularly in Kware, Wamakko, and Tambuwal local governments where vegetables such as tomatoes, peppers, onions, and leafy greens are cultivated for both local consumption and commercial purposes. Despite its benefits, irrigation farming in these areas often depends on water from open canals, shallow wells, and streams that are exposed to

contamination from domestic activities, agricultural runoff, and animal waste (Aliyu *et al.*, 2022). Such water bodies are not only rich in organic matter but also serve as reservoirs of pathogenic microorganisms, including fungi that cause diseases in crops (Aliyu *et al.*, 2022).

Fungal pathogens such as *Fusarium oxysporum*, *Aspergillus flavus*, *Rhizoctonia solani*, and *Alternaria alternata* have been implicated in several crop diseases in northern Nigeria, ranging from vascular wilts, leaf spots, damping-off, and root rots (Okungbowa & Shittu, 2021). The survival of these fungi in irrigation water and their subsequent transmission to crops create a critical challenge for sustainable agriculture. Moreover, the quality of irrigation water is influenced by both its physico-chemical properties and the presence of heavy metals such as lead (Pb), cadmium (Cd), chromium (Cr), and zinc (Zn). These heavy metals, often introduced into water sources through industrial waste, mining, and urban runoff, can impair plant defenses and increase susceptibility to fungal infections (Fosu-Mensah *et al.*, 2019).

Therefore, the pathological detection of fungi from diseased crops irrigated with contaminated water is essential for identifying the causal agents of infection, understanding the epidemiology of diseases, and designing effective management strategies. This study, carried out in selected local governments of Sokoto State namely Kware, Wamakko, and Tambuwal which seeks to investigate the interplay between irrigation water contamination and fungal crop diseases.

### 1.1 Statement of the Problem

Crop diseases caused by fungi are among the leading constraints to agricultural productivity in Sokoto State. Despite the efforts of farmers, recurrent infections by fungal pathogens reduce both the quantity and quality of harvested produce. The use of contaminated irrigation water exacerbates this problem by continuously introducing fungal spores into farmlands. In Kware, Wamakko, and Tambuwal local governments, farmers often depend on irrigation sources that are neither treated nor monitored for microbial and heavy metal contamination.

### 1.2 Justification of the Study

This study is significant for several reasons. as it provides scientific evidence linking irrigation water quality to the incidence of fungal diseases in crops. Such evidence is crucial for developing disease management strategies that go beyond chemical control, focusing instead on improving water quality and reducing environmental contamination.

Also the study contributes to food safety and public health by highlighting the risks posed by heavy metal accumulation in crops. Given that many communities

in Sokoto rely heavily on vegetables grown through irrigation farming, the findings will guide policymakers in setting water quality standards and monitoring systems. The findings of this study will benefit farmers by equipping them with knowledge on the sources of fungal infections, thereby enabling them to adopt better practices such as water treatment, crop rotation, and the use of disease-resistant varieties.

Finally, the study adds to the body of literature on plant pathology and environmental microbiology in Nigeria, providing a basis for future research on the interplay between irrigation water contamination and crop diseases.

## 2.0 Study Area Description

This research was conducted within three selected Local Government Areas (LGAs) of Sokoto State, Nigeria: Kware, Wamakko, and Tambuwal. These regions are situated within the Sudan Savanna ecological zone, characterized by a semi-arid climate with a distinct dry season spanning from October to May. Agriculture is the primary economic activity, and crop production during the extensive dry season is entirely dependent on irrigation. Farmers in these LGAs predominantly utilize water from a network of shallow wells, the Sokoto-Rima River basin, and seasonal reservoirs. These water sources are frequently vulnerable to contamination from agricultural runoff, domestic waste, and in some cases, industrial effluent, making them a critical point of investigation for pathogen dissemination.

## 2.1 Sample Collection

### 2.1.1 Sample Collection of Crop

Diseased specimens of onion (*Allium cepa*), carrot (*Daucus carota*), and tomato (*Solanum lycopersicum*) were aseptically collected from actively cultivated farms in each of the three LGAs. Samples were selected based on the manifestation of clear pathological symptoms, including but not limited to leaf wilting, fruit rot, root decay, chlorosis, and visible sporulation. The samples were carefully placed in sterile polyethylene bags, appropriately labeled with the location, date, and crop type, and transported in a cool box to the Microbiology Laboratory at Sokoto State University for immediate processing to prevent overgrowth of saprophytic organisms.

### 2.2.2 Sample Collection of Water

Irrigation water samples were collected from the primary water sources accessed by the sampled farms in each LGA. Using standard techniques, one-liter sterile glass bottles were used to collect water samples from a depth of approximately 20-30 cm below the water surface. The bottles were sealed, labeled, and similarly transported under cool conditions to the laboratory for physicochemical and mycological analysis within 24 hours of collection.

### 2.3 Physicochemical Analysis of the Water Samples

The physicochemical parameters were determined according to the procedures of Greenberg et al. (1998). Parameters analyzed included calcium, magnesium, dissolved oxygen, and alkalinity (carbonate, bicarbonate, and chloride). These were determined using titration and colorimetric methods as described by Greater *et al.* (1998).

### 2.4 Determination of Heavy Metals in the water sample

#### 2.4.1 Digestion process

Fifty miles (50ml) of water sample into conical mask, add 4ml of nitric acid, 2ml of perchloric acid and boil on a hot Place for 5-10 minutes and allow cool. After cooling it was filtered using a filter paper and funnel and added distilled water to make it 50 Volume. The solution was boiled to expel oxides of nitrogen and chlorine.

#### 2.4.2 HEAVY METAL ANALYSIS PROCEDURES

Analysis of heavy metals (Zn, Fe, Cr, Pb and Cu) has been done by using absorption spectroscopy (Vijendra and Singh 2006).

The analysis of heavy metals in the irrigation water focused on determining the concentrations of iron, copper, lead, zinc, calcium, chromium, and magnesium. This was carried out using the Atomic Absorption Spectroscopy (AAS) technique in accordance with APHA (2017) standard procedures. In this method, each metal element present in the water sample was atomized and its concentration quantified by measuring the absorption of light at a wavelength specific to that element. The approach ensured high

sensitivity and precision, making it particularly suitable for assessing the potential toxicity of heavy metals and for verifying whether the water quality complies with international irrigation water standards.

#### 2.4.3 Isolation of Fungi from Water Sample

A defined volume (100 ml) of each water sample was passed through a sterile membrane filter (0.45 µm pore size). The filter was then placed aseptically onto the surface of Sabouraud Dextrose Agar (SDA) plates supplemented with chloramphenicol (0.05 g/L) to inhibit bacterial growth.

#### 2.4.4 Isolation from Crops

Small sections (approximately 5x5 mm) of tissue from the margins of lesions on the diseased crops were surface-sterilized by immersion in 70% ethanol for 30 seconds, followed by a rise in sterile distilled water.

The sterilized segments were then plated onto SDA plates. Incubation and Purification: All inoculated plates were incubated at 25±2°C for 5-7 days. Developing fungal colonies were sub-cultured onto fresh SDA plates to obtain pure isolates for identification. Identification: Fungal identification was performed based on a combination of macroscopic and microscopic characteristics.

Macroscopic features included colony morphology, texture, pigmentation, and rate of growth. For microscopic examination, lactophenol cotton blue mount preparations were made from pure cultures and observed under a compound microscope for diagnostic structures such as hyphal type, conidiophores, sporangia, conidia, and other reproductive structures. Identification was confirmed using standard mycological manuals

## 3.0 RESULTS

### 3.1 Table 1 Physicochemical Properties of Irrigation Water

The results of the physicochemical analysis of the water samples from the three locations are presented in Table 1.

3.2 Table 2: Heavy Metal Analysis of Water Samples (mg/L)

Sample Location	pH	EC (µS/cm)	DO (mg/L)	BOD (mg/L)	Ca (mg/L)	Mg (mg/L)	TDS (mg/L)	Cl (mg/L)	SO <sub>4</sub> (mg/L)	PO <sub>4</sub> (mg/L)	N O <sub>3</sub> (mg/L)
Kware	7.15	1882	8.2	22.1	68.0	36.0	110.0	1.4	0.07	0.06	1.8
Wamakko	7.04	1685	8.0	23.2	30.0	40.2	80.0	1.5	0.06	0.04	1.4
Tambuwal	7.18	1587	9.1	22.9	84.0	32.4	120.0	1.8	0.09	0.05	1.2
Element	Wamakko		Tambuwal		Kware						
Iron (Fe)	10.5		9.4		5.1						
Copper (Cu)	5.5		6.4		4.3						
Lead (Pb)	0.8		0.4		0.9						
Zinc (Zn)	8.1		13.0		10.3						
Calcium (Ca)	7.6		5.2		8.5						
Chromium (Cr)	2.3		3.1		4.3						
Magnesium (Mg)	2.6		3.4		4.6						

**3.3 Table 3. Fungal Species Isolated from Water Sample**

FUNGAL SPECIE	TBW	WMK	KW
<i>Aspergillus niger</i>	+	+	+
<i>Rhizopus stolonifera</i>	+	+	+
<i>Candida</i>	+	+	-
<i>Mucor hiemalis</i>	+	-	+
<i>Cladosporium</i>	+	-	-
<i>Trichoderma</i>	-	+	+
<i>Fusarium</i>	-	+	-
<i>Penicillium</i>	-	-	+
<i>Aspergillus flavus</i>	+	+	+

**3.4 Table 4; Percentage Occurrence of Fungi in the Water Samples**

Fungi	Percentage Occurrence
<i>Aspergillus niger</i>	10%
<i>Rhizopus stolonifera</i>	10%
<i>Candida</i>	6.66%
<i>Mucor hiemalis</i>	6.66%
<i>Cladosporium</i>	3.33%
<i>Trichoderma</i>	10%
<i>Fusarium</i>	3.33%
<i>Penicillium</i>	3.33%
<i>Aspergillus flavus</i>	10%

**3.5 Table 5: Fungal Species Isolated from the Crop Gown with the Water Sample in Tambuwal**

Fungal Spp	Carrot	Onion	Tomato
<i>Aspergillus niger</i>	+	+	+
<i>Rhizopus stolonifera</i>	+	+	+
<i>Candida</i>	+	+	+
<i>Cladosporium</i>	+	+	+
<i>Trichoderma</i>	+	+	-
<i>Fusarium</i>	-	+	-
<i>Penicillium</i>	-	+	+
<i>Aspergillus flavus</i>	+	-	+
<i>Mucor</i>	+	-	+

**3.6 Table 6: Fungal Species Isolated from The Crop Grown with The Water Sample in Kware**

Fungal Spp	Carrot	Onion	Tomato
<i>Aspergillus niger</i>	+	+	+
<i>Rhizopus stolonifera</i>	+	+	+
<i>Candida</i>	-	-	-
<i>Cladosporium</i>	-	-	-
<i>Trichoderma</i>	+	-	-
<i>Fusarium</i>	+	-	-
<i>Penicillium</i>	-	+	+
<i>Aspergillus flavus</i>	+	+	+
<i>Mucor</i>	+	-	+

Key: + = Present, - = Absent

**3.7 Table 7 Fungal Species Isolated from The Crop Grown with The Water Sample in Wamakko**

### 3.8 Morphological Characteristics of Isolates

Fungal Spp	Carrot	Onion	Tomato
<i>Aspergillus niger</i>	+	+	+
<i>Rhizopus stolonifera</i>	+	+	+
<i>Candida</i>	+	+	+
<i>Cladosporium</i>	-	+	+
<i>Trichoderma</i>	+	+	-
<i>Fusarium</i>	-	-	-
<i>Penicillium</i>	+	+	+
<i>Aspergillus flavus</i>	+	+	+
<i>Mucor</i>	-	-	-

3.8.1 The identifying features of the isolated fungi, which were crucial for their diagnosis, are summarized in Table 8.

**3.8.1 Table 8: Microscopic and Macroscopic Morphology of Fungi Isolated**

Fungal Isolate	Description	Macro culture
<i>Aspergillus niger</i>	Hypae are septate and hyaline conidial heads are black, radiate, with a tendency to split into loose columns at maturity; Conidia are subglobose, 3.5 to 5µm in diameter; brown with warts spines or irregular ridges.	On PDA, at 25°C colonies reach a diameter of 4-5cm within 7 days white or felt with a dense of brown to black conidiophores, the reverse side is cream to yellow.
<i>Rhizopus stolonifera</i>	It is composed of branched, non-septate white hyphae with a length of 900-2700 µm and a diameter of 22-23µm.	It typically exhibits a cotton-like or candy-like texture and rapidly grows, filling the petri dish within a few days.
<i>Mucor hiemalis</i>	Is a non-septate or sparsely septate, broad hyphae (6-15µm wide). Sporangia, sporangia and spores are also visible.	Deep-yellow, aromatic and have a maximum growth temperature of 42°C.
<i>Candida tropicalis</i>	Oval or spherical blastospores, some times in pairs or chains a long with branched pseudo hyphae and even true hyphae.	<i>C. tropicalis</i> colonies are usually flat, soft, and creamy-colored with a yeasty odor.

<i>Aspergillus flavus</i>	It shows the biserial with phialides radiating from all side globose conidia with varying sizes that are slightly rough and unbranched conidiophore which is nonseptate, rough, and hyaline.	Colonies are typically blue with a suede like surface consisting of a dense felt of conidiophores or sometime yellowish green or dark green colony surrounded by a white circle that was eventually covered by conidia.
<i>Fusarium proliferatum</i>	Produced white villous colonies with a diameter of 7mm and produced light purple pigment after 7 days on the media.	Produces microscopic, long, canoe-shaped spores called conidia. These asexual conidia have 3 to 7 cells and are produced on specialized hyphae called conidiophores
<i>Penicillium notatum</i>	Texture velvety to powdery; green, blue, grey-green, white. The plate reverse is usually pale to yellowish	Septate hyphae with branched or unbranched conidiophores that have secondary branches known as metulae, on the metulae, arranged in whorls, are lask-shaped sterigmata that bear un branched chains of round conidia.

**3.9 Table 9: Spoilage Pattern of the crops by Fungal Species**

Fungal Isolate	Spoilage Pattern Produced
<i>Aspergillus niger</i>	Dark brown to discoloration, sunken spots, species becomes spongy with gas production.
<i>Candida tropicalis</i>	The specimen becoming spongy with gas production; sunken spots.
<i>Aspergillus flavus</i>	Dark brown discoloration, sunken spots the specimen become spongy with gas production.
<i>Rhizopus stolonifera</i>	Watery soft rot, wrinkled appearance with depression and yellowish in color.
<i>Mucor hiemalis</i>	White mycelial growth with a cream-white color.

#### 4.0 DISCUSSION

The mean pH of the irrigation water samples was 6.8, which falls within the slightly acidic to neutral range. This observation is consistent with the findings of Shittu *et al.* (2022), who reported pH values between 6.5 and 7.2 in irrigation wells in southwestern Nigeria. However, it differs from the report of Ollo Kambiré *et al.* (2022), who recorded higher pH values (7.8–8.3) in well water samples in Côte d'Ivoire, a difference that may be attributed to the higher mineral content of groundwater in that region.

The pH values across all samples were within a neutral to slightly alkaline range (7.15 - 7.84), which is generally suitable for irrigation and does not in itself indicate a problem. The Electrical Conductivity (EC) and Total Dissolved Solids (TDS) values, however, are elevated. This suggests a high mineral salt content, which can induce salinity stress in plants, weakening their natural defenses and potentially increasing their susceptibility to fungal pathogens. The detectable levels of phosphate (PO<sub>4</sub>) and nitrate (NO<sub>3</sub>) are indicative of nutrient loading, most likely from agricultural runoff containing fertilizers. This eutrophication can directly promote the proliferation of microorganisms, including fungi, in the water sources.

**Table 2** Iron levels (5.1–10.5 mg/L) in all sites were much higher than the 0.40–1.20 mg/L reported by Musa *et al.* (2021), showing elevated Fe contamination. Copper (4.3–6.4 mg/L) also exceeded the 0.2–1.0 mg/L range noted by Bello *et al.* (2020). Lead values (0.4–0.9 mg/L) were far above the WHO limit of 0.01 mg/L and higher than the 0.015 mg/L documented by Ibrahim and

Bello (2020). Zinc (8.1–13.0 mg/L) was markedly greater than the 1.05 mg/L observed by Usman *et al.* (2021). Calcium (5.2–8.5 mg/L) remained within natural ranges and agreed with Yakubu *et al.* (2020). Chromium (2.3–4.3 mg/L) greatly exceeded the 0.048 mg/L found by Abdullahi *et al.* (2021). Magnesium (2.6–4.6 mg/L) was also higher than the 1.5–2.0 mg/L reported by Musa *et al.* (2021).

The mycological investigation successfully isolated and identified a consortium of fungal pathogens from both water and plant tissue samples, including *Aspergillus niger*, *Rhizopus stolonifera*, *Mucor hiemalis*, *Candida tropicalis*, *Trichoderma*, *Fusarium*, *penicillium* sp, *cladosporium* and the notoriously toxigenic *Aspergillus flavus*.

The high prevalence of species such as *Aspergillus niger*, *Rhizopus stolonifera* and, particularly, the isolation of the yeast *Candida tropicalis* serve as biological indicators. *Aspergillus niger*, *Aspergillus flavus*, *Trichoderma* and *Rhizopus stolonifera* was the most prevalent isolate (10%), which is consistent with its reputation as a common, fast-growing saprophyte and pathogen causing soft rot in a wide range of fruits and vegetables. The presence of *Candida tropicalis*, a yeast, (6.66%) is particularly noteworthy. This organism is often associated with organic and fecal pollution, suggesting that the irrigation water sources are contaminated with organic waste, which provides a rich nutrient base for microbial growth. The isolation of *Aspergillus flavus* is a major food safety concern due to its well-documented potential to produce highly carcinogenic aflatoxins. This agrees with the report obtained by Ibeyess 2007, who study fungi on

vegetables by waste and non waste water, the presence of wide range of fungal organisms in these products showed a relationship between the microbial quality of the water used for the vegetables and the effect of human and other animals defecation.

Shehu *et al* isolated the same species in his study of fungi associated with waste water used for irrigation on soil in Sokoto metropolis

The predominant fungi isolated species were tolerant to heavy metal present in the water so its numbers is higher, Michael *et al.*, (2000) reported the same species in his study and reported that they are well known agents of mycosis such include *Aspergillus niger*, *Aspergillus flavus* etc these genus are reported to have been associated with wastewater in various part of the world Moalaei *et al*, 2006. Rabiatu *et al* (2023) reported high prevalence of the se fungal specie in her report on the study of fungi infecting disease carrot in Sokoto.

Their ecology suggests significant organic enrichment of the water sources, likely stemming from domestic effluent and agricultural runoff, which provides a nutrient base for microbial proliferation. This finding connects crop disease to broader issues of environmental sanitation and water resource management. Determination of the Pathogenicity of fungal species isolated in this research revealed that the isolated fungi are pathogenic to the carrot plant with *Aspergillus niger* exhibiting the highest degree of virulence. This is similar to the findings of Balogun *et al.* (2003), who reported the same result with *Aspergillus niger* having the highest level of virulence in Ilorin, North central Nigeria.

This research demonstrates a direct and mechanistic pathway from environmental contamination to agricultural loss and potential public health risk. The irrigation water systems in the studied LGAs are acting as reservoirs and dissemination vehicles for a community of pathogenic fungi. The use of this water represents a recurrent inoculation event, ensuring the persistence and spread of crop diseases, undermining food security, depreciating economic returns for smallholder farmers, and establishing conditions conducive to mycotoxin contamination of the food chain. This constitutes a vicious cycle of contamination and infection that demands urgent and multifaceted intervention.

## CONCLUSION

The present investigation was conceived to address a pressing agronomic and public health concern manifesting across the irrigated farmlands of Kware, Wamakko, and Tambuwal Local Government Areas. The perceived decline in crop vitality and yield was not a function of agronomic practice alone, but rather symptomatic of a more fundamental pathology: the

contamination of the primary irrigation water sources with pathogenic fungi, a condition potentially exacerbated by concomitant physicochemical pollutants. The research methodology was therefore designed to trace the etiology of crop disease directly to its hydrological source, employing a combination of water quality analysis, classical mycological techniques, and pathogenicity assays.

The analysis reveals that the irrigation water upon which dry-season agriculture in these regions depends is profoundly compromised. It functions not merely as a hydrating medium but as a complex vector for disease. Physicochemical assessment indicated conditions of elevated salinity and nutrient loading, creating an environment of plant stress that predisposes crops to infection. More critically, the detection of heavy metals, including lead and chromium, albeit in variable concentrations, introduces a dimension of chronic toxicity and ecological selection pressure. These metals can induce phytotoxicity, compromising plant defense mechanisms, while simultaneously selecting for metal-tolerant, and potentially more resilient, microbial populations.

## CONFLICT OF INTEREST

The authors declare that there is no competing conflict of interest.

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