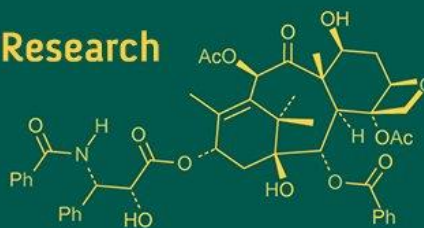


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Evaluation of inorganic compounds for the management of potato dry rot caused by *Fusarium incarnatum* under storage conditions

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Abstract

Potato dry rot caused by *Fusarium incarnatum* is an important postharvest disease responsible for severe quantitative and qualitative losses during storage. The present investigation was undertaken to evaluate the efficacy of selected inorganic compounds against potato dry rot under tuber storage conditions. The experiment was conducted under Completely Randomized Design (CRD) with three replications using artificially inoculated potato tubers of cv. Kufri Pukhraj. Eight treatments comprising different inorganic compounds at three concentrations were evaluated against *F. incarnatum*. The pathogen isolate was molecularly confirmed as *Fusarium incarnatum* based on ITS rDNA sequencing and deposited in GenBank under accession number PZ384665. Significant differences were observed among inorganic compounds and concentration levels for lesion development, disease incidence, disease severity and weight loss. Among the evaluated treatments, copper oxychloride recorded minimum lesion diameter (7.90 mm), disease incidence (26.00%), disease severity (12.43%) and weight loss (4.83%), followed by copper sulfate and sodium carbonate. Increasing concentration significantly reduced disease development and tuber deterioration, indicating concentration-dependent antifungal activity. Interaction effects between treatments and concentrations were highly significant for disease incidence, disease severity and weight loss. Copper oxychloride at the highest concentration (0.30%) recorded minimum disease severity (4.44%) and weight loss (3.53%), whereas untreated control recorded maximum disease development. The superior efficacy of copper compounds may be associated with their multi-site antifungal activity, while sodium carbonate and calcium chloride likely suppressed pathogen development through osmotic stress, alkalinity and enhanced host tissue resistance. The present findings demonstrated that inorganic compounds, particularly copper oxychloride, copper sulfate and sodium carbonate, possess considerable potential as eco-friendly alternatives of potato dry rot under storage conditions.

Keywords: Potato dry rot, *Fusarium* spp., inorganic salts, disease management, postharvest pathology, tuber rot, alternative fungicides

1. Introduction

Potato (*Solanum tuberosum* L.) is one of the most important food crops cultivated worldwide and contributes significantly to global food and nutritional security due to its large amount of carbs, vitamins and minerals. The crop is grown extensively for both fresh and industrial processing and constitutes a major part of the agricultural economy of many countries. Potato production has substantial financial opportunities for farmers and stakeholders in the storage, transportation and marketing systems besides its nutritional value. However, several microbial diseases cause a lot of quantitative and qualitative losses during postharvest handling and storage. One of the most severe storage diseases of potato tubers is dry rot caused by *Fusarium* spp. (Lionelle *et al.*, 2023) [5]. Potato dry rot is caused largely by many species of *Fusarium* such as *Fusarium sambucinum*, *F. solani* and *F. sulphureum* depending upon the geographical distribution and storage conditions. The bacterium cannot penetrate the undamaged tuber periderm directly, and the disease usually originates through cuts and injuries incurred during harvesting, grading, packaging and shipment. Infected plants usually show tubers with sunken lesions, internal browning, desiccation and shrivelling of tissue, resulting in the formation of mummified tubers with decreased marketability. Under good storage conditions, incidence of disease may develop rapidly with severe economic losses in

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the order of 25 to 60% during storage. Some *Fusarium* species responsible for dry rot not only reduce yields but also have the capacity to produce mycotoxins such as trichothecenes and other secondary metabolites hazardous to human and animal health (Mecteau *et al.*, 2002; Hay *et al.*, 2019; Li *et al.*, 2009) [6, 2, 4]. Historically, control of potato dry rot has depended on the use of cultural practices and postharvest administration of fungicides, particularly thiabendazole and other benzimidazole compounds. These fungicides initially provided adequate disease control; however, their extensive and repeated usage has resulted in the development of fungicide resistant strains of *Fusarium* spp. and their effectiveness is therefore diminished under storage conditions. Furthermore, the growing public concern about fungicide residues, environmental pollution, food safety and pathogen resistance has sped up the search for safer and eco-friendly options for disease management. The use of chemical fungicides has been shown to be disadvantageous by several studies and there is a need for sustainable approaches that can limit disease development without negatively affecting tuber quality or the health of the environment (Mecteau *et al.*, 2002; Hay *et al.*, 2019; Mohammed *et al.*, 2020; Lionelle *et al.*, 2023) [6, 2, 7, 5]. Over the past few years, great attention has been given to the investigated alternative methods, inorganic and organic salts, because of their wide spectrum of antibacterial activity, low mammalian toxicity, biodegradability and compatibility with systems of postharvest treatment. Most of these salts are generally recognised as safe (GRAS) compounds and are already extensively utilised in food preservation and processing industries. Their antifungal activity has been linked to several mechanisms including osmotic stress, pH alteration, disruption of fungal membrane integrity, blockage of spore germination and suppression of mycelial growth. Moreover, it is known that some salts can enhance the host resistance responses and promote the wound healing processes in stored tubers (Elsheerbiny and El-Khateeb, 2012; Mecteau *et al.*, 2002; Li *et al.*, 2009) [1, 6, 4]. Much progress has been accomplished in the selection of antifungal salts for control of potato dry rot. Antifungal salts were found to vary in efficacy, salt, concentration and storage conditions, highlighting the necessity for further research of antifungal salts under specific experimental conditions. Further, there is less evidence on comparative efficacy of different inorganic salts against the locally occurring isolates of *Fusarium* associated potato dry rot. Thus, the present study was conducted to evaluate the antifungal activity of different inorganic salts against *Fusarium* spp. producing potato dry rot under the conditions of tuber storage with an objective to find some viable and ecologically safe alternatives for sustainable postharvest disease management.

2. Materials and Methods

The experiment was conducted in the Department of Plant Pathology, C.P. College of Agriculture, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar. The experiment was laid out in a Completely Randomized Design (CRD) with three replications for each treatment. The efficacy of selected inorganic compounds against potato dry rot caused by *Fusarium incarnatum* was evaluated under room conditions using the tuber wound inoculation technique.

2.1 Source of Pathogen

The pathogen used in the present investigation was *Fusarium incarnatum*, isolated from dry rot infected potato tubers collected from the market. The isolate showing characteristic dry rot symptoms and high pathogenicity was selected for further experimentation. Infected tuber tissues exhibiting typical dry rot lesions were surface sterilized with 1 percent sodium hypochlorite solution for one minute, rinsed thoroughly with sterile distilled water and transferred aseptically onto Potato Dextrose Agar (PDA) medium. The inoculated plates were incubated at 25 ± 1 °C for seven days to obtain pure fungal cultures. The purified isolate was maintained on Potato Dextrose Agar (PDA) slants and stored at 4 °C under refrigerated conditions. Periodic subculturing was carried out at regular intervals to maintain culture viability and pathogenicity throughout the experimental period. The ITS rDNA sequence of the representative isolate was deposited in the NCBI GenBank database under accession number PZ384665. BLASTn analysis of the obtained sequence revealed 99.82 percent sequence similarity with *Fusarium incarnatum* sequences available in the GenBank database, confirming the identity of the pathogen as *Fusarium incarnatum*.

2.2 Evaluation of Inorganic Compounds Against *Fusarium incarnatum* on Potato Tubers Under Room Conditions

The efficacy of selected inorganic compounds against *Fusarium incarnatum* causing potato dry rot was evaluated under controlled room conditions (25-28 °C temperature and 70-80% relative humidity) using artificially inoculated potato tubers. Healthy and uniform-sized tubers of potato cultivar 'Kufri Pukhraj' were procured from the Potato Research Station, Sardarkrushinagar Dantiwada Agricultural University, Deesa. Tubers free from mechanical injury, insect damage and visible disease symptoms were selected for the experiment and washed thoroughly under running tap water to remove adhering soil particles. The tubers were surface sterilized with 1 percent sodium hypochlorite solution for one minute, followed by three successive rinses with sterile distilled water to eliminate residual disinfectant. The sterilized tubers were air dried under aseptic laboratory conditions. Artificial inoculation was carried out by making a wound approximately 5 mm deep on each tuber using a sterile cork borer. A 5 mm diameter mycelial disc obtained from the actively growing culture of *Fusarium incarnatum* was aseptically placed into the wound so that direct contact was established between the fungal inoculum and tuber tissue. The inoculated tubers were dipped separately for 10 minutes in the prepared solutions of inorganic compounds at different concentrations. Tubers treated with sterile distilled water served as untreated control. After treatment, tubers were placed on sterile blotter paper and incubated under ambient room conditions (25-28 °C and 70-80% RH) for 28 days. Each treatment was replicated three times with five tubers per replication. Observations were recorded after the incubation period by measuring lesion diameter or rot development around the inoculation site.

2.2.1 Parameters Recorded

2.2.1.1 Disease Incidence (%)

Disease incidence was calculated based on the number of infected tubers in each treatment using the following formula (James, 1971) [3]:

$$\text{Disease incidence (\%)} = \frac{\text{Number of infected tubers}}{\text{Total number of tubers}} \times 100$$

2.2.1.2 Disease Severity (%)

Disease severity was assessed based on lesion development and rot severity around the inoculation site using standard disease rating scales. The percent disease severity was calculated using the following formula:

$$\text{Disease severity (\%)} = \frac{\sum(\text{Disease rating} \times \text{Number of tubers})}{\text{Total tubers} \times \text{Maximum disease grade}} \times 100$$

2.2.1.3 Weight Loss (%)

Weight loss of tubers during storage was determined by recording initial and final tuber weight and expressed as percentage using the following formula:

$$\text{Weight loss (\%)} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

Table 1: Evaluation of inorganic compounds against potato dry rot

Tr. No.	Inorganic compounds	Concentration 1	Concentration 2	Concentration 3
T ₁	Control	0	0	0
T ₂	Borax (Sodium borate)	0.25%	0.50%	1.00%
T ₃	Sodium chloride	0.50%	1.00%	2.00%
T ₄	Calcium chloride	0.25%	0.50%	1.00%
T ₅	Potassium tetraborate	0.25%	0.50%	1.00%
T ₆	Sodium carbonate	0.25%	0.50%	1.00%
T ₇	Copper sulfate	0.10%	0.25%	0.50%
T ₈	Copper oxychloride (treated check)	0.10%	0.25%	0.30%

The concentrations of inorganic compounds were expressed as percentage (w/v) solutions for ease of tuber dip application. The concentration ranges were selected based on previously reported antifungal efficacy and phytotoxicity limits reported in earlier studies. Copper-based compounds were maintained at concentrations ≤ 0.5 percent to minimize tuber injury, whereas sodium chloride was evaluated up to 2 percent considering its relatively low phytotoxicity and possible osmotic inhibitory effect on the pathogen.

2.3 Statistical Analysis

The experimental data generated from tuber assay studies were subjected to statistical analysis using Completely Randomized Design (CRD). Analysis of variance (ANOVA) was performed to determine the significance of treatment effects. Treatment means were compared using Duncan's Multiple Range Test (DMRT) at 5 percent level of significance. Wherever necessary, percentage data were subjected to appropriate transformation prior to analysis to normalize variance.

3. Results

3.1 Effect of Inorganic Compounds on Lesion Development in Potato Tubers Inoculated with *Fusarium incarnatum*

The data presented in Table 2 and Figure 1 & 2 revealed that all evaluated inorganic compounds significantly reduced lesion development in potato tubers inoculated with *Fusarium incarnatum* compared with the untreated control. Among the tested treatments, copper-based compounds exhibited the highest antifungal activity. The treated check, copper oxychloride, recorded the minimum mean lesion diameter (7.90 mm) and was significantly superior to all other treatments. This was followed by copper sulfate (10.16 mm), which was statistically comparable with sodium carbonate (12.38 mm), calcium chloride (13.69 mm), and sodium chloride (13.97 mm), but significantly superior to borax (15.47 mm) and potassium tetraborate (16.87 mm).

The untreated control recorded the maximum lesion diameter (45.19 mm), indicating rapid colonisation of tuber tissues by *F. incarnatum* under favourable conditions. Among the non-copper treatments, sodium carbonate showed relatively higher efficacy and substantially reduced lesion development. A significant reduction in lesion diameter was observed with increasing concentration of inorganic compounds. The minimum lesion diameter was recorded at concentration C3 (12.05 mm), which was significantly superior to C2 (14.43 mm) and C1 (17.00 mm), indicating a concentration-dependent inhibitory effect on pathogen development. The interaction between treatments and concentrations ($T \times C$) was found to be non-significant, suggesting that the relative efficacy of inorganic compounds remained consistent across concentration levels.

Table 2: Effect of inorganic compounds on lesion development (mm) in potato tubers inoculated with *Fusarium incarnatum*

Tr. No.	Inorganic compounds	C1	C2	C3	Mean
T ₁	Control	44.90	46.00	44.67	45.19 ^a
T ₂	Borax (Sodium borate)	18.40	15.20	12.80	15.47 ^{bc}
T ₃	Sodium chloride	17.10	13.23	11.57	13.97 ^{bcd}
T ₄	Calcium chloride	16.57	13.93	10.57	13.69 ^{bcd}
T ₅	Potassium tetraborate	19.33	16.60	14.67	16.87 ^b
T ₆	Sodium carbonate	15.97	12.43	8.73	12.38 ^{cd}
T ₇	Copper sulfate	13.40	10.20	6.87	10.16 ^{de}
T ₈	Copper oxychloride (treated check)	10.33	7.87	5.50	7.90 ^e
	Mean	17.00 ^a	14.43 ^b	12.05 ^c	

	S.E.m.±	C.D. at 5%	C.V. (%)
Treatments	0.69	1.96	14.30
Concentration	0.42	1.20	
$T \times C$	1.19	NS	

*Means followed by the same letter(s) are not significantly different at 5 percent level according to Duncan's Multiple Range Test (DMRT). Since the interaction ($T \times C$) was non-significant, comparisons were made only for main effects.

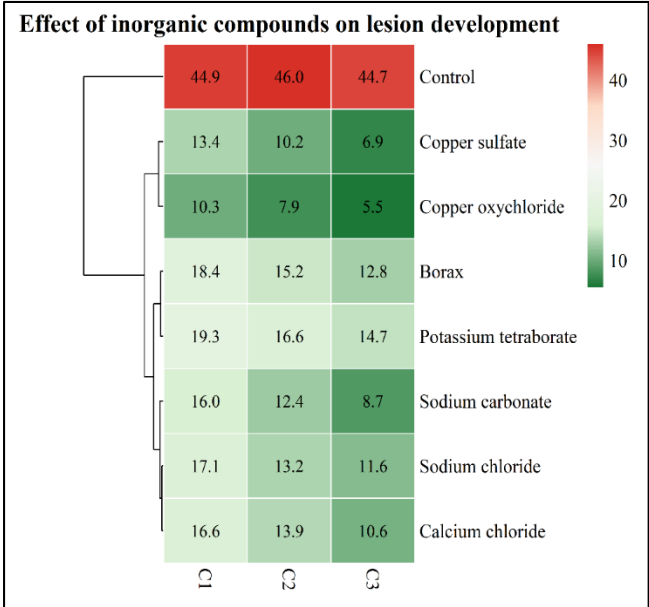


Fig 1: Clustered heatmap showing the effect of inorganic compounds and concentration levels on lesion development (mm) in potato tubers inoculated with *Fusarium incarnatum*. Lower lesion diameter is represented by green colour intensity, while higher lesion development is represented by red colour intensity.

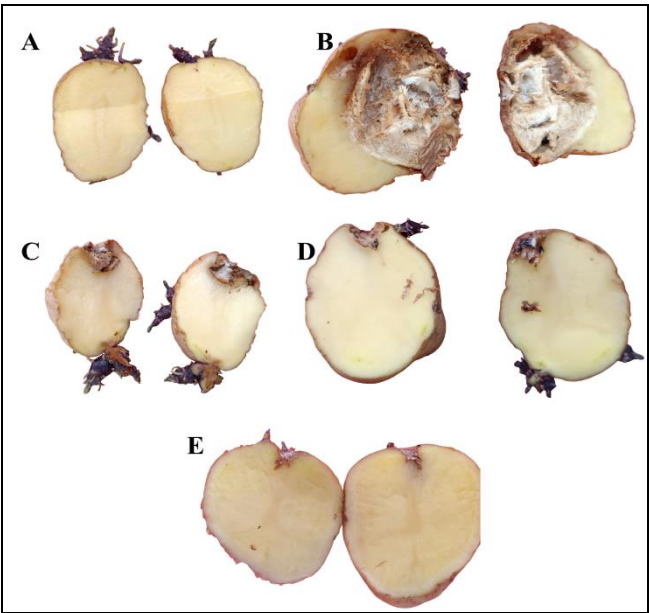


Fig 2: Effect of inorganic compounds on dry rot development in potato tubers inoculated with *Fusarium incarnatum* under storage conditions.

(A) Healthy tuber, (B) inoculated untreated control showing extensive dry rot development and tissue maceration, (C) sodium carbonate-treated tuber, (D) copper sulfate-treated tuber and (E) copper oxychloride-treated tuber showing significant reduction in lesion development and tuber

deterioration under storage conditions.

3.2 Effect of Inorganic Compounds on Disease Incidence, Disease Severity and Weight Loss in Potato Tubers Inoculated with *Fusarium incarnatum*

The data presented in Table 3 and Figure 3 revealed that all inorganic compounds significantly reduced disease incidence, disease severity and weight loss in potato tubers inoculated with *Fusarium incarnatum* compared with the untreated control. The magnitude of reduction varied considerably among the tested compounds and concentration levels, indicating differential antifungal efficacy under storage conditions.

With respect to disease incidence, the treated check copper oxychloride recorded the lowest mean disease incidence (26.00%), followed by copper sulfate (39.89%) and sodium carbonate (55.56%). Calcium chloride also exhibited appreciable disease suppression with a mean disease incidence of 60.11 percent. In contrast, potassium tetraborate (79.94%) and borax (73.44%) were comparatively less effective, although they significantly reduced disease incidence compared with the untreated control (100%). The progressive decline in disease incidence with increasing concentration clearly indicated a concentration-dependent inhibitory effect of inorganic compounds against *F. incarnatum*. Among concentration levels, C3 recorded the lowest mean disease incidence (51.50%), followed by C2 (62.24%) and C1 (74.35%). A similar trend was observed for disease severity. Copper oxychloride recorded the minimum mean disease severity (12.43%), followed by copper sulfate (18.56%) and sodium carbonate (26.15%). The untreated control exhibited maximum disease severity (72.22%), indicating extensive tissue colonisation and rapid disease progression under favourable storage conditions. Among non-copper compounds, calcium chloride significantly reduced disease severity (30.62%), while potassium tetraborate (42.79%) and borax (38.43%) showed comparatively lower suppression. Increasing concentration significantly reduced disease severity, with C3 recording the lowest mean severity (27.32%) compared with C2 (34.32%) and C1 (41.05%). The results pertaining to weight loss also demonstrated significant differences among treatments and concentrations. Minimum mean weight loss was recorded in copper oxychloride-treated tubers (4.83%), followed by copper sulfate (6.57%) and sodium carbonate (8.43%). Maximum weight loss was observed in untreated control tubers (18.67%), indicating severe deterioration and moisture loss due to extensive fungal colonisation. Calcium chloride also effectively reduced weight loss (9.94%), possibly due to its role in maintaining membrane stability and reducing tissue maceration. Increasing concentration significantly decreased weight loss, with concentration C3 recording minimum mean weight loss (9.25%) compared with C2 (10.70%) and C1 (12.04%).

Table 3: Effect of inorganic compounds on disease incidence, disease severity and weight loss in potato tubers inoculated with *Fusarium incarnatum*

Tr. No.	Inorganic compounds	Disease incidence (%)				Disease severity (%)				Weight loss (%)			
		C1	C2	C3	Mean	C1	C2	C3	Mean	C1	C2	C3	Mean
T ₁	Control	100 ^a	100 ^a	100 ^a	100.00	70.83 ^c	73.08 ^a	72.77 ^b	72.22	17.83 ^c	18.97 ^b	19.20 ^a	18.67
T ₂	Borax (Sodium borate)	86.56 ^c	73.78 ^d	60.00 ^k	73.44	46.20 ^e	38.67 ^h	30.43 ^m	38.43	14.20 ^e	12.40 ^h	10.70 ^k	12.43
T ₃	Sodium chloride	80.26 ^d	66.33 ^j	53.33 ^m	66.64	40.87 ^g	32.42 ⁱ	24.52 ^p	32.60	12.80 ^g	10.87 ⁱ	8.93 ⁿ	10.87
T ₄	Calcium chloride	73.33 ^g	60.33 ⁱ	46.67 ^o	60.11	38.41 ⁱ	30.43 ^m	23.02 ^q	30.62	11.93 ⁱ	9.93 ^m	7.97 ^q	9.94
T ₅	Potassium tetraborate	93.33 ^b	80.15 ^e	66.33 ^j	79.94	50.47 ^d	42.61 ^f	35.31 ^j	42.79	15.17 ^d	13.57 ^f	11.93 ⁱ	13.56
T ₆	Sodium carbonate	67.00 ^h	53.67 ^k	46.00 ^p	55.56	34.73 ^k	26.32 ^o	17.42 ^t	26.15	10.17 ^j	8.43 ^o	6.70 ^r	8.43
T ₇	Copper sulfate	53.00 ⁿ	40.00 ^r	26.67 ^s	39.89	26.62 ⁿ	18.43 ^s	10.64 ^v	18.56	8.07 ^p	6.57 ^s	5.07 ^u	6.57
T ₈	Copper oxychloride (Treated check)	41.33 ^q	23.67 ^t	13.00 ^u	26.00	20.25 ^f	12.59 ^u	4.44 ^w	12.43	6.13 ^t	4.83 ^v	3.53 ^w	4.83
Mean		74.35	62.24	51.50	-	41.05	34.32	27.32	-	12.04	10.70	9.25	-
		S.E.m.±	C.D. at 5%	CV (%)	-	S.E.m.±	C.D. at 5%	CV (%)	-	S.E.m.±	C.D. at 5%	CV (%)	-
Treatments		0.97	2.75	5.36	-	0.55	1.56	4.68	-	0.66	1.87	9.80	-
Concentration		0.59	1.68		-	0.34	0.95		-	0.40	1.15		-
T × C		1.68	4.77		-	0.95	2.70		-	1.14	3.24		-

Means followed by the same letter(s) within the interaction are not significantly different at 5 percent level according to Duncan's Multiple Range Test (DMRT)

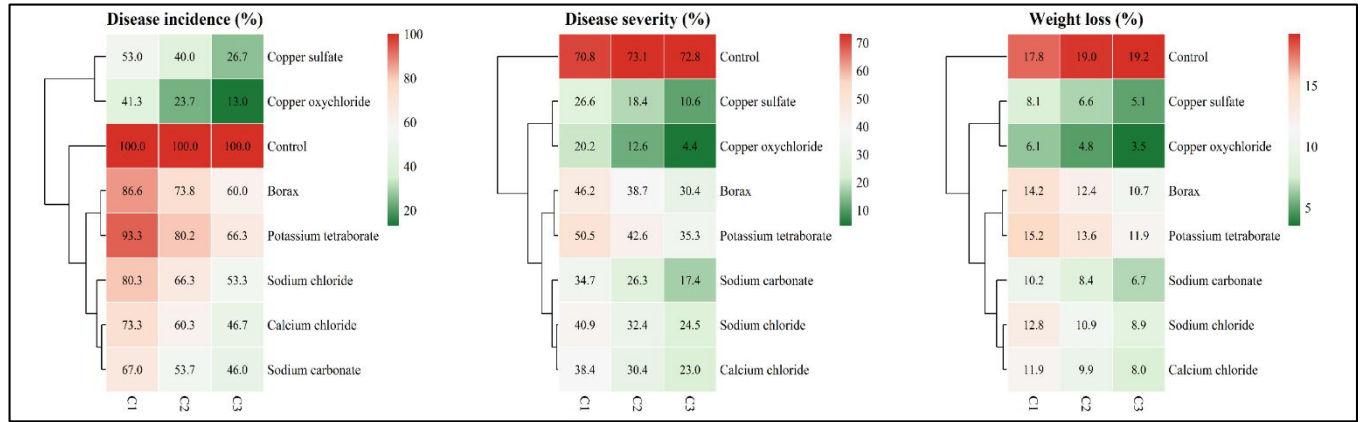


Fig 3: Multi-panel heatmap illustrating the effect of inorganic compounds and concentration levels on disease incidence, disease severity and weight loss in potato tubers inoculated with *Fusarium incarnatum*. Lower values are represented by green colour intensity, whereas higher disease development and tuber deterioration are represented by red colour intensity.

4. Discussion

The higher efficacy of copper oxychloride and copper sulphate in the present investigation can be attributed to the well-established multi-site mode of action of copper ions on fungal infections. Copper compounds are part of certain critical physiological and biochemical processes such as membrane permeability, protein synthesis, enzyme activity and cellular respiration. Copper ions combine readily with fungal enzymes and proteins sulfhydryl groups, denature enzymes and interfere with metabolic pathways that are vital for fungal development and sporulation. Moreover, oxidative stress due to copper increases the production of reactive oxygen species (ROS) which damage cellular membranes, nucleic acid structures and mitochondrial and induce cell death in fungus. Copper compounds can act at many places at the same time, so that resistance is less likely to develop. They have a wide spectrum of activity against storage diseases. Moreover, the copper fungicides suppressed potato dry rot associated *Fusarium* spp. Lionelle *et al.* (2023) [5] reported that copper-based treatments were very suppressive to the mycelial proliferation and lesion formation. The great efficacy of sodium carbonate is associated with its high alkalisng activity that changes the pH of the microenvironment of the pathogen and creates conditions that are not suitable for the production and colonisation of the fungus. High pH levels can limit spore

germination, movement of materials across the cell membrane and production of extracellular enzymes necessary for maceration of host tissues by *Fusarium* spp. Alkaline salts are known to disrupt ionic homeostasis and cause osmotic stress, therefore affecting the turgor of the fungal cells and their metabolic activities. Mecteau *et al.* (2002) [6] and Naffa (2012) [8] reported similar results and reported that sodium carbonate and bicarbonate salts are significant inhibitors of the development of potato dry rot. Also, the inhibition of *Fusarium* spp. by sodium carbonate could be attributed to the disruption of polysaccharides of the fungal cell wall and the inhibition of the activity of pectolytic enzymes responsible for the degradation of tuber tissues. The addition of calcium chloride dramatically reduced the formation of lesions, probably via a combined action of direct suppression of the pathogen and increased resistance of the host tissue. In the intermediate lamella calcium pectate complexes are formed, which reinforce the cell walls and prevent tissue maceration and penetration of pathogens. Calcium also stabilises cell membranes, reducing the flow of nutrients from host tissues, and inhibits the activity of fungal cell wall-degrading enzymes, including polygalacturonase and cellulase. Similar results were reported by Mohammed *et al.* (2020) [7] who observed a considerable reduction in the severity of *Fusarium* dry rot after calcium chloride application under field and storage

circumstances. The inhibitory impact of Sodium chloride in the present study could be due to mainly osmotic disruption and ionic toxicity to the fungal cells. High salt concentrations may reduce water availability to the pathogen and may interfere with membrane transport processes, enzyme activity and uptake of nutrients. High osmotic stress conditions can also impede hyphal extension and spore germination and restrict pathogen colonisation of tuber tissues. Sodium chloride was less effective than the copper compounds and sodium carbonate but it significantly reduced lesion formation compared to the untreated control, demonstrating a minor fungistatic action against *F. incarnatum*. Boron based treatments, borax and potassium tetraborate showed much less inhibition of lesion formation, but were still much better than untreated control. Borates have an anti-fungal action, disrupting fungal membrane function and interfering with glucose metabolism and spore germination. Boron chemicals have also been reported to alter the cell wall production and membrane related enzymatic systems of fungal infections. However, their efficacy was significantly reduced in the present trial, showing their antifungal activity against *F. incarnatum* was weaker than that of copper-based fungicides and alkaline salts. Earlier studies on postharvest disease control have revealed similar results where boron-containing chemicals mildly suppressed fungal infections. The diameter of inhibition zone was gradually decreased with the increase of inorganic chemicals concentration demonstrating the concentration dependent inhibitory activity against *F. incarnatum*. Higher concentrations are considered to have increased availability of physiologically active ions and increased the disruption of fungal physiology, membrane integrity and metabolic activity. Higher doses may also enhance penetration and durability of antifungal chemicals at the site of infection leading to more powerful prevention of pathogen colonisation and spread of lesions. Significant treatment-by-concentration interactions were seen for illness incidence, disease severity and weight loss, but not for lesion breadth. These results suggest varying treatment response at different doses. The results obtained are in good agreement with other publications on the antifungal activity of inorganic salts and copper fungicides against potato dry rot pathogens under storage conditions. Inorganic salts such as sodium carbonate and sodium bicarbonate were strongly inhibitory in *Fusarium sambucinum* (Mecteau *et al.* 2002) [6]. Potato storage diseases are inhibited in mycelial development, sporulation and spore germination by inorganic salts (Elsherbiny and El-Khateeb, 2012) [1]. Effective control of potato dry rot and reduction of storage losses after treatment with carbonate and bicarbonate salts was also reported by Naffa (2012) [8]. Recently, Lionelle *et al.* (2023) [5] reported the substantial inhibitory action of copper sulphate and sodium carbonate against *Fusarium* spp. associated with potato dry rot. The results of the present investigation imply that inorganic compounds, especially copper-based fungicides and alkaline salts, might be effective components of integrated management systems for potato dry rot during storage in conclusion.

5. Conclusion

The present investigation demonstrated that inorganic compounds significantly reduced lesion development, disease incidence, disease severity and weight loss in potato tubers inoculated with *Fusarium incarnatum* under storage

conditions. Among the evaluated treatments, copper oxychloride proved most effective, followed by copper sulfate and sodium carbonate. Higher concentrations consistently enhanced antifungal efficacy, indicating a clear concentration-dependent inhibitory effect against the pathogen. The significant interaction between inorganic compounds and concentration levels further confirmed differential treatment responses across concentrations. Copper oxychloride at 0.30 percent recorded minimum disease severity and weight loss, whereas untreated control exhibited maximum disease development and tuber deterioration. The superior performance of copper-based compounds may be attributed to their broad-spectrum multi-site mode of action, while alkaline salts and calcium compounds likely suppressed fungal colonisation through osmotic imbalance, altered pH conditions and reinforcement of host tissue integrity. The results clearly indicate that selected inorganic compounds, particularly copper oxychloride, copper sulfate and sodium carbonate, can serve as effective and comparatively eco-friendly alternatives for the management of potato dry rot during storage. The study further highlights the potential integration of inorganic salts into sustainable postharvest disease management strategies for reducing storage losses and maintaining tuber quality. Further validation under commercial cold storage conditions is required before large-scale recommendation.

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