Biocides as Alternatives Fungicides for the Control of Postharvest Potato Dry Rot Disease

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ABSTRACT

Post-harvest potato disease management remains a major problem. Using of biological and environmentally friendly alternatives has become the most important to protect potato tubers from post-harvest diseases, especially *Fusarium solani* that causes dry rot disease. We applied eleven treatments compared to the control to suppress *Fusarium* dry rot disease in potato tubers. Laboratory tests revealed citric acid has much greater antifungal activity than biological agents, seaweed products, and inorganic salts. *In vivo* test revealed that citric acid was the best choice in this application, followed by aluminum chloride, sodium carbonate, and boric acid. The polyphenol content of tubers increased compared to the control, and the protein content of potato tubers also increased through the addition of algae and aluminum chloride treatments. The impact of these treatments on the quality characteristics of potato tubers was investigated, in this regard, the effect total soluble solids content (TSS) improved as follows: first salicylic acid, then citric acid, then copper sulphate, then boric, and finally Gino S compared to the control and thiabendazole as a reference fungicide. Our study showed that all treatments led to a significant decrease in total acid levels in potato tubers, except for Biozeid, aluminum chloride, salicylic acid, oxalic acid and Biozeid had the highest significant amount of ascorbic acid.

Key words: *Fusarium* dry rot, Postharvest disease, biocides, potato tubers, organic acids, inorganic salts, bio-agents, seaweeds.

INTRODUCTION

Potato is one of the most widely farmed tuber crops in the world, coming in fourth place behind the major cereal crops of rice, wheat, and maize (Gul *et al.*, 2011; Hailu & Mosisa, 2019 and Younis *et al.*, 2024). Potato is considered the Egypt's second-largest export crop and is regarded as a key commodity, potatoes are grown on 450 thousand acres (Meligy *et al.*, 2020). The production of potato has become more in demand since it has been shown to satisfy the four essential requirements for food security, stability, accessibility, quality, and availability. According to Younis *et al.* (2024), its starch content, high-quality protein, important vitamins especially vitamin C, minerals, and extremely low-fat content help to maintain a balanced diet and enhance human health.

Fusarium dry rot is among the most prevalent post-harvest potato illnesses worldwide. At least 20 known *Fusarium* species are responsible for the dry rot infection of potatoes during storage, which causes enormous losses estimated to reach 6.25–25% every year (Millard, 2016 and Xue *et al.*, 2023). To control or manage potato dry rot, Mancozeb, carbendazim, and thiabendazole (TBZ) are examples of chemical synthetic fungicides that are utilized. However, synthetic chemical fungicides aren't a long-term solution. In order to control post-harvest disease in potato tubers used environmentally friendly control methods are investigated and developed, these include the use of organic acids, inorganic salts, biological antagonists, and seaweed extracts (Al-Mughrabi *et al.*, 2013; Yaganza *et al.*, 2014; Xue *et al.*, 2017; Aydin, 2019 and Ahmed *et al.*, 2022).

Several inorganic and organic salts that are categorized as generally recognized as safe (GRAS) substances or food additives have been shown to be somewhat successful in reducing postharvest illnesses of fresh horticultural product when used as water solutions. The majority of these compounds have well-known with broad antibacterial properties and are categorized as food preservatives. Although acidic forms of salts can occasionally exhibit antibacterial action, the salts are best for postharvest treatments because of their superior solubility, ease of application, and extra activity of cations like Na^+, K^+, or $NH4^+$ (Smilanick *et al.*, 1999).

Mecteau *et al.* (2008) proved the antifungal properties of salts (ammonium phosphate) in relation to dry rot of potatoes *(Fusarium* spp.), Sodium bicarbonate (SBC) was used to manage pH and preserve flavor and texture, it has been demonstrated that applying sodium carbonate to potato tubers as post-harvest treatments significantly lessens the severity of silver scurf (*Helminthosporium solani*) (Corral *et al.*, 1988 and Ziv & Zitter, 1992). It has also been shown to have broad-spectrum antifungal action against a number of plant diseases. The bioagents showed a wide range antifungal activity such as *Trichoderma* spp., *Pseudomonas* spp. and *Bacillus* spp., and became the great alternatives for disease prevention. Seaweed extracts showed capacity

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to inhibit *Fusarium* dry rot in recent decades, particularly showed in post-harvest applications (Ammar *et al.,* 2018).

The current study examined the effects of two bio-agent products, three inorganic salts, three organic acids and two seaweed products on dry rot post-harvest disease in stored potato, as well as the effects of these treatments on quality indices and biochemical components.

MATERIALS AND METHODS

Fungal inoculum preparation:

Fusarium solani culture was acquired from the Fungicide Bioassay Laboratory, Pesticide Chemistry & Technology Department, Faculty of Agriculture, Alexandria University Throughout the experiments. The fungus was kept at 25ºC on potato dextrose agar medium.

Preparation of tubers:

For *in vivo* tests, healthy potato tubers of the Spunta variety (the most popular in Egypt) were chosen for their consistency in size, appearance, ripeness, and lack of physical flaws. Before being used, they were kept for a month at 6°C in the dark. A few hours prior to the start of the trials, they were allowed to come to room temperature. Rinsed with sterile distilled water (SDW) and allowed to air dry after being sterilized for five minutes in a 10% v/v sodium hypochlorite solution.

Treated chemical and biocides:

1- Seaweed products: Algifol (*Ascophyllum nodosum*, Chema Industries products, Egypt) and Geno-s (*Ulva lactuca extract* & *Ascophyllum nodosum* extract, produced in Spain by Agrega Global Chemical Industries).
2- Bio-agents products: Biozeid 2.5% WP (*Trichoderma album*, Organic biotechnology, Egypt) and Bio-arc 6% (*Bacillus megaterium*, Organic biotechnology, Egypt).
3- Organic acids: Citric acid, Oxalic acid and Salicylic acid.
4- Inorganic salts: Copper sulfate, Sodium carbonate and Aluminum chloride (Sigma USA).
5- Standard fungicide Tecto 50%SC (Thiabendazole, Syngenta agro.) at recommended dose.

In vitro assay for biocides' antifungal efficacy:

The method of radial growth as stated by Asthana *et al.* (2016). The percentage of mycelial growth suppression was determined using the formula [(DC-DT) /DC] × 100 (Hadian *et al.*, 2019). DT stands for "diameter of treatment," and DC for "diameters of control." A linear regression method was used to determine the treatment concentration that inhibits fungal mycelia development by 50% (LC_{50}) (Finney, 1971).

Evaluation of biocides ability to prevent the dry rot disease on potato tubers post-harvest:

Using a sterile cork borer, potato tubers were punctured at three locations along their longitudinal axis at a depth of 6 mm. Every treatment was applied four hours prior to the pathogen challenge by dipping each treatment concentration. A 6 mm agar plug colonized by *F. solani* that was taken from a 7-day-old culture at 25°C was deposited in the occasioned wound to create the tuber inoculation. For 30 days, six potato tubers each with three inoculation sites were incubated at 25°C with a comparatively high humidity level. Based on Cohen *et al.* (1991) suggestion of using the external extent of the induced decay to estimate the severity of *Fusarium* dry rot, the following formula was applied: ((n*c)/N*df) = DSI, Where: DSI stands for disease severity, n for the number of infected tubers in each category, c for the number of categories and N is the total number of tubers examined.

Biochemical studies:

Analysis of polyphenols content:

The amount of polyphenols in potato tubers was determined by using a spectrophotometer (Tuner, model 390) and the formula Slinkard and Singleton (1997): µg tannic acid/gm fresh weight = (((A/K)*(20/0.2)/1)), where A = absorbance at 765 nm, K = the extension coefficient = 0.016898 µg ml^{-1}.

Determination of total protein content:

Dixon's (1985) method was used to compute total protein, with a modification recommended by Lowry *et al.* (1951), mg protein/g fresh weight = ((A/K)*100)/0.25), K=0.029 mg ml^{-1}, A= absorbance at 700 nm utilizing a Tuner, model 390 spectrophotometer.

Quality parameters:

1. Determination of Total acids of potato tubers:

Using the following formula, the percentage of citric acid was determined in accordance with Sabra (1993), % Total acids as (citric acid) = ((V1×N×E)/V2*1000) *100), where V1 means the amount of NaOH solution needed (in milliliters), N= NaOH solution normality. C = citric acid equivalent weight. V2 is the potato filtrate's volume (in milliliters).

2. Determination of ascorbic acid of fresh potato tubers:

According to Sabra (1993), the ascorbic acid content was computed using the formula that follows in relation to a standard curve, µg ascorbic acid /gm. F. Wt. of potato tuber = ((A/K)*40/5). Anywhere: A= absorbance at 520 nm. K= 0.0040712 μg^{-1}.

3. Total soluble solids T.S.S:

A digital refractometer was used to measure the total soluble solid (TSS) in the sap of fresh potato tubers (Cox and Pearson, 1962).

Statistical analysis of Data:

Using MSTAT version 4 (1987), the acquired data were statistically analyzed using ANOVA for three-way Randomized Blocks. LSD (Least Significant Differences Test, 0.05 probability) was used to determine whether there were significant differences between the means of the various treatments.

RESULTS AND DISCUSSIONS

***In vitro* assay for biocides' antifungal efficacy:**

The antifungal effectiveness of biocides against *Fusarium solani*, the cause of potato dry rot disease is shown in Table (1). These treatments' activities could be organized in ascending order as follows: citric acid was the best treatment with LC_{50} value 429.00 µg ml^{-1}, followed by oxalic acids (638 µg ml^{-1}), salicylic acid (866 µg ml^{-1}), bio-arc (LC_{50} = 915 µg ml^{-1}), algaefol and geno-s (LC_{50} = 1968 and1979 µg ml^{-1}), sodium carbonate, aluminum **chloride**, and copper sulfate with LC_{50} values 3602, 4379 and 6511 µg ml^{-1}, respectively. The *in vitro* experiment showed that the organic acids had considerably stronger antifungal activity than the bio-agent, seaweeds, and inorganic salts.

Our findings go with by Ammar *et al.* (2018), who discovered that seaweed algae had antifungal potential against some pathogenic fungus. These algae's antifungal properties could be linked to phenolic components like quercetin and rosmarinic acid, in addition to substances like oleic acid and palmitic acid (Pourakbar *et al.*, 2021).

The development of *Sclerotinia sclerotiorum* was completely inhibited by oxalic and boric acids at tested values of 0.3% and 0.4%, according to Attia *et al.* (2019). At both concentrations, Salicylic acid showed a less significant influence on *Sclerotinia sclerotiorum* growth. The data clearly showed that *Fusarium solani* was the least sensitive pathogen to oxalic and boric acid, while *S. sclerotiorum* was the most sensitive, given their concentrations. Furthermore, it was clear that raising the concentration of the tested acids to 0.3% and 0.4% progressively improved their capability to stop the growth of the tested pathogen. Rashied (2008) and Panahirad *et al.* (2012) found that salicylic acid at 0.25% completely stopped *Fusarium* from growing *in vitro*. Our findings also agreed with those of Mecteau *et al.* (2002 and 2008) demonstrated a number of salts had an impact on *F. solani var Coeruleum in vitro* development. Aluminum chloride was one of the most intriguing of them since it showed effectiveness in lowering infection with potato dry rot caused by *F. solani var. coeruleum* and *F. sambucinum*. Mills *et al.* (2004) assessed the impact of a number of inorganic and organic salts at 3 distinct concentrations affected the development of postharvest pathogens on potato tubers, including *Altranria alternate, Fusarium solani*, *Verticillium* spp. and *Phytophthora* spp. Generally, propyl-paraben and sodium metabisulfite significantly reduced the spore germination and mycelium growth of every pathogen, aluminum salts reliably suppressed spore germination in a lot of cases.

Table 1. Biocides antifungal activity against *Fusarium solani*

Treatments	LC_{50} (µg/ml)	Confidence limit		SLOPE
		LOWER	UPPER	
Algaefol	1968.00	1494.00	2996.00	1.06
Geno-S	1979.00	1679.00	2364.00	1.62
BioArc	915.00	783.00	1089.00	1.97
BioZeid	2063.00	1653.00	2678.00	1.17
Citric acid	429.00	273.00	650.00	1.66
Oxalic acid	638.00	572.00	711.00	2.24
Salicylic acid	866.00	789.88	955.00	2.64
Copper Sulfate	6511.00	5409.00	8216.00	1.36
Sodium Carbonate	3602.00	3098.00	4194.00	1.50
Aluminum Chloride	4379.00	3780.82	5290.00	1.70

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Evaluation of biocides ability to prevent the post-harvest potato dry rot disease:

The efficacy of eleven treatments including two sea weed products (algafol and geno-s), two bioagents (biozeid and bioarc), three organic acids (citric acid, oxalic acid and salicylic acid), three inorganic salts (sodium carbonate, copper sulfate and aluminum chloride) finally standard fungicide, thiabendazole and untreated control treatment on dry rot disease of potato tubers. It was evident from Table (2) that all applications decreased the % of dry rot infection on potato tubers. The relative disease control percentage (RDC %) increased significantly in comparison to the untreated treatment and the disease severity index (DSI) highly significantly decreased. In this context, citric acid came in first place with a DSI of 3.14 and an RDC of 89.48%, followed by aluminum chloride in second place with a DSI of 4.89 and an RDC of 83.79%, sodium carbonate (DSI 6.50 and RDC of 79.91%) and bioarc (*Bacillus megaterium*) gave DSI 6.56 and RDC of 80.00%. These results are encouraging because they surpassed the control rate attained with these treatments, which was non-significant when thiabendazole (TBZ) was used as the standard. These findings provided the highly effective and environmentally benign technique for keeping potato tubers from developing *Fusarium* dry rot. These included organic acids, particularly citric and oxalic acids, with a significant difference in concentration of 0.1 to 0.2%; bio-agents for controlling potato dry rot, bioarc (*Bacillus megaterium*) and biozeid (*Trichoderma ablum*), at concentrations of 0.2 to 0.5%; inorganic salts, sodium carbonate and aluminum chloride, with concentrations of 1% to 2%, which produced non-significant values in relation to one another; and, lastly, seaweeds, such as algaefol and geno-s.

Our results are in agreement with Daami-Remadi *et al.* (2006 and 2012) who found that certain *Trichoderma* species decreased the incidence of dry rot disease in tubers; Cherif *et al.* (2001); Ru & Di (2012) and Wharton & Kirk (2014) indicated that biological control was effective and no appreciable differences in the effects on the various pathogen isolates. This indicates that antagonists have settled into the tissue and are still active. Likwise, Howell (2003) and Aydın & Turhan (2013) reported that during the production season, *Trichoderma* species have been seen colonizing and remain active in an assortment of plant organs, including tubers, roots and stolons. In acceptance with Rashied (2008), who discovered that the dry rot of potato decreased both naturally occurring and intentionally inoculated potato with ascorbic and salicylic acid, particularly when the acid was 2% concentrated and stored at 10°C for 90 days or 20°C for 45 days. Our results shown that after 30 days of storage, potato tubers treated with citric, oxalic and salicylic acids at concentrations of 0.05, 0.1 and 0.2% showed varied degrees of reduction in the severity of tuber-rot caused by *F. solani*. Moreover, Attia *et al.* (2019) demonstrated that by treating potato tubers with salicylic and oxalic acids at concentrations of 0.4, 0.3, and 0.2% the severity of tuber-rot caused by *F. solani* and *S. sclerotiorum* was reduced to varied degrees after two months of storage as compared to control. Hilal *et al.* (2006) discovered that at high concentrations (1500 ppm), salicylic and oxalic acids inhibited *S. sclerotiorum's* linear growth. According to Naffa (2012) the development dry rot in tubers of potato was considerably decreased prophylactic application of sodium carbonate, sodium bicarbonate and sodium metabisulfite. According to our findings, potato can be protected from dry rot by applying specific salts, these findings make evident the beneficial function seaweeds play in preventing fungal infections that impact plants, as demonstrated by a number of earlier investigations. Chitosan and *Ascophyllum nodosum* extract together had good suppressive effect on pea powdery mildew according to Patel *et al.* (2020) as it decreased disease severity to 35% from the control level of 90.5%. Extracts of the brown algae *Fucuss piralis*, *Laminaria digitata*, and *Cystoseiramyrio phylloides* significantly reduced the severity of *Verticillium dahliae* and *Agrobacterium tumefaciens* disease in tomato plants, according to Esserti *et al*. (2016). Seaweed water extract exhibited antifungal action agains*t the* zucchini squash *Podosphaera xanthii*, according to Roberti *et al.* (2016). In contrast to infection rates observed in the control treatment, studies by Ambroziak *et al.* (2015) and Ahmed *et al.* (2016) found that a variety of green algae extract and commercial algae products decreased degree of disease on potato plants. Similarly, the green alga *Ulva armoricana* has been shown to lessen powdery mildew disease severity in cucumber, grapevine, and bean by as much as 90% (Moenne, 2009 and Jaulneau *et al.*, 2011). Carrot plants treated with the brown algae *Ascophyllum nodosum* considerably decreased the severity of the fungal disease *Botrytis cinerea* and *Alternaria radicina* according to Jayaraman *et al.* (2008). Klarzynski *et al.* (2000) and Aziz *et al.* (2003) discovered that brown alga (Phaeophyta) was highly effective at shielding grapevine plants from the *Plasmopara viticola* fungus-induced illness.

Table 2. Disease severity index (DSI) and relative disease control (RDC) of boicides against potato tubers post-harvest dry rot disease

Treatments	Disease index				RDC %			
Sea weed conc	0.05%	0.1%	0.2%	Mean	0. 05%	0.1%	0.2%	Mean
Algaefol	16.00	14.67	6.67	12.44c	52.00	56.00	80.00	62.67b
Geno-S	13.00	10.67	8.00	10.56d	60.00	68.00	76.00	68.00 b
Bioagent	0.1%	0.2%	0.5%	Mean	0.1%	0.2%	0.5%	Mean
BioArc	10.33	8	1.33	6.56 f	68.00	76.00	96.00	80.00 a
BioZeid	18.67	6.67	1.33	8.89 e	44.00	80.00	96.00	73.33 b
Organic acids	0.05%	0.1%	0.2%	Mean	0. 05%	0.1%	0.2%	Mean
Citric acid	8.00	1.33	0.10	3.14g	76.00	96.00	100.00	89.48a
Oxalic acid	18.67	10.67	0.067	9.80 e	44.00	68.00	100.00	67.28 b
Salicylic acid	12.70	16.00	12.67	13.78 c	40.00	52.00	60.00	54.08 c
In-organic salts	0.5%	1%	2%	Mean	0.5%	1%	2%	Mean
Copper Sulfate	29.33	21.33	20.00	23.56 b	12.00	36.00	40.00	21.38 d
Sodium. Carbonate	9.33	5.33	3.33	6.50f	60.00	84.00	92.00	79.91a
AluminumChloride	10.67	2.67	1.33	4.89g	68.00	92.00	96.00	83.79 a
Thiabendazole (Recommended dose				0.10 h				99.67 a
Control				30.00a				0.00 f

Different letters denote significant changes between treatments within the same column, using the least significant difference test (p=0.05).

Biochemical studies:

Impact of biocides treatments on potato tubers polyphenol content:

Plant phenols, particularly the toxic free phenols, play a significant role in protecting plants from pathogenic microorganisms. Higher phenol levels were found in plants that were induced by biotic or abiotic factors. Numerous plants contain phenolic chemicals that have single molecules with antimicrobial properties or serve by way of building blocks for structural polymers like lignin (Hammerschmidt, 2005). The level of disease resistance in plants was positively correlated with a significant rise in phenolic content (Abo-Elyousr *et al.,* 2009). Clearly, applying biocides to dry rot potato tubers raised their content of polyphenolic compounds in comparison with control.

Table 3. Impact of biocides on polyphenol content as µg tannic acid g-1 fresh weight of potato tubers

Treatment	phenol content (µg tannic acidg^{-1} fresh weight)			
Sea weed conc	0.05%	0.1%	0.2%	Mean
Algaefol	815.52	874.16	988.56	892.74 b
Geno-S	777.91	822.13	900.47	833.50 d
Bioagent conc	0.1%	0.2%	0.5%	Mean
BioArc	735.31	800.39	859.78	798.49 e
BioZeid	686.61	818.15	819.39	774.71 f
Organic acids	0.05%	0.1%	0.2%	Mean
Citric acid	906.73	975.15	982.25	954.71 a
Oxalic acid	748.72	751.48	819.17	773.13 f
Salicyllic acid	811.60	887.18	936.09	878.29 c
In-organic salts	0.5%	1%	2%	Mean
Copper Sulfate	898.99	872.58	910.45	879.13b
Sodium Carbonate	891.13	931.26	1016.17	946.19 a
Aluminum Chloride	851.28	878.02	908.10	894.01 b
Thiabendazole (Recommended dose)				845.36d
Control				738.86g

Different letters denote significant changes between treatments within the same column, using the least significant difference test (p=0.05).

This increase was particularly noticeable when citric acid treatment resulted in 954.71 µg tannic acid / gram of potato, while sodium carbonate treatment produced 946.19 µg/g potato, aluminum chloride treatment produced 894.01 µg/g potato and aglaefol treatment produced 892.74 µg/g potato, respectively. In contrast, the control tubers contained 738.86 µg/g potato of these compounds (Table 3). Our findings concurred with those of Ashok Kumar *et al.* (2012) and Ahmed *et al.* (2016, 2022), who demonstrated that the application of algaefol treatment resulted in a rise and build-up of phenols, whether bound or soluble, within the plant. The plant's defenses against disease may have grown and developed, which could explain the increase in phenol content (Daayf *et al.*, 1995, 1997 and Aly *et al.*, 2003).

Impact of the used on total protein content:

Total proteins are essential for plant defense and can therefore prevent or delay the onset of symptoms, Because of their rapid accumulation and antimicrobial activity (Wang *et al.*, 2005). Thus, one of the most crucial methods suggested to achieve a wide and long-lasting degree of resistance against various phytopathogenic fungi is the expression of genes encoding protein related pathogens (PRPs) (Veronese *et al.*, 1999).

According to Table (4), the protein content of potato treated with algaefol and aluminum chloride was a significant value of 188.73 and 176.78 mg protein per gram of potato tuber, respectively. This was in contrast to the protein content of control and the standard fungicide, thiabendazole, which were 172.18 and 164.11mg, respectively. Our results were consistent with the findings reported by Ashok Kumar *et al.* (2012) and Ahmed *et al.* (2016) as they found that the total protein content and algal treatments were positively correlated.

We were in a harmony with Ahmed *et al.* (2022) that showed the seaweeds extract and their products possibly will a great option for controlling squash plant powdery mildew illness, either directly or indirectly, by raising the amount of protein and phenolic substances and activating certain enzymatic systems that allow the plant to defend itself off disease. El-Sheekh *et al.* (2020) discovered that employing algal extracts to treat *Fusarium* wilt disease decreased the amount of protein found in tomato plants. These results differed from those presented in this investigation**.**

quality parameters:

Impact of the used biocides on several potato tubers quality parameters:

Table (5a) displays the potato tubers' total soluble solids content as a result of eleven treatments in contrast to the untreated treatment; the results demonstrated that there were notable variations across the treatments. In comparison to control and thiabendazole, the treatment of citric acid, copper sulfate, bioarc was the highest TSS with a same value of 6.90% followed by salicylic acid and geno-s, with mean values of 6.73% and 6.70%, respectively.

Table 4. Impact of biocides on fresh weight of potato tubers in terms of total protein content, expressed as mg protein g^{-1}

Treatments	Total Protein (mg protein/g potato tuber)			
Sea weeds conc	0.05%	0.1%	0.2%	Mean
Algaefol	130.45	193.78	241.95	188.73 a
Geno-S	121.03	187.24	209.99	172.75 c
Bioagent conc	0.1%	0.2%	0.5%	Mean
BioArc	74.48	81.61	178.75	111.61 g
BioZeid	92.89	106.66	110.80	103.45i
Organic acids	0.05%	0.1%	0.2%	Mean
Citric acid	59.54	101.26	191.95	117.59 f
Oxalic acid	77.47	120.00	214.02	137.16 e
salicylic acid	107.10	113.79	122.07	114.32 g
In-organic salts	0.5%	1%	2%	Mean
Copper Sulfate	97.13	106.67	126.21	110.00 g
Sodium Carbonate	47.93	138.17	145.17	110.42 h
Aluminum Chloride	101.03	212.64	216.67	176.78 b
Thiabendazole(Recommended dose)				164.11d
Control				172.18c

Different letters denote significant changes between treatments within the same column, using the least significant difference test (p=0.05).

From Table (5a), the total acids expressed as citric acid amount of tubers exhibited that all treatments caused a substantial drop in total acid percentages in potato tubers, with the total acid percentage ranging from 0.17 to 0.31%. These findings concurred with those of Gobara *et al.* (2002); Abd El Moniem & Abd-Allah (2008); Spinelli *et al.* (2009); Pise & Sabale (2010); Haider *et al.* (2012) and Ahmed *et al.* (2016). They noted that the TSS on potato tubers was greatly impacted through the application of seaweed extract.

One of the finest antioxidants in the human diet is found in potato tubers, as primarily a source of ascorbic acid, generally known as vitamin C. Table (5b) showed how the ascorbic acid content was affected by the dipping application of 11 treatments in comparison to control. It was evident that the share of aluminum chloride, salicylic acid, oxalic acid, biozeid, and algifol exhibited the biggest significant quantity of ascorbic acid measured by average of the three concentrations which were 1035.92; 1018.31; 1013.40; 1008.00 and 960.12 µg gm^{-1} fresh weight of potato tubers, respectively. These findings concurred with those of Zodape *et al.* (2011); Zamani *et al.* (2013) and Ahmed *et al.* (2016), as they noted an improvement in fruit quality in ascorbic acid suggesting that seaweed sap may be used as supplementary fertilizer.

Table 5a. Impact of biocides on TSS and citric acid% of potato tubers

Treatments	%TSS				% of Citric acides			
Sea weed conc	0.05%	0.1%	0.2%	Mean	0. 05%	0.1%	0.2%	Mean
Algaefol	5.73	7.00	5.20	5.98 b	0.15	0.26	0.29	0.24 c
Geno-S	7.17	7.17	5.67	6.70 a	0.17	0.16	0.19	0.17d
Bioagent conc	0.1%	0.2%	0.5%	Mean	0.1%	0.2%	0.5%	Mean
BioArc	6.67	6.67	7.30	6.90a	0.3	0.21	0.16	0.22c
BioZeid	5.27	6.33	7.13	6.24b	0.32	0.29	0.33	0.31 a
Organic acids	0.05%	0.1%	0.2%	Mean	0. 05%	0.1%	0.2%	Mean
Citric acid	6.00	7.50	7.13	6.90 a	0.24	0.23	0.27	0.25 c
Oxalic acid	6.73	6.13	5.2	6.02 b	0.27	0.27	0.29	0.28b
Salicyllic acid	6.70	6.73	6.8	6.73a	0.28	0.29	0.29	0.23a
In-organic salts	0.5%	1%	2%	Mean	0.5%	1%	2%	Mean
Copper Sulfate	7.2	6.43	7.07	6.90 a	0.36	0.26	0.28	0.30 a
Sodium Carbonate	5.767	4.8	5.9	5.5 c	0.23	0.28	0.34	0.28 a
Aluminum Chloride	5.90	6.10	7.30	6.43 ab	0.28	0.21	0.19	0.23 b
Thiabendazole (Recommended dose)				5.17c				0.23c
Control				6.03b				0.30b

Different letters denote significant changes between treatments within the same column, using the least significant difference test (p=0.05).

Table 5b. Impact of biocides onpotato tubers' ascorbic acid

Treatments	Ascorbic (Ug Ascorbic acid/gm tubers)			
Sea weed conc	0.05%	0.1%	0.2%	Mean
Algaefol	993.56	913.74	952.14	960.12 g
Geno-S	973.91	974.25	932.16	953.15 h
Bioagent conc	0.1%	0.2%	0.5%	Mean
BioArc	965.32	952.37	933.54	950.41 i
BioZeid	1005.51	1013.88	1004.62	1008.00d
Organic acids	0.05%	0.1%	0.2%	Mean
Citric acid	1039.57	1000.93	961.97	1000.82 e
Oxalic acid	1010.76	975.14	1054.30	1013.40c
Salicylic acid	1010.32	972.35	1072.27	1018.31 b
In-organic salts	0.5%	1%	2%	Mean
Copper Sulfate	954.60	954.26	941.655	950.17 i
Sod. Carbonate	981.62	1000.60	975.81	986.01 f
Alum. Chloride	1036.22	1007.74	1063.80	1035.92 a
Thiabendazole (Recommended dose)		911.51j		
Control		1000.60e		

Different letters denote significant changes between treatments within the same column, using the least significant difference test (p=0.05).

CONCLUSION

The development of dry rot potato tubers was significantly inhibited by administration of protective biocides and synthesis of several defensive compounds such as total soluble proteins and total phenols. Whether ascorbic acid or citric acid was present in the tubers, the impact of applying biocides to dry rot disease on the quality of the tuber yield was unclear and nonspecific. Therefore, the use of biocides in sustainable agriculture might be a superior option for managing this disease.

REFERENCES

Abd El Moniem, E.A. and A.S.E. Abd-Allah. 2008. Effect of green algae cells extract as foliar spray on vegetative growth, yield and berries quality of superior grapevines. Am. Euras. J. Agric. and Environ. Sci. 4 (4): 427-433.

Abo-Elyousr, K.A.M., M. Hashem and E.H. Ali. 2009. Integrated control of cotton root rot disease by mixing fungal biocontrol agents and resistance inducers. Crop Protection. 28: 295 – 301.

Ahmed, S. M., S. R. El-Zemity, R. E. Selim, and F. A. Kassem. 2016. A potential elicitor of green alga (*Ulva lactuca*) and commercial algae products against late blight disease of *Solanum tuberosum L*. Asian J. of Agriculture and Food Sci. (ISSN: 2321 – 1571). 4(2): 86 – 95.

Ahmed, S. M., R. E. Selim, F. S. Sabra, and H. A. Aamer. 2022. Commercial algae products as biocide treatments for controlling squash powdery mildew disease. Alexandria sci. exchange j. (43) 4: 669-679.

Al-Mughrabi, K.I., A.Vikram, R.D.Peters, R.J.Howard, T.L.Grant, K.Barasubiye, R. Lynch, K.A. Poirier and I.K. Drake. 2013. Efficacy of *Pseudomonas syringae* in the management of critical reviews in food science and nutrition potato tuber diseases in storage.Biol. Control. 64: 315–322.

Aly, A., Z.AbdEl-Kader, A. Dawlat, A. A. Hilal and M.G.A. Nada. 2003. Performance of some medicinal and aromatic plant products, especially water extracts, in controlling powdery mildew disease of squash caused by *(Sphaerotheca fuliginea Polla cci*) of squash. Proc. 10^{th} Cong Phytopathol. Soc., Giza, Egypt. 195-217.

Ambroziak, C. B., M.Głosek-Sobieraj, E. Kowalska. 2015. The effect of plant growth regulators on the incidence and severity of potato diseases. Pol. J. Natur. Sc. 30(1): 5–20.

Ammar, N., H.Jabnoun-Khiarreddine, A.Nefzia, B. Mejdoub-Trabelsi and M.Daami-Remadi. 2018. Extracts from the brown macroalga *sargassum vulgare* for postharvest suppression of potato *Fusarium* dry rot. Nat Prod Chem Res 6: 329. doi:10.4172/2329-6836.1000329.

Ashok Kumar, N., B.Vanlalzarzova, S.Sridhar, and M.Baluswami. 2012. Effect of liquid seaweed fertilizer of *Sargassum wightii grev*. on the growth and biochemical content of green gram (*Vigna radiata (L.) R. wilczek*). Recent Research in Sci. and Technology. 4(4): 40-45.

Asthana, R., S.Saxena, S. Saxena and A. Singh. 2016. Antifungal activity of *Moringa oleifera Lam.* in vitro on *Botrytis cinerea*, *Fusarium oxysporum*, and *Aspergillus flavus*. J. of Pharmacy and Bioallied Sci. 8: 54–57. doi: 10.4103/0975-7406.171718.

Attia, M.F., K.A.Abada, A.M.A.K. Naffa and S.F. Boghdady. 2019. Management of potato post-harvest tuber rots by some organic acids and essential plant oils. Egypt. J. Phytopathol. 47(1): 257- 276.

Aydın, M. H. and G.Turhan. 2013. The Efficacy of *Trichoderma* Species against *Rhizoctonia solani* in potato and their integration with some fungicides. Anadolu J. of AARI. 23(1): 12-30.

Aydin, M.H. 2019. Evaluation of some *Trichoderma* species in biological control of potato dry rot caused by *Fusarium sambucinum fuckel* isolates. Appl. Ecol. Environ. Res. 17:533–546.

Aziz, A., B., X.Poinssot, M.Daire, A.Adrian, and L. B. Bezier. 2003. Laminarin elicits defense responses in grapevine and induces protection against *Botrytis cinerea and Plasmopara viticola*. Molecular Plant-Microbe Interactions. 16: 1118–1128.

Cherif, M., N.Omri, M. R.Hajlaoui, M.Mhamdi and A. Boubaker. 2001. Effect of some fungicides on *Fusarium roseum var. sambucinum* causing potato tuber dry rot and on *Trichoderma* antagonists. Annales de I'INRAT. 74: 131-149.

Cohen, Y., U.Gisi and E.Mosinger. 1991. Systemic resistance of potato plants against *phytophthora infestans* induced by unsaturated fatty acids. Physiol. Mol. Pathol. 38: 255-263.

Corral, L. G., L. S.Post and T. J. Montville. 1988. Antimicrobial activity of sodium bicarbonate. J. Food Sci. 53:981-982.

Cox, H. E. and D.Pearson. 1962. The chemical analysis of foods, chemical publishing, New York, NY. P. 309.

Daami-Remadi, M., I.Dkhili, H. Jabnoun-Khiareddine and M. El Mahjoub. 2012. Biological control of potato leak with antagonistic fungi isolated from compost teas and solarized and non-solarized soils. Pest Technol. 6:32-40.

Daami-Remadi, M., K.Hibar, H.Jabnoun-Khiareddine, F.Ayed and M. El Mahjoub. 2006. Effect of two *Trichoderma* species on severity of potato tuber dry rot caused by Tunisian *Fusarium* complex. Int J. Agric Res. 1: 432-441.

Daayf, F., A.Schmitt and R. R. Bélanger. 1995. The effects of plant extracts of *Reynoutria sachalinensis* on powdery mildew development and leaf physiology of long english cucumber. Plant Dis. 79:577–580.

Daayf, F., A.Schmitt and R.R.Belanger. 1997. Evidence of phytoalexins in cucumber leaves infected with powdery mildew following treatment with extracts of *Reynoutria sachalinesis*. Plant Physiol. 113(3): 719-727.

Dixon, R.A. 1985. Plant cell culture. A practical Approach IRLPRESS. Oxford. Washington DC.1-235.

El-Sheekh, M.M., A.S.H. Mousa and A.A.M. Farghl. 2020. Biological control of *Fusarium* wilt disease of tomato plants using seaweed extracts. Arabian J. for Sci. and Engineering. 45:4557–4570.

Esserti, S., A.Smaili, L.A.Rifai, T.Koussa, K.Makroum, M.Belfaiza, E. Kabil, L.Faize, L.Burgos, N.Alburquerque and M.Faize. 2016. Protective effect of three brown seaweed extracts against fungal and bacterial diseases of tomato. J Appl Phycol. 29:1081–1093.

Finney, D. J. 1971. Probit analysis, 3rd Edn. Cambridge University Press, Cambridge, UK. pp 1–333.

Gobara, A.A., A.M.Aki, A.M. Wassel and M.A. Abada. 2002. Effect of yeast and some micro-nutrients on the yield and quality of red roomy grape vines. Inter. Conf. Hort. Sci., Kafr El-Sheikh, Tanta Univ., Egypt p. 709-718.

Gul, Z., A.A. Khan and K.Jami. 2011. Review: Study of potato leaf roll virus (PLRV) of potato in pakistan. Canadian Journal on Scientific and Industrial Research. 2(1): p24.

Hadian, S. H., M. A.Aghajani and H. R.Pordeli. 2019. The effect of plant essential oils on citrus green mold. Applied Entomology and Phytopathology. 86 (2): p1-11.

Haider, M.W., C.M.Ayyub, M.A.Pervez, H.U. Asad, A.Manan, S.A. Raza and I.Ashraf. 2012. Impact of foliar application of seaweed extract on growth, yield and quality of potato (*Solanum tuberosum* L.).Soil Environ. 31(2): 157-162. www.se.org.pk.

Hailu, D. M. and C.A. Mosisa. 2019. Role of nitrogen on potato production: A Review. J. of Plant Sci. 7(2): 36-42.

Hammerschmidt, R. 2005. Phenols and plant-pathogen interactions: The saga continues. Physiol. Mol. Plant Pathol. 66: 77-78.

Hilal, A., M.G.A. Nada and W.H. Zaky. 2006. Induced resistance against disease in some umbelliferous medicinal plants as possible and effective control men. Egypt. J. Phytopathol. 34 (2): 85-101.

Howell, C. R. 2003. Mechanisms employed by *Trichoderma* species in the biological control of plant diseases: the history and evolution of current concepts.–Plant Dis. 87: 4-10.

Jaulneau, V., C.Lafitte, M.F.Corio-Costet, M. J.Stadnik, S. J.Salamagne, X.Briand, M. T. Esquerré-Tugayé and B.Dumas. 2011. An *Ulvaarmoricana* extract protects plants against three powdery mildew pathogens. Eur J. Plant Pathol. 131: 393–401.

Jayaraman, J., A.Wan, M.Rahman, Z.Punja. 2008. Seaweed extract reduces foliar fungal diseases on carrot. Crop Protection. 27(10):1360 - 1366.

Klarzynski, O., Plesse, BJ.M. Joubert, J.C. Yvin, M. K. Kopp and B. Fritig. 2000. Linear b-1,3 glucans are elicitors of defense responses in tobacco. plant physiology. 124: 1027–1037.

Lowry, O.H., N.J.Rosebrough, A.L. Farr and R.J. Randall. 1951. Protein measurement with folin phenol reagent. J. of Biological Chemistry. 193: 256-275.

MSTAT version 4 (1987). https://mcardle.wisc.edu/mstat/index.html.

Mecteau, M.R., J.Arul and R. J.Tweddell. 2008. Effect of different salts on the development of *Fusarium solani var. coeruleum*, a causal agent of potato dry rot. Phytoprotection -Quebec-Online ISSN: 1710-1603.

Mecteau, M.R., J.Arul and R.J.Tweddell. 2002. Effect of organic and inorganic salts on the growth and developmentof *Fusarium sambucinum*, a causal agent of potato dry rot. Mycol. Res. 106: 688-696.

Meligy, M.M., M.Z.El-Shinawy, U.A.El-Behairy, A.F.Abou-Hadid. 2020. Impact of climate change on water requirements and the productivity on potato crop. Egypt. J. Hort. 47(1): 57-68.

Mills,A. A. S., H. W. Platt and R.A.R. Hurta. 2004. Effect of salt compounds on mycelial growth, sporulation and spore germination of various potato pathogens. Postharvest Biology and Technology. 34(3): 341-350

Millard, C. 2016. Final report: *Fusarium* dry rot of potatoes in South Africa.

Moenne, A. 2009. Composition and method to stimulate growth and defense against pathogens in plants. 12,666,700. US Patent.

Naffa, A.M.A. 2012. Control of dry rot disease on potato during storage. Egypt. J. Phytopathol. 40 (1): 29-40.

Panahirad, S., F.Zaare-Nahndii, R. Safaralizadeh and S.Alizadeh-Salteh. 2012. Postharvest control of *Rhizopus stolonifer* in peach (*Prunus persica L. Batsch*) fruits using salicylic acid. J. of Food Safety. 32: 502-507.

Patel, J.S., V.Selvaraj, L.R.Gunupuru, P.K. Rathor and B. Prithiviraj. 2020. Combined application of *Ascophyllum nodosum* extract and chitosan synergistically activates host-defense of peas against powdery mildew. BMC Plant Biology. 20:113. https://doi.org/10.1186/s12870-020-2287-8.

Pise, N.M. and A.B. Sabale. 2010. Effect of seaweed concentrates on the growth and biochemical constituents of *Trigonellafoenum-Graecum L.* J. of Phytology. 2: p 50-56.

Pourakbar, L., S.S. Moghaddam, H.A.E. Enshasy, and R.Z. Sayyed. 2021. Antifungal activity of the extract of a macroalgae, *gracilariopsis persica*, against four plant pathogenic fungi. Plants.10(9):1781. https://doi.org/10.3390/ plants10091781.

Rashied., D.I.S. 2008. Studies on fungal post-harvest diseases of potatoes preparedfor exportation and processing. Ph.D. Thesis, Fac. Agric., AL-Azhar Univ.244Pp.

Roberti, R., H. Righini and C. Pérez Reyes. 2016. Activity of seaweed and cyanobacteria water extracts against *Podosphaera xanthii* on *zucchini*. Italian j. of Mycology vol. 45: 66-77.

Ru, Z. and W. Di. 2012. *Trichoderma spp*. from rhizosphere soil and their antagonism against *Fusarium sambucinum.* African J. of Biotechnology. 11(18): 4180-4186.

Sabra, F.S. 1993. Studies on the chemical weed control. studies on the efficiency of certain herbicides and their side effect on potato plants and soil. Ph.D. thesis, Faculty of Agric.Alex.University.

Slinkard, K. and V.L. Singleton. 1997. Total phenol analysis: automation and comparison with manual methods. American J. of Enology and Viticulture. 28: 49-55.

Smilanick, J.L., D.A. Margosan, F. Mlikota J. U. Gabler and I.F. Michael. 1999. Control of citrus green mold by carbonate and bicarbonate salts and the influence of commercial postharvest practices on their efficacy. Plant Dis. 83: 139-145.

Spinelli, F., G.Fiori, M.Noferini, M.Sprocatti and G.Costa. 2009. Perspectives on the use of seaweed extract to moderate the negative effects of alternate bearing in apple trees. The J. of Horticultural Sci. and Biotechnology. 84:131-137.

Veronese, P., P.Crino, M.Tucci, F.Colucci, D.J.Yun, M.P.Hasegawa, R.A.Bressan. and F.Saccardo. 1999. Pathogenesis-related proteins for the control of fungal diseases of tomato. Genetics and Breeding for Crop Quality and Resistance Proceedings of the XVEUCARPIA Congress. pp: 15–24.

Wang, X., A.El Hadrami, L.R.Adam and F. Daayf. 2005. Local and distal gene expression of pr-1 and pr-5 in potato leaves inoculated with isolates from the old (US-1) and the new (US-8) genotypes of *Phytophthora infestans* (Mont.) de Bary. Environ. Exp. Bot. 1–11.

Wharton, P.S. and W.W. Kirk. 2014. Evaluation of biological seed treatments in combination with management practices for the control of *Fusarium* dry rot of potato. *Biocontrol Control*. *73*: 23–30.

Xue, H.L., Y.Bi, Y.Y.Zong, C.U.Alejandro, H.J.Wang, L.M. Pu, Y.Wang and Y.C. Li. 2017. Effects of elicitors on trichothecene accumulation and Tri genes expression in potato tubers inoculated with *Fusarium sulphureum.* Eur. J. Plant Pathol. 148:673–685.

Xue, H.L., Q. Liu and Z. Yang. 2023. Pathogenicity, mycotoxin production, and control of potato dry rot caused by *Fusarium spp*. J. Fungi. 9: 843.

Yaganza, E.S., R.J. Tweddell and J. Arul. 2014. Postharvest application of organic and inorganic salts to control potato (*SolanumtuberosumL*.) storage soft rot:Plant tissue-salt physicochemical interactions. J. Agric. Food Chem. 62: 9223–9231.

Younis, A. A., R.A.Hassanein, R.S. Ghanem, and S. A. Elkhawas. 2024. Natural postharvest treatments to potato tubers stored at different temperatures delayed sprouting and preserved tuber quality. Egypt. J. Bot. 64(3): 243-257.

Zamani, S., S.Khorasaninejad and B.kashefi. 2013. The importance role of seaweeds of some characters of plant. Int J. Agri Crop Sci. 5(16):1789-1793.

Ziv, O. and T. A. Zitter. 1992. Effects of bicarbonates and film-forming polymers on cucurbit foliar diseases. Plant Dis. 76:513-517.

Zodape, S.T., A. Gupta, S.C.Bhandari, U.S.Rawat, D.R. Chaudhary, K.Eswaran and J.Chikara. 2011. Foliar application of seaweed sap as biostimulant for enhancement of yield and quality of tomato (*Lycopersicon esculentum Mill*). J. SciInd Res. 70: 215-219.

الملخص العربي

المبيدات الحيوية كمبيدات بديلة لمكافحة مرض العفن الجاف على البطاطس بعد الحصاد

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مازلت إدارة أمراض البطاطس بعد الحصاد تمثل مشكلة كبيرة. ولقد أصبح استخدام البدائل الحيوية والصديقة للبيئة هي الأكثر أهمية لحماية درنات البطاطس من أمراض مابعد الحصاد وخصوصاً مرض العفن الجاف الذي يسببه فطر الفيوزرايوم سولاني. تم تطبيق 11 معاملة بالمبيدات الحيوية مقارنة بالكنترول على تثبيط مرض العفن الجاف الفيوزاريومي في درنات البطاطس ولقد كشفت الاختبارات المعملية أن حمض الستريك له نشاط مضاد للفطريات أكبر بكثير من العوامل الحيوية ومنتجات الأعشاب البحرية والأملاح غير العضوية. كشفت الاختبارات داخل درنات البطاطس أن حامض الستريك كان الخيار الأفضل في هذا التطبيق، وجاء الاختيار الثاني لكل من كلوريد الألومنيوم وكربونات الصوديوم وقد زاد محتوى الدرنات من البولي فينول مقارنة بالكنترول وأيضا زاد محتوى البروتين في درنات البطاطس من خلال إضافة معاملات الطحالب وكلوريد الألومنيوم. تمت دراسة تأثير هذه المعاملات علي صفات الجودة لدرنات البطاطس وكان تأثير المبيدات الحيوية على محتوى المواد الصلبة الذائبة الكلية كالأتي: كانت الأفضلية لاستخدام حامض الساليسيليك ثم حامض الستريك ثم كبريتات النحاس ثم البيوارك وأخيراً الجينو إس مقارنة بالكنترول والثيابندازول كمبيد مرجعي. أوضحت الدراسة أن جميع المعاملات أدت إلى انخفاض معنوي في نسب الحمض الكلي في درنات البطاطس وكان لكل من كلوريد الألومنيوم، وحمض الساليسيليك، وحامض الأوكساليك، والبيوزايد أعلى كمية معنوية من حمض الأسكوربيك.