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Plant Protection

Effects of Foliar Applications of Bicarbonates, Phosphate and Potassium Salts on the Powdery Mildew of Wheat Seedlings

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Abstract. Powdery mildew caused by *Erysiphe graminis f.p. tritici* was significantly controlled by sprays of aqueous solution (1%) containing mixture of phosphate and potassium salts, sodium and potassium bicarbonates (0.5%). Salt treatments in combination with Tween–20 were evaluated on Yucora Rojo wheat cultiver in greenhouse. Salt treatments were more effective in causing disappearance of powdery mildew pustulets in diseased foliage. Treatments also markedly reduced production of conidia from colonies .The results indicated that these salts could be used as effective fungicides for controlling powdery mildew in wheat fields.

Introduction

Powdery mildew of wheat (*Triticum aestivum* L.) caused by *Erysiphe graminis f.sp. tritici* Em. Marchal is one of the most important economical wheat diseases in various parts of the world and has been studied intensively by scientists over the past fifty years [1]. Disease control is generally achieved by use of fungicidal chemicals. The demand to reduce pesticide usage in food crops, concern for a healthy environment and the unavailability of commercially acceptable resistant cultivars mean that alternative methods of disease control are needed. One such method is the use of inorganic salts. These salts have been used to inhibit many pathogen development stages on various host plants. Carbonate and bicarbonate salts of ammonium, potassium, sodium, and lithium were fungicidal to *Sclerotium rolfsii* [2]. Sodium, potassium and ammonium bicarbonate provide good control to gummy stem blight and *Alternaria* leaf blight of muskmelon, and *Ulocladium* leaf spot of cucumber in greenhouse trials [3]. Phosphate and potassium salts were found to be effective in causing the disappearance of cucumber powdery mildew

pustules when applied as foliar sprays [4]. Sodium bicarbonate or sodium carbonate reduced the subsequent incidence of post-harvest green mold, caused by *Penicillium digitatum* [5]. Phosphorus acid and potassium phosphate inhibit development of downy mildew caused by *Plasmopara viticola* on grapevine [6]. A foliar spray of 1% solution of monopotassium phosphate on the upper surfaces of lower leaves of greenhouse grown peppers induced local and systemic control of *Leveillula taurica* [7]. Also sodium bicarbonate control powdery mildew caused by *Sphaerotheca pannosa* in rose plants [8]. Potassium phosphate should be used for the control of *Phytophthora palmivora* in piper betle plants, as it had no phytotoxic effect [9]. The objective of this study was to determine if powdery mildew on wheat seedlings could be control by using bicarbonates, phosphate and potassium salts.

Materials and Methods

Seedlings

Twenty grains of Ycora Rojo wheat cultivar were grown in greenhouse in 15cm diameter plastic pots containing a mixture of peat and soil (1:1 v/v). Seedlings with four or more expanded true leaves were used in all experiments.

Pathogen

An isolate of *Erysiphe graminis* f. sp. *tritici* was obtained from a certified source as fresh infected leaves, and used to inoculate wheat seedling plants to produce high volume of spores. Inoculation was obtained from freshly sporulating leaves 9-12 days after inoculation. Fresh conidiospores were collected from shaking infected plants over aluminum foil. Then, transferred to a fluorinert electronic liquid (3M®). The concentration of spore suspension was corrected to $2.5X10^4$ spores/ml by the mean of hemeocytometer.

Inoculation

One ml of the conidiospore suspension was sprayed uniformly over the upper leaf surfaces of 20 plants by the means of Airbrush set (Badger®), at the rate of 50-60 conidia/cm^2 of leaf. Inoculated plants were incubated in growth chambers at a temperature of 20±2°C and high relative humidity (±75). Later in the same day, the upper leaves surfaces (upper) were sprayed with 2ml of freshly prepared aqueous solutions (1%) of Phosphate and potassium salts (K_2HPO_4, KH_2PO_4), 0.5% sodium and potassium bicarbonates ($NaHCO_3$, $KHCO_3$), Combination with 0.5 ml/L of tween–20. Four replicates were used for each treatment. Controls consisted of plants sprayed with water, tween-20 and systemic fungicide (Anvil®-5SC). Later treated plants were arranged in a complete randomized design.

Disease assessment

Effective of the various treatments were determined by counting the number of powdery mildew lesions. On each leaf at intervals after 14 days from inoculation, the percentages and reduction of infection on each treatment were calculated. The numbers of conidia on each leaf were counted according to following: the oldest leaf (most active

lesions) form each treatment was harvested and placed in vials containing 5ml ethanol/formaldehyde (95:5 v/v). Numbers of conidia were counted with using a haemocytometer and four readings were taken.

Experiments

Exp. 1: Primarily, leaves were sprayed with aqueous solutions of salts, later inoculated with spore suspension after 0, 1,2,4,6,8 and 10 days from salts application. Results were obtained after 14 days from inoculation. This experiment was repeated twice.

Exp. 2: Firstly, upper leaves surfaces were inoculated with spore suspension, then sprayed with salts solutions after 0, 1,2,4,6,8 and 10 days from inoculation. Infected leaves were recorded after 14 days from inoculation. This experiment was repeated twice.

Results

Data of spraying aqueous solutions of the salts suppressed pustules of powdery mildew are shown on Tables 1 and 3. Both applications style, pre or after inoculation, were effect the powdery mildew infection (pustulets/leaf). Despite, some variations, previous foliar applications of selected salts gave significant control on the primary infection, where later application of salts depressed spores germination and pustulets growth and appearance. All tested salts had varied effects on the fungus growth with some differences in the level of significance. A high and long fungicidal activity (up to 10 days) by the tested salts was clearly demonstrated. Infection was reduced 68% with the treatment of $KHCO_3$ was used (Table 2), and most significant suppressive effect was 96% (3.3% severity) which found one day after inoculation when $NaHCO_3$ was applied.

Table 1. Effect of earlier foliar application of bicarbonates, phosphate and potassium salts on the powdery mildew infection (pustulets/leaf)

Treatment	Days after plants inoculation						
	0	1	2	4	6	8	10
K_2HPO_4	3.7 ^{d}	11.0 ^{d}	17.3 ^{c}	24.7 ^{d}	30.7 ^{d}	43.7 ^{d}	55.7 ^{c}
KH_2PO_4	14.7 ^{c}	20.7 ^{c}	27.7 ^{b}	32.7 ^{c}	39.3 ^{c}	51.0 ^{c}	68.7 ^{b}
$NaHCO_3$	0.0 ^{e}	2.0 ^{f}	8.0 ^{e}	17.7 ^{e}	24.7 ^{e}	28.7 ^{f}	30.0 ^{e}
$KHCO_3$	3.7 ^{d}	8.3 ^{e}	14.7 ^{d}	19.0 ^{e}	25.7 ^{e}	31.7 ^{e}	36.7 ^{d}
Tween-20	19.3 ^{b}	25.0 ^{b}	29.3 ^{b}	41.3 ^{b}	56.3 ^{b}	61.3 ^{b}	70.7 ^{b}
Fungicide	0.0 ^{e}	0.0 ^{f}	0.0 ^{f}	0.0 ^{f}	4.7 ^{f}	11.7 ^{g}	18.7 ^{f}
Water	86.7 ^{a}	86.7 ^{a}	86.7 ^{a}	86.7 ^{a}	86.7 ^{a}	86.7 ^{a}	86.7 ^{a}

*Means are average of four replicates, means followed by the same letter (s) in columns are not significantly different at P= 0.05.

Table 2. Effect of earlier foliar application of bicarbonates, phosphate and potassium salts on the powdery mildew severity (%)

Treatment	Days after plants inoculation						
	0	1	2	4	6	8	10
K_2HPO_4	5.0 [d]	10.3 [d]	12.7 [e]	15.7 [e]	23.7 [f]	30.7 [d]	41.0 [d]
KH_2PO_4	7.0 [c]	14.7 [c]	20.0 [c]	23.3 [c]	31.3 [c]	36.3 [c]	44.3 [c]
$NaHCO_3$	0.0 [e]	3.3 [e]	10.0 [f]	15.7 [e]	17.7 [f]	25.3 [f]	28.3 [f]
$KHCO_3$	4.3 [d]	11.0 [d]	15.0 [d]	21.3 [d]	25.7 [d]	27.7 [e]	32.0 [e]
Tween-20	9.7 [b]	20.0 [b]	30.3 [b]	35.3 [b]	56.3 [b]	56.3 [b]	68.0 [b]
Fungicide	0.0 [e]	0.0 [f]	0.0 [g]	0.0 [f]	4.7 [g]	10.3 [g]	15.3 [g]
Water	90.7 [a]	90.7 [a]	90.7 [a]	90.7 [a]	90.7 [a]	90.7 [a]	90.7 [a]

* Means are average of four replicates, means followed by the same letter (s) in columns are not significantly different at P= 0.05.

The suppression of *Erysiphe graminis* f. sp. *tritici* conidiospores was effected by the duration of salt treatment; consequently the number of conidia per leaf was efficiently reduced up to 8 days from spraying salts (Fig. 1). However, the treatment of salts when before or after adding spore suspension shows no significant differences after 10 days from the application. Figures 2, 3 indicate the variable effect of different salts and the further used materials, similar result of the fungicide on mildew infection and severity was noticed when previous application $NaHCO_3$ was used. Adding up, the strong reduction of the disease by other tested salts. Also, no damage to the plant tissues or the suppression acts due to the use of tween-20 was recorded. Among tested salts, $NaHCO_3$ had similar effects to the systemic fungicide (Anvil®-5SC), both agents decreased the level of disease infection and severity of powdery mildew pre and post inoculation (Tables 2,4).

Discussion

In this study, we demonstrate that the solutions of bicarbonate, phosphates and potassium salts clearly were effective in suppression of fungal growth of *Erysiphe graminis* f. sp. *tritici* on wheat seedlings. Fungal growth and infection was measured as number of pustulets per leaf or percent infected leaf area. It was evident throughout the treatments that the used salts were effective in suppressing the lesions in diseased foliage (data in Tables 1-4). However, the effectiveness was improved when applied in a combination with the Tween-20 agent, probably owing to the spreader-sticker characteristics of this material, which retained ions of salts on foliar surfaces. These findings have been reported by many investigators, they noticed that the effectiveness is quite good when individually applied, but improved when used with Tween-20 or horticultural oil, which keep the salts ions on the foliar surfaces as film forming polymers.

Table 3. Disease infection (pustulets/leaf) of powdery mildew on wheat leaves that inoculated with conidia of *Erysiphe graminis f. sp. tritici*, later leaves were sprayed with bicarbonates, phosphate and potassium salts

Treatment	Days after spraying salts						
	0	1	2	4	6	8	10
K_2HPO_4	11.7 [e]	19.7 [d]	25.0 [d]	28.0 [d]	28.0 [e]	31.3 [d]	35.3 [d]
KH_2PO_4	17.3 [d]	18.3 [d]	23.7 [d]	30.7 [c]	32.3 [d]	36.0 [c]	38.0 [c]
$NaHCO_3$	6.7 [f]	15.3 [e]	16.7 [e]	24.7 [e]	26.0 [f]	27.7 [e]	30.3 [e]
$KHCO_3$	19.7 [c]	22.3 [c]	30.3 [c]	32.0 [c]	34.7 [c]	35.0 [c]	35.7 [d]
Tween-20	30.0 [b]	30.7 [b]	32.7 [b]	37.7 [b]	41.0 [b]	45.3 [b]	50.7 [b]
Fungicide	0.0 [g]	0.0 [f]	0.0 [f]	0.0 [f]	8.3 [g]	11.3 [f]	24.7 [f]
Water	72.3 [a]	72.3 [a]	72.3 [a]	72.3 [a]	72.3 [a]	72.3 [a]	72.3 [a]

* Means are average of four replicates, means followed by the same letter (s) in columns are not significantly different at P= 0.05.

Table 4. Disease severity of powdery mildew on wheat leaves that inoculated with conidia of *Erysiphe graminis f. sp. tritici*, later leaves were sprayed with bicarbonates, phosphate and potassium salts

Treatment	Days after spraying salts						
	0	1	2	4	6	8	10
K_2HPO_4	19.7 [d]	29.7 [d]	30.3 [d]	35.7 [c]	36.0 [c]	40.7 [c]	45.3 [d]
KH_2PO_4	19.7 [d]	19.6 [e]	24.7 [e]	30.7 [d]	35.0 [c]	41.7 [c]	50.3 [c]
$NaHCO_3$	9.7 [e]	19.3 [e]	20.0 [f]	30.3 [d]	31.0 [d]	34.7 [e]	39.7 [e]
$KHCO_3$	30.0 [c]	32.0 [c]	32.7 [c]	35.0 [c]	35.3 [c]	38.3 [d]	45.3 [d]
Tween-20	40.3 [b]	40.7 [b]	44.7 [b]	48.7 [b]	50.7 [b]	52.0 [b]	55.0 [b]
Fungicide	0.0 [e]	0.0 [f]	0.0 [g]	0.0 [e]	10.0 [e]	15.0 [f]	30.0 [f]
Water	68.0 [a]	68.0 [a]	68.0 [a]	68.0 [a]	68.0 [a]	68.0 [a]	68.0 [a]

*Means are average of four replicates, means followed by the same letter (s) in columns are not significantly different at P= 0.05.

This justification could explain the reason behind the forming of the physical barrier on leaf surfaces against germ tube penetrations by conidiospores of powdery mildew [4,10,11]. Application of tested solution salts has been seen to reduce the number of powdery mildew colonies, conidia and percent of infection. This may be related to the direct effect against the fungus or by encouraging antagonistic phylloplane organisms or even stimulating the host defense reaction by indirect effect on the development of powdery mildew. Similar results were mentioned in many reports [2,4,5,6,7,9,11]. In this study the higher effect occurred by $NaHCO_3$ and $KHCO_3$, these salts reduced the development and sporulation of powdery mildew.

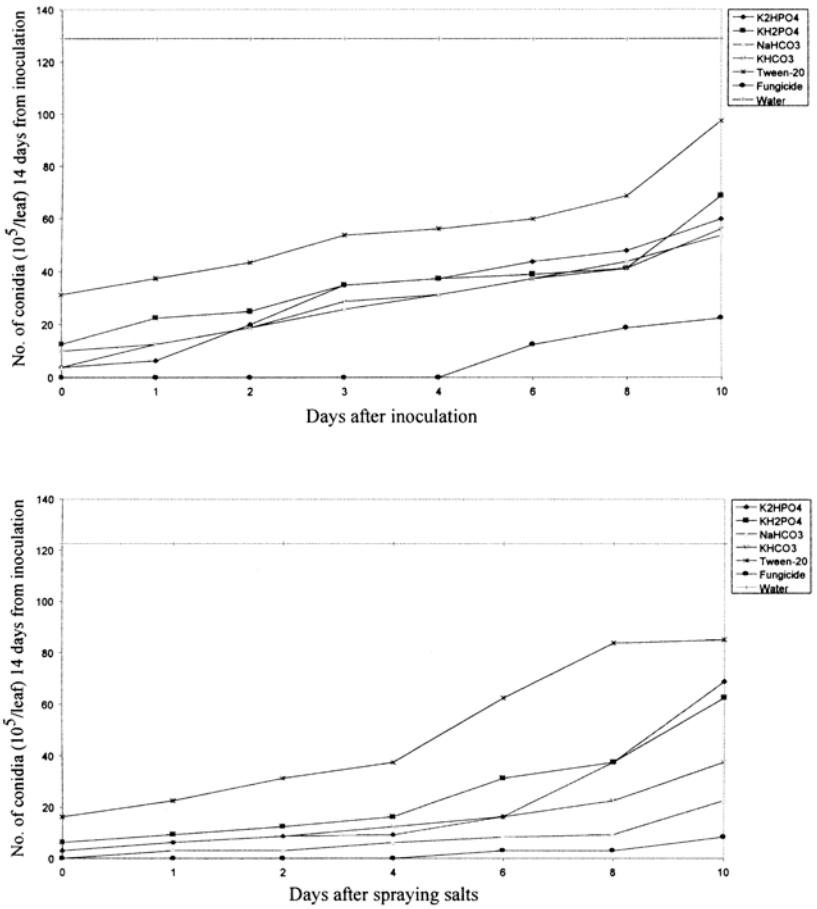

Fig. 1. Effect of bicarbonates, phosphate and potassium salts applications on the conidia count (10^5/leaf) 14 days from inoculation.

In literature we found the same finding in many pathogens, sodium bicarbonate inhibited mycelial growth *of Alternaria alternata*, *Fusarium spp*. and *Rhizopus stolonifer* [12]. Also, sodium and potassium bicarbonate suppressed silver scurf disease in potato tubers caused by *Helminthosprium soloni* [13]. In our study there was a strong decline in the formation of powdery mildew pustules when plant sprayed by salts solutions pre or post conidiospores inoculation, similar details were detected in powdery mildew of cucumber. The number and the size of pustule were reduced when the cucumber leaves were sprayed with sodium bicarbonate one day before and six days after inoculation

[14]. Also, $KHCO_3$ solution was shown to reduce powdery mildew by 95-100% on cucumber 3-4 days after application [15].

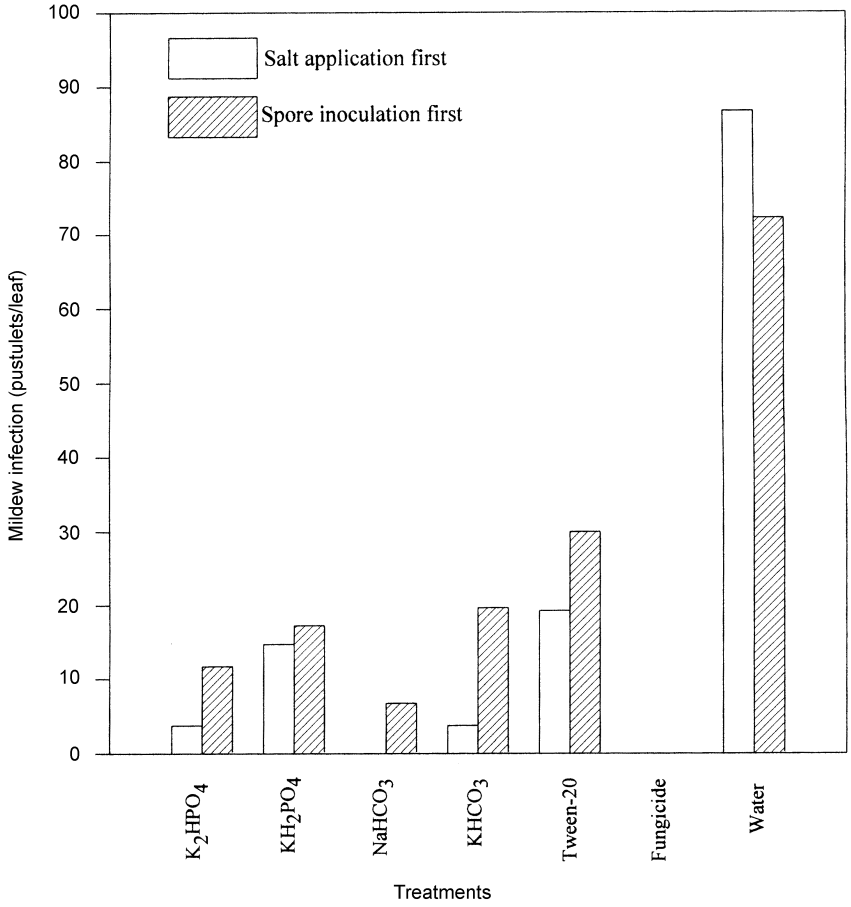

Fig. 2. Effect of previous or immediate (day 0) application of bicarbonates, phosphate and potassium salts on the mildew infection (pustulets/leaf).

The contrast between tested salts and the systemic fungicide Anvil-5SC indicates that $NaHCO_3$ and $KHCO_3$ had comparable effects, especially when applied in early infection, but after infection systemic fungicide was more effective than salts solutions. Similar result was reported by Reuveni *et al*., 1998 [16]. They found that K_2HPO_4 and KH_2PO_4 controlled powdery mildew on mango trees, but systemic fungicides were more effect than the used salts. Many investigators suggested that salts possibly applied as an alternative practice for controlling powdery mildew. Ziv *et al*., in 1992 [3], applied the fungicide (Benomyl or Tridimefon) on an alternating schedule with

bicarbonate salts proveded the necessary systemic activity for a good control of cucumber powdery `mildew. Also, Reuveni *et al*. (1998) [16] used K_2HPO_4 and KH_2PO_4 in alternation systemic fungicide (Diniconezole) for controlling powdery mildew on mango trees. The comparison between salts and fungicides cleared that selected salts have rapid absorption by the plant tissues. Nevertheless, their extreme mobility within the tissues, as well as their characteristics in stimulating plant growth, low cost and human, animal toxicity, comparative environmental safety and nutrient value could make them ideal foliar fertilizers, which should be considered for application in the field for diseases control [17].

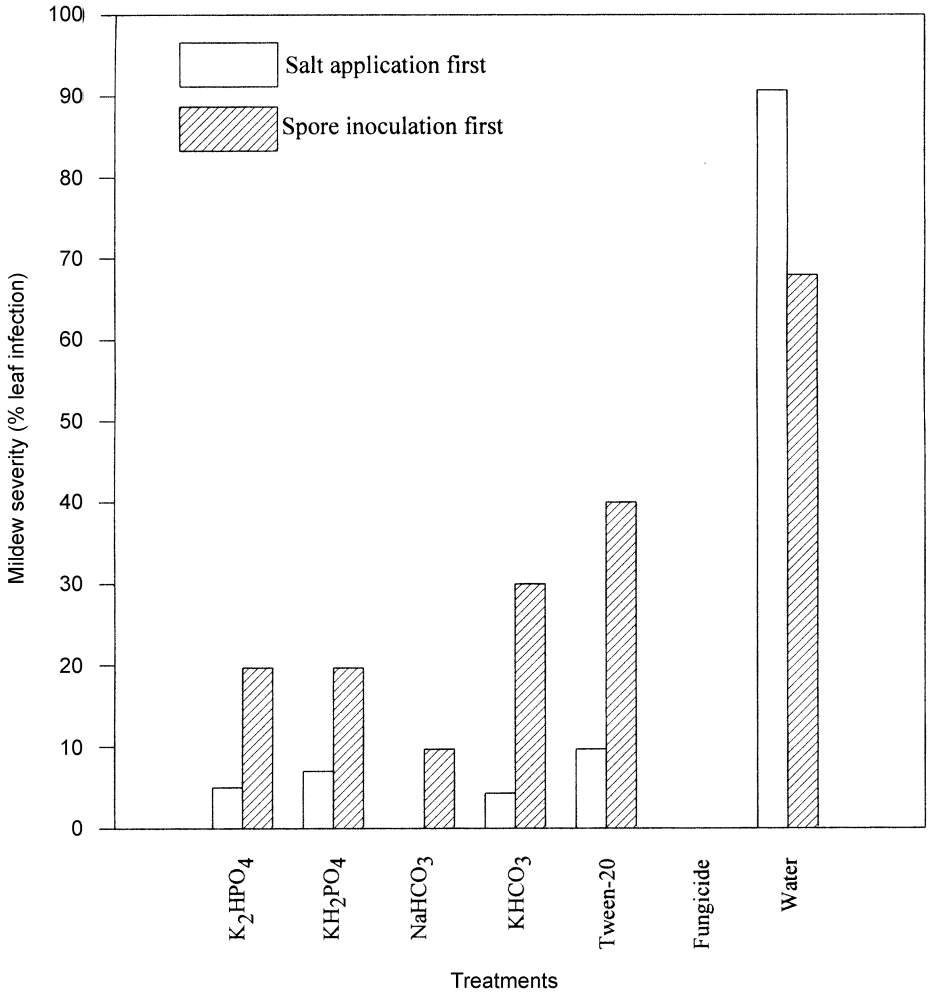

Fig. 3. Effect of previous or immediate (day 0) application of bicarbonates, phosphate and potassium salts on the mildew severity (% leaf infection).

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رش أملاح البيكربونات والفوسفات والبوتاسيوم على المجموع الخضري لبادرات القمح لتقليل شدة الإصابة بالبياض الدقيقي

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ملخص البحث. مقاومة مرض البياض الدقيقي المتسبب في الفطر اريسفي جرامنس تريتساي أعطت تأثيراً معنوياً عند استخدام أملاح الفوسفات والبوتاسيوم (بتركيز ١**%**) وكذلك عند استخدام بيكربونات الصوديوم والبوتاسيوم (بتركيز ٠,٥**%**) وقد خلطت هذه الأملاح بمادة ناشرة هي توين-٢٠ . وقد أجريت هذه التجربة على بادرات قمح صنف ايكورواروجو في الصوبة الزجاجية.

واتضح من النتائج أن هذه المعاملات كانت ذات تأثير معنوي على اختفاء بقع البياض الدقيقي الموجودة على المجموع الخضري وكذلك أثرت على عدد الجراثيم الكونيدية الموجودة في البقعة. وبذلك يمكن القول بأنه يمكن استخدام هذه الأملاح كمبيدات فطرية لمقاومة مرض البياض الدقيقي على القمح.