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Effect of some alternative control compounds to fungicides on sugar beet Cercospora leaf spot under greenhouse conditions

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تأثير بعض بدائل المبيدات لمكافحة مرض تبقع الأوراق السيركوسبوري لبنجر السكر تحت ظروف الصوبة

ABSTRACT

Cercospora leaf spot (CLS) disease is one of the most important diseases affecting sugar beet production in Egypt; caused by *Cercospora beticola* Sacc. The sensitivity of five beet cultivars were examined for their CLS infection: "Farida, Oscar Poly, Pleno, Arthos Poly, and Gaselle" under natural infection at Kafr-El Sheik, Egypt. Farida cv. was the most sensitive cultivar and was used for a greenhouse trial. This was conducted at the experimental Farm of the Faculty of Agriculture, Fayoum University, Fayoum, Egypt. Soil was divided into two parts, the 1st part was treated by potassium humate (KH) addition, while the other part had no KH treatments. However, sugar beet plants within the two soil parts were treated with foliar application included ten treatments of four different induced resistant chemicals; zinc-sulphate (ZnS-1 and ZnS-2), ammonium-molybdate (AmMo-1 and AmMo-2), salicylic-acid (SA-1 and SA-2), and calcium-silicate (CaSi-1 and CaSi-2), (concentrations; 6, 12, 0.8, 1.6, 3, 6, 5, and 10 mM, respectively), and two control treatments; fungicide (0.5 m/L) and negative control. All the chemical inducers treatments had recorded a significant decrease in disease severity and incidence (DS and DI) compared to negative control. Fungicide recorded the highest decrease in DS and DI, 7.33 and 23.33, respectively. Followed by CaSi-2, AmMo-2, and SA-2 treatments, where DS estimated data were 11.33, 12, and 13.33%, respectively. No significant differences were observed in growth parameters within foliar and soil treatments. CaSi-1 and fungicide treatments showed the most significant increases in extractable sugar. CaSi, AmMo, and SA treatments could be alternatives to fungicide managing CLS.

***Keywords*:** Cercospora-leafspot, Sugar beet, Potassium-humate, Zinc-Sulphate, Ammonium-molybdate, Salicylic-acid, Calcium-silicate, fungicide

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1. INTRODUCTION

Sugar production is a crucial and significant aspect of the Egyptian economy, which mainly produced from sugar cane and sugar beet plants **(Abd El-Motagally and Attia 2002)**. The preference of Sugar beet cultivation was increased recently in Egypt due to their ability to grow on the recently reclaimed ground and providing a high sugar recovery rate, as well as its lower water need when compared to sugarcane. Moreover, sugar beet is a short-duration crop, with a growth time around half that of sugarcane **(Nassar *et al*. 2022)**. As a result, it became the first source of sugar production in Egypt **(Amr and Ghaffar 2010)**. Egypt has a total sugar beet cultivated area of 617000 feddan (4200 m^2) **(Nassar *et al*. 2022)**.

Cercospora leaf spot (CLS) represents the most destructive foliar disease in sugar beet production which is caused by the fungal pathogen *Cercospora beticola* **(Rangel *et al.* 2020)**. CLS disease, significantly reduces sugar beet production in the Egyptian Delta, and causes significant reductions in leaves, roots, and sugar yield **(Gouda *et al*. 2022)**, which consequently reduces the sucrose yields, increasing impurity concentrations, and leading to processing losses **(Farahat 2018)**. The sugar beet cultivars productivity differs from one to another depending on the sowing timing and irrigation regime **(El-Mansoub *et al*. 2020; Gobarah *et al*. 2019)**

Generally, using chemical fungicides is the main traditional management method for fungal disease in Egypt, which has an adverse impact on the environment. Many investigations concerning the use of alternative safe control methods controlling fungal diseases as induce plant resistance chemicals against several diseases; Moreover, their direct impact on the mycelial growth of the fungal pathogens; Zinc sulphate **(Mousavi *et al*. 2013)**, ZnO NPs (**Rafiq *et al*. 2022)** and Na_2HPO_4 **(El-Fawy and El-Said 2018)**. Furthermore, the ability of certain elements as Zn and Mo to enhance sugar beet growth and yield in alkaline Egyptian soil **(Zewail *et al*. 2020)** There has been considerable interest in the use of Ammonium molybdate (NH_4Mo) for controlling various fungal diseases in plants (**Wan *et al.* 2003** and **Nunes *et al.* 2002**). Spraying with solution of salicylic acid (SA) provided the most effective protection against plant diseases **(Meena *et al.* 2001**; **Abd El-Al *et al.* 2012**; **El-Beltagi *et al.* 2017**; **Ali 2021, Ding and Ding 2020**; **Gorni *et al.* 2020**; **El-Hady *et al.* 2021).** On the other hand, induction of resistance using calcium silicate (CaSi) was reported in many plants since Si in the epidermal cell wall and increasing lignin content in the leaves **(Ng *et al*. 2019)**. Potassium humate (KH) application improves plant performance and fertility by increasing water content and membrane stability, decreasing electric leakage, and enhancing growth characteristics, physio-biochemical properties, and nutrients **(Mahdi *et al*. 2021)**. According to **Abdel-Monaim *et al*. (2014)**, KH enhanced plant growth characteristics (plant height and the number of branches). The application of KH can enhance soil properties, fertility, plant performance, and productivity by increasing potassium levels in the soil **(Taha *et al*. 2020)**. Potassium humate is a potent fertilizer that enhances plant growth and productivity by increasing nutrient uptake, enhancing plant biomass, and reducing soil compaction **(Osman *et al*. 2017)**.

Despite of the positive effect of the chemical fungicide in controlling fungal diseases on sugar beet crops increased root yield, sugar content, and white sugar yield **(Baltaduonytė *et al*. 2013)** specifically reducing CLS disease in sugar beet, with Score, Eminent, Montro, Opus, Foliogold, and Amistar providing high efficacy. Fungicide treatment increased yield and quality traits **(El-Sayed *et al*. 2017)**. But the negative side of chemical fungicides treatments was the development of resistant strains **(Rangel *et al*. 2020).**

The objectives of this study were to; 1) Evaluate different cultivar's sensitivity of sugar beet for Cercospora leaf spot disease under natural infection; 2) develop a controlling strategy for CLS disease that offers an environmentally acceptable alternative to chemical fungicides.

2. MATERIALS AND METHODS

2.1. Evaluation of sugar beet cultivars sensitivity to Cercospora leaf spot disease

Five multi-germ cultivars of sugar beet plants (*Beta vulgaris*, L.); Farida, Pleno (Ses, Germany), Oscar poly, Gaselle (Maribo, Germany) and Athos poly (Kuhn, Netherland); were cultivated in the open field under natural condition at Kafr El-Sheikh governorate, El-Hamol County, during the growing season 2018/19, in order to evaluate their sensitivity to Cercospora leaf spot disease. Seeds were obtained from Sugar Crops Research Institute, Agric., Research Center, Ministry of Agric, Egypt. Cultivars were cultivated in plots (4 × 3 m = 12 m^2) with three replicates for each cultivar, under field condition, which had a history of Cercospora leaf spot disease heavy infection and assessment diseases severity.

2.2. Greenhouse experiment

2.2.1. Experiment location

The greenhouse experiment was conducted during summer season of 2019/2020 in an open greenhouse at the Experimental Farm of the Faculty of Agriculture, Fayoum University, Southeast Fayoum (29°17' 41.9" N 30°54' 57.2" E), Egypt. Physical and chemical properties of the experimental soil during the 2016 and 2017 seasons are given in **Tables 1**.

Table 1. Initial physicochemical properties of the soil for experiment

Particle size distribution			Texture class	Field Capacity	pH	EC dS/m	$CaCo_3$
Sand	Silt	Clay					
73.50	12.90	14.60	Sandy Loam	19.79	7.43	5.93	9.18

All analyses were performed at the Central Laboratory of Soil, Water and Plant Analysis (Iso17025), Faculty of Agriculture, Fayoum University, Fayoum, Egypt.

2.2.2. Isolation and identification the pathogenic fungus

Cercospora beticola (Sacc.), the causal agent of sugar beet CLS, was isolated from infected sugar beet leaves which were collected from naturally infected fields at Itsa region, Fayoum Governorate, Egypt. Sugar beet leaf samples showing typical symptoms of Cercospora leaf spot; small round grey spots with reddish margins were collected. Cercospora was isolated and purified **Ahmed *et al.* (2023)** on PDA media and incubated at 22° C for 14 days. The purified fungus was identified using morphological and microscopical examinations at the Plant Pathology department, Faculty of Agriculture, Fayoum University.

2.2.3. Spore suspension preparation

Cercospora beticola spore suspension for seedlings inoculation was prepared as mentioned by **El-Fawy (2016)**. The spore suspension was adjusted to $4×10^4$ spores ml^{-1} of water using a hemacytometer and was sprayed onto the upper and lower side of the leaves after 24h sprayed of the treatment.

2.2.4. Experimental, plant material, treatment, and growth conditions

The effects of different treatments mentioned in **Table 3** were evaluated on the incidence of CLS disease in sugar beet under greenhouse conditions which were artificially inoculated with the causal fungus. Seeds of the selected *cv.* Farida; up on the results obtained from the sensitivity *in vivo* trail of tested five cultivars; were sowed in plastic pots (35 cm in diameter, 32 cm in depth) filled with 10 kg of soil.

Soil amendment with KH (potassium 11%, humic acid 80%, Ecocert Comp., Spain) at a level of 0.5 g kg^{-1} of soil were added to with half of the experimented pots' soil, after month of seed sowing. While the other half pot's soil had no additions soil amendment treatment. All the pots were fertilized with the NPK fertilizer and root rot fungicide with recommended doses of Egyptian ministry of Agriculture for sugar beet production. Ten different spraying treatments are illustrated in **Table 2**. A factorial arrangement in a randomized complete block design was used. Three replicates per treatment were used, where each pot was represented as a replicate. Two foliar treatments were sprayed at 90 and 120 days after sowing followed by spraying (inoculation) plants with spore suspension containing fresh conidiospores of *C. beticola* about 24h from treatments applications under infection condition. Disease assessment was assessed 7 days after the foliar applications as shown in **Fig. 1**.

Table 2. Treatments and their concentrations

Treatment	Chemical formula	Code	Concentration
Zinc sulphate	$ZnSO_4$	ZnS-1	6 mM
Zinc sulphate	$ZnSO_4$	ZnS-2	12 mM
Ammonium molybdate	$(NH_4)_6Mo_7O_{24}.4H_2o$	AmMo-1	0.8 mM
Ammonium molybdate	$(NH_4)_6Mo_7O_{24}.4H_2o$	AmMo-2	1.6 mM
Salicylic Acid	$C_7H_6O_3$	SA-1	3 mM
Salicylic Acid	$C_7H_6O_3$	SA-2	6 mM
Calcium Silicate	Ca_2O_4Si	CaSi-1	5 mM
Calcium Silicate	Ca_2O_4Si	CaSi-2	10 mM
Difenoconazole 25 EC (Score)	$C_{19}H_{17}Cl_2N_3O_3$	Score	0.5ml/L (recommended dose)
Control	Untreated	Control	---

Pots were irrigated with an equal volume of tap water daily or once every 3 days, according to the climate condition, to maintain 100% field capacity. All other agriculture practices for commercial sugar beet production, in particular plant protection against pests and weeds were performed according to the appropriate procedure.

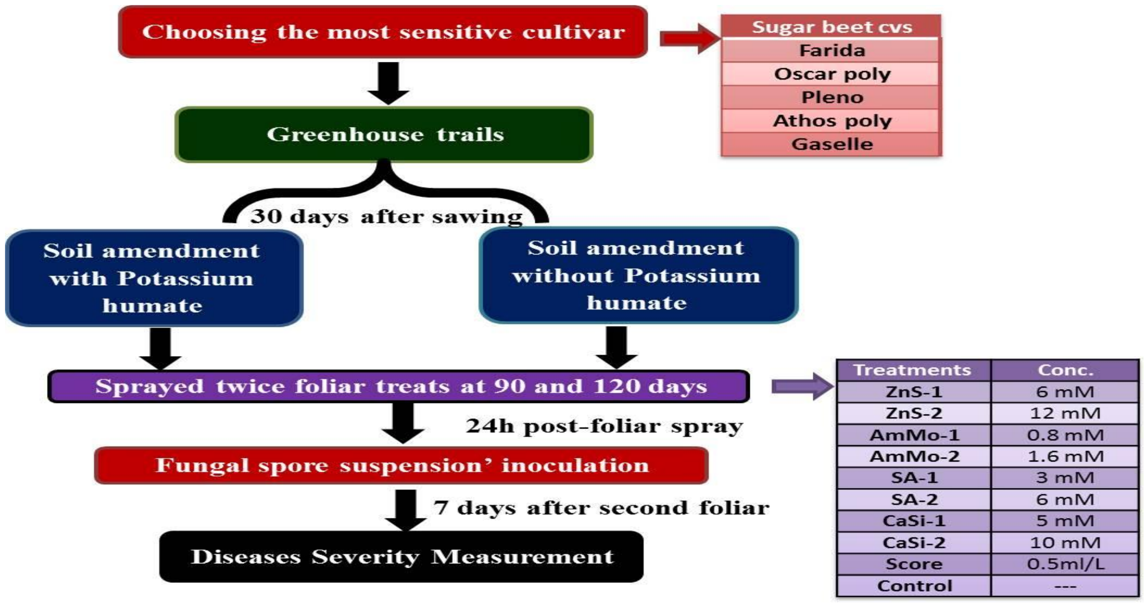

Fig. 1. Flow chart of methodology

2.3. Disease assessment

Sugar beet plants were periodically examined for disease symptoms estimating the disease incidence (DI%) and disease severity (DS%). Disease severity and disease incidence under greenhouse was assessed 7 days after the last treatment.

The disease severity of Cercospora leaf spot was assessed on sugar beet plants from rated as a 0-5 scale according to **Suresh (2013)** based on the leaf area infected with modified as following scale in **Table 3** and **Fig. 2** using the formula given by **Suresh (2013).**

Table 3. Scale of disease severity

Degree	Description
0	No Infection, No Spots on leaves.
1	10% Percent leaf area (Few brown spots with red edges, towards tip)
2	25% Percent leaf area (More brown spots, Spots coalesce, Blighted leaves)
3	50% Percent leaf area (Numerous brown spots, Leaves wilt)
4	75% Percent leaf area (Numerous brown spots, Leaves wilt, dried and full)
5	<75% Percent leaf area (Breaking of the leaves)

The following formulas were used to calculate each foliar disease's severity percentage (DS%) and disease incidence (DI%) (**Ahmed *et al.* 2023**).

$$\text{Disease severity (DS\%)} = \frac{\text{Sum of individual rating}}{\text{No. of leaves observed} \times \text{Max. disease grade}} \times 100$$

$$\textbf{Diseases incidence (\%)} = \frac{\text{No. of infected leaves}}{\text{No. of total leaves}} \times 100$$

Fig. 2. Standard area diagrams of disease severity for Cercospora leaf spot of sugar beet

2.4. Plant growth and yield assessment

One hundred eighty-day-old sugar beet plants were kindly removed from each treatment to extract and clean plant roots. Plants were separated into shoots and roots; growth and quality characteristics were measured. Certain growth parameters were measured as root length (cm), root diameter (cm) and fresh weights of root and top (kg/plant).

Quality parameters of the yielded sugar beet were determined in Al-Fayoum sugar company laboratories; Impurities of juice (K, Na, and α-amino N) were determined the digested extract of root dry matter as follows; Sodium and potassium concentrations were estimated as meq/100 g beet according to the procedures of Sugar Company by automated analyzer, as described by **Brown and Lilliand (1964)**. While α- amino N was determined using Hydrogenation method according to **Carruthers *et al.* (1962)**.

Sucrose percentage (Pol. %) was Polari metrically determined on a lead acetate extract of fresh macerated root. While Purity % and Sucrose loss to molasses (SLM %) were assessed according to the formula of **Devillers** (**1988).** While extractable sugar percentage was estimated according to the following formula described by **Dexter *et al.* (1967)**.

$$\boldsymbol{Purity}\ (\%) = 99.36 - 14.27\ \frac{(\mathrm{Na} + \mathrm{K} + \alpha\ \mathrm{amino\ N})}{\mathrm{Sucrose}\ \%}$$

$$\boldsymbol{SLM}\ (\%) = 0.14(Na + K) + 0.25(\alpha\ \mathrm{amino\ N}) + 0.5$$

$$\boldsymbol{Extractable\ sugar}\ (\%) = Sucrose\% + SLM\% - 0.6$$

2.5. Statistical analysis

Data obtained were subjected to statistical analysis according to the standard methods recommended by **(Gomez and Gomez 1984)** using the computer program (InfoStat software estadistico, 2016). The mean differences were compared by the least significant difference test (LSD) at 5% level of significance according to **(Fisher 1984)**.

3. RESULTS AND DISCUSSION

3.1. Sugar beet cultivars sensitivity for Cercospora leaf spot disease under field conditions

Data presented in **Table 4** and **Fig. 3** show the DS and DI of CLS disease. Significant differences were observed between tested cultivars in their sensitivity for the CLS infection, DS and DI. Farida cultivar had the highest sensitivity to CLS disease infection, where it gave the highest DS (36.43%) and disease incidence (52.23%). While, Oscar Poly had the highest resistance one, recording in DS and DI 12% and 33.33%, respectively. On the other hand, in DI, there were no significant differences between Oscar Poly, Pleno, Athos Poly, and Gazelle. Also, Athos Poly, Gaselle, and Pleno cultivars recorded a DS of 12.67, 13.33, and 18.67%, respectively. Sugar beet varieties with CLS genetic resistance are effective limiting strategies for CLS infection in field **(Tan *et al*. 2023)**. This study reveals significant differences in DS of CLS and incidence among tested cultivars. Farida had the highest sensitivity, causing the highest DS and incidence, these findings disagreed with **El-Fiki *et al*. (2007)** ones that classified Farida *cv.* as a low sensitive cultivar. While other tested cultivars showed a moderate CLS resistance activity (Oscar Poly, Athos Poly, Gaselle, and Pleno) which agreed with **El-Fiki *et al*. (2007)** that classified Gazail and Pleno cultivars as moderate susceptible cultivars for rust infection.

Table 4. Cercospora leaf spot disease on different cultivars of sugar beet during the growing season 2019/2020

Disease assessment	Sugar beet cultivars				
	Farida	Oscar Poly	Pleno	Athos Poly	Gaselle
DS	36.43^{A}	12.00^{C}	18.67^{B}	12.67^{C}	13.33^{C}
DI	52.23^{A}	33.33^{B}	40.00^{B}	33.33^{B}	33.33^{B}
LSD 5% for					
DS			4.25		
DI			11.69		

Whereas DS= Diseases severity and DI = Diseases incidence.

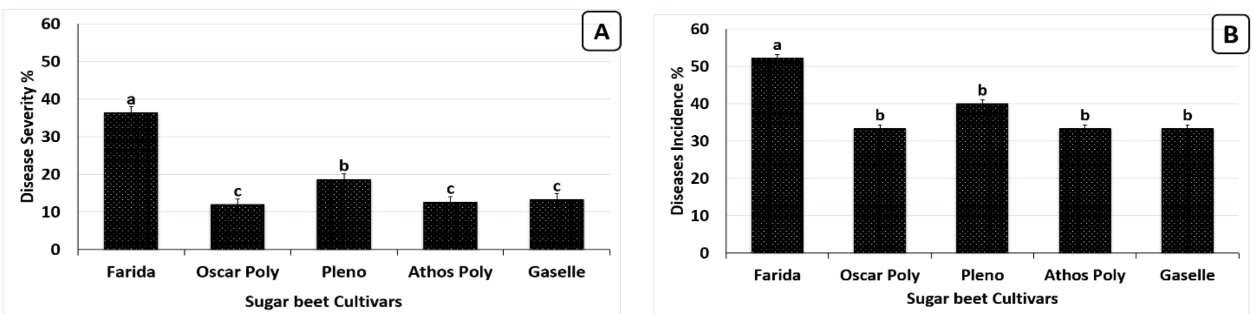

Fig. 3. Cercospora leaf spot disease A: Diseases severity (DS) and B: Disease incidence (DI) of on different cultivar of sugar beet**.**

3.2. Effect of induced resistance chemicals alone or in combination with potassium humate on Cercospora leaf spot disease of sugar beet plants grown under greenhouse conditions

The most significant sensitive cultivar was used for the greenhouse experiment, Farida cultivar. Data presented in **Table 5** highlights the effect of induced resistance chemicals on the DS and DI of CLS. All treatments had recorded significant decrease of the disease severity and disease incidence with reference to the control one. Fungicide (score 25EC) recorded the highest decrease in DS and DI, 7.33 and 23.33, respectively. Followed by CaSi-2, AmMo-2, and SA-2 treatments where DS estimated data were 11.33, 12, and 13.33%, respectively. Among treatments, ZnS-1 showed the highest record of DS and DI, 28.67 and 66.67%, respectively. On the other hand, no significant differences were observed between estimated DI of ZnS-2, AmMo-2, and SA-2 treatments (about 40% in average /each). Meanwhile, the highest DS and DI were observed in the untreated plants (control treatment), 46.67 and 86.67%, respectively. Meanwhile, no significant differences were observed for the soil amendment with KH, **Table 5** on the DS and DI. However, the lowest DS and DI were observed with KH (17.20 and 44.67%, respectively).

The conducted greenhouse trail using Farida *cv.* showed that Score© fungicide had the highest decrement of DS and DI of the CLS disease, that was confirmed by **El-Sayed *et al*. (2017)** findings that fungicide (Score), significantly reduced the radial growth of *C. beticola in vitro*, and demonstrated the highest decrease in DS and DI *in vivo***.** A similar conclusion was reached by **Jaskulska *et al*. (2023)** that chemical fungicide application is an effective protection method for sugar beet against CLS infection. Our greenhouse and *in vivo* trails' results were broadly in line with **Liebe *et al*. (2023)** that a single fungicide application was significantly reduced Spores aggressiveness intensity and DS. The application of induced resistance chemicals as Calcium silicate had significantly decreased the CLS disease incidence and severity. This is consistent with what has been found previously by **El-Kholi and Esh (2011)** who located Calcium treatments reduce conidiospore density and stomatal guard cells, promoting disease resistance and stomatal function. While, the rice foliar application of calcium silicate had significantly enhanced its resistance against *Pyricularia. oryzae* infection by fortifying the epidermal cell wall and increasing leaf lignin content **(Ng *et al*. 2019).** This may explain why calcium silicate had significantly decreased the CLS disease. Our results demonstrate that ammonium molybdate had significantly decreased the sugar beet CLS infection. Other similar results were obtained on other crops as those found by **Arslan *et al*. (2006)** who proved the inhibition effect of ammonium molybdate on the fungal spore germination of rust disease**.** Further positive effect for ammonium molybdate application was found by **Wan and Tian (2005)** that revealed incidence reduction of postharvest diseases in pear fruit. **Thanh *et al*. (2017)** reported that foliar sprays with SA provided an increase production of O_2^-. The O_2^- not only has direct toxicity to pathogens, but it is also the central component of the plant defense signal transduction pathways. Also, they observed enhancement of polyphenoloxidase activity and production of plant phytoalexins. However, the SA had significantly decreased CLS infection in this study, that could be explained by the previous report of **Shalaby *et al*. (2023)** that the application of SA could enhance the enzymatic antioxidant activities. The other promising induced resistance chemicals is zinc sulphate controlling sugar beet CLS disease infection in the greenhouse and *in vivo* trails. This agrees with **Duffy (2007)** who proves that Zinc application has decreased the severity of various plant pathogens. A similar pattern of results was obtained by **Ward (2015)** that zinc was drastically reduced fungal growth of soybean CLS and rust fungi. While sulfur (S) has been used to control different foliar diseases such as leaf blights **(Ghazy *et al*. 2020).**

However, many reports mentioned the positive effect of KH soil amendments on the decrement of plant disease incidence as **Idrees *et al*. (2018)**, **Dawood *et al*. (2019), Taha *et al*. (2020), and Mahdi *et al.* (2021).** That gave certain explanations as the KH application can improve soil properties and fertility by increasing potassium levels, which boost plant performance and productivity, raising the relative water content and the membrane stability index, KH administration improved tissue water status. At the same time, electric leakage decreased, along with improved growth characteristics, physio-biochemical properties, and nutrients. Increased concentration of impurities decreased sugar concentration in beet roots, and decreased root weight were generally correlated with DS. Beets with a higher concentration of impurities yielded less pure sugar and more unrefined sugar (molasses) in the extraction process, in diseased to reductions in root weight and sugar content **(Shane and Teng 1992)**. Potassium humate is a commercial product resulting from the reaction of potassium salt with humic acid to produce complex humic substances **(Howladar 2018; Torun and Toprak 2020).** Results of the current study showed that KH affected DS and incidence under artificial conditions in greenhouse.

Table 5. Effects of induced resistance chemicals alone or in combination with potassium humate on Cercospora leaf spot disease of sugar beet plants grown under artificial infection with *Cercospora beticola*

IRCs	Diseases severity (%)			Diseases incidence (%)		
	With KH	Without KH	Mean	With KH	Without KH	Mean
ZnS-1	26.67	30.67	28.67	53.33	80.00	66.67
ZnS-2	16.00	16.00	16.00	40.00	40.00	40.00
AmMo-1	8.00	29.33	18.67	60.00	60.00	60.00
AmMo-2	5.33	18.67	12.00	26.67	53.33	40.00
SA-1	22.67	17.33	20.00	53.33	46.67	50.00
SA-2	18.67	8.00	13.33	46.67	33.33	40.00
CaSi-1	14.67	22.67	18.67	40.00	60.00	50.00
CaSi-2	8.00	14.67	11.33	20.00	46.67	33.33
Score	9.33	5.33	7.33	26.67	20.00	23.33
Control	42.67	50.67	46.67	80.00	93.33	86.67
Mean	17.20	21.33	---	44.67	53.33	---
L.S.D. at 5%	IRCs: 12.05 Soil Amendments (KH): NS IRCS * KH: NS			IRCs: 31.21 Soil Amendments (KH): NS IRCS * KH: NS		

KH: Potassium humate, IRCs: Induced resistance chemicals, NS: Not-Significantly. ZnS: Zinc sulphate (6 and 12 mM), AmMo: Ammonium molybdate (0.8 and 1.6 mM), SA: Salicylic acid (3 and 6 mM), CaSi: Calcium silicate (5 and 10 mM), Score: fungicide (Difenoconazole 25% EC) (0.5 ml/L), Control (untreated).

3.3. Effect of induced resistance chemicals alone or in combination with potassium humate on quality traits of sugar beet plant under greenhouse conditions

3.3.1. Sucrose and extractable sugar percentage

Sugar beet roots were tested for the quality features regarding the effect of induced resistance chemicals treatments, as shown in the data presented in **Table 6**. Sucrose percentage measured data showed insignificantly slight differences, which ordered by CaSi-1, SA-2, AmMo-2, score fungicide, ZnS-1, AmMo-1, and CaSi-2, 17.21, 16.95, 16.93, 16.93, 16.89, 16.79, 16.78, and 16.76, respectively regarding the untreated control one. While, ZnS-2 and SA-1 treatments had the highest negative effect on the sugar percentage. Concerning the effect on extractable sugar percentage, as shown in **Table 6** CaSi-1 and fungicide recorded the highest increments' percentages at 14.57 and 14.42%, followed by SA-2, ZnS-1, AmMo-2, and AmMo-1 at 14.31, 14.27, 14.26, 14.15, and 14.13%, respectively) compared with untreated control. Conversely, the lowest percentages were observed by CaSi-2, ZnS-2, and SA-1, at 14.12, 14.05, and 13.99%, respectively.

No significant differences were found within the different induced resistance chemicals treatments under investigation in the extractable sugar % nor sucrose % with references to the fungicide Score treatment and control one. These results were parallel with the finding of **El-Sayed *et al*. (2017)** that reported that the Score was the most efficient in CLS disease suppression**.** On the other hand, **El-Shazly *et al*. (2018)** disagreed with our findings that observed significant sucrose (%) increment within the induced resistance chemicals, Zinc sulphate, Salicylic acid, and Calcium chelate regarding the untreated control**.** Another investigation conducted by **Merwad (2016)**. As **Table 6**, the effect of KH increased significantly with the sucrose percentage and the extractable sugar percentage, recording 16.99% and 14.35%, respectively.

3.3.2. Purity percentage and sucrose loss to molasses (SLM) percentage

Regarding the impact of induced resistance chemicals on purity percentage, **Table 6** shows that the fungicide significantly increased purity percentage (83.48%). ZnS-1, SA-2, and CaSi-1 also significantly increased purity percentage with respect to the untreated plants control (81.43, 81.36, 81.35%, and 81.24, respectively). Conversely, the purity percentages of AmMo-1, AmMo-2, ZnS-2, CaSi-2, and SA-1 were marginally lower than those of the untreated ones, at 81.07, 81.01, 81, 80.91, and 80.88%, respectively. **Table 6** presents the data concerning the effect on sucrose loss to molasses percentage (SLM). The results indicate that the fungicide treatment (Score 25 EC) resulted in the largest decrease in SLM%, with 1.9%. Meanwhile, ZnS-1 and ZnS-2 also showed a significant decrease in SLM%, at 2.02, 2.02, and 2.03%, respectively, with reference to the untreated control. AmMo-1, SA-2, and CaSi-1 all recorded the same percentage of 2.04%, meanwhile SA-1 was non-significant with the control which recorded at 2.03%. AmMo-2 and CaSi-2, on the other hand, showed the most positive results, recording 2.06% and 2.07%, respectively.

The study shows induced resistance chemicals' effects on sugar beet purity percentage and sucrose loss to molasses percentage. The fungicide treatment resulted in the largest decrease in sucrose loss to molasses percentage (SLM%), Fungicide Score treatment caused a significant increase in total soluble solids (T.S.S.), and purity compared with control plots. Also, T.S.S., and purity were increased in root samples stored 15 days after harvest. Other studies had similar result trends where, Score treatment was the most efficient in this respect **(El-Sayed *et al*. 2017).** Foliar spray with Zn had significant effects on all studied traits in both seasons, except juice purity% in the 1st season only **(Mohamed and Yasin 2013)**. Meanwhile, no significant effect was observed in the purity percentage for KH treatments as shown in **Table 6**, even with the slight increase from 81.21% without KH to 81.54% with KH. Whereas this slight increase in the sucrose loss to molasses percentage has a significant affect for the KH treatment from 2.01 to 2.04 %. Potassium humate's effect increased significantly with sucrose and extractable sugar percentages. Also, no significant effect was observed for KH treatments with purity, however, KH had the highest purity percentage. KH observed a negative effect of sucrose loss on molasses percentage. This was broadly in line with **Elgamal *et al*. (2021)** findings that humic application was significantly affected and gave the highest values of sucrose and purity percentages.

Table 6. Means of SLM, extractable sugar, purity, and sucrose of sugar beet as affected with different applied treatments under artificial infection with *Cercospora beticola*

IRCs	SLM (%)		Mean	Extractable sugar (%)		Mean	Purity (%)		Mean	Sucrose (%)		Mean
	With KH	Without KH		With KH	Without KH		With KH	Without KH		With KH	Without KH	
ZnS-1	2.04	2.00	2.02	14.36	14.18	14.27	81.39	81.47	81.43	17.00	16.78	16.89
ZnS-2	2.06	1.98	2.02	14.89	13.20	14.05	81.82	80.18	81.00	17.55	15.78	16.67
AmMo-1	2.08	1.99	2.04	14.19	14.12	14.15	80.81	81.33	81.07	16.87	16.72	16.79
AmMo-2	2.09	2.04	2.06	14.16	14.36	14.26	80.88	81.14	81.01	16.85	17.00	16.93
SA-1	2.04	2.02	2.03	13.91	14.06	13.99	80.84	80.92	80.88	16.55	16.68	16.62
SA-2	2.07	2.00	2.04	14.31	14.31	14.31	80.82	81.90	81.36	16.98	16.92	16.95
CaSi-1	2.03	2.05	2.04	14.45	14.68	14.57	81.42	81.27	81.35	17.08	17.33	17.21
CaSi-2	2.03	2.10	2.07	14.37	13.86	14.12	81.49	80.33	80.91	17.00	16.57	16.78
Score	1.86	1.95	1.90	14.84	14.00	14.42	85.17	81.79	83.48	17.30	16.55	16.93
Control	2.08	1.97	2.03	14.06	14.21	14.13	80.75	81.73	81.24	16.74	16.78	16.76
Mean	2.04	2.01	-	14.35	14.10	-	81.54	81.21	-	16.99	16.71	-
L.S.D at 5%	IRCs: 0.059 Soil Amendments (KH): 0.026 IRC_S * KH: 0.083			IRCs: NS Soil Amendments (KH): 0.247 IRC_S * KH: 0.782			IRCs: 0.985 Soil Amendments (KH): NS IRC_S * KH: 1.393			IRCs: NS Soil Amendments (KH): 0.243 IRC_S * KH: 0.770		

KH: Potassium humate, IRCs: Induced resistance chemicals, NS: Not-Significantly. ZnS: Zinc sulphate (6 and 12 mM), AmMo: Ammonium molybdate (0.8 and 1.6 mM), SA: Salicylic acid (3 and 6 mM), CaSi: Calcium silicate (5 and 10 mM), Score: fungicide (Difenoconazole 25% EC) (0.5 ml/L), Control (untreated).

3.3.3. Sugar beet impurities

Data in **Table 7** indicate that impurities (potassium K, sodium Na, and alpha-amino nitrogen N) are affected by induced resistance chemicals, which were significantly associated with both potassium and sodium. Fungicide (score 25EC) treatment had decreased significantly in K content. While, it showed the lowest mean values for K and Na, with values, 4.05 and 2.90 meq/100g beet, respectively. Whereas the treatments of CaSi-1 and CaSi-2 showed the highest significant increase of potassium content in beets with reference to the control one, 4.66, 4.56 and 4.44 respectively. While AmMo-2 and ZnS-2 had the highest content of Sodium content in beets with reference to the control one, 3.56, 3.49 and 3.40 respectively. The lowest mean values Alpha-amino nitrogen was found in ZnS-2 and Casi-1 treatments which were the same value of 1.66 meq/100g beet. Regarding the soil amendment of KH, the data presented in **Table 7** shows a non-significant variance for K and Na ($P \leq 0.05$) for all impurities with or without KH except α-amino N, which is 1.78. A reverse relationship was observed between the accumulations of Na in leaves in parallel with the decrements of K content.

Table 7. Means of potassium (K), sodium (Na), and alpha-amino nitrogen (N) of sugar beet as affected with different applied treatments under artificial infection with *Cercospora beticola*

IRCs	K content (meq/100 g beet)		Mean	Na content (meq/100 g beet)		Mean	Alpha-amino N content (meq/100 g beet)		Mean
	With KH	Without KH		With KH	Without KH		With KH	Without KH	
ZnS-1	4.53	4.48	4.51	3.37	3.28	3.33	1.73	1.66	1.69
ZnS-2	4.50	4.29	4.40	3.47	3.50	3.49	1.77	1.56	1.66
AmMo-1	4.66	4.37	4.52	3.44	3.45	3.45	1.79	1.59	1.69
AmMo-2	4.47	4.44	4.46	3.57	3.55	3.56	1.85	1.68	1.79
SA-1	4.44	4.57	4.50	3.49	3.42	3.45	1.72	1.62	1.67
SA-2	4.46	4.46	4.46	3.52	3.34	3.43	1.82	1.64	1.73
CaSi-1	4.54	4.78	4.66	3.41	3.39	3.40	1.68	1.64	1.66
CaSi-2	4.40	4.72	4.56	3.45	3.43	3.44	1.73	1.84	1.79
Score	3.93	4.18	4.05	2.48	3.32	2.90	1.84	1.60	1.72
Control	4.55	4.33	4.44	3.49	3.31	3.40	1.83	1.61	1.72
Mean	4.45	4.46	-	3.37	3.40	-	1.78	1.65	-
L.S.D. at 5%	IRCs: 0.276 Soil Amendments (KH): NS IRC_S * KH: NS			IRCs: 0.174 Soil Amendments (KH): NS IRC_S * KH: 0.246			IRCs: NS Soil Amendments (KH): 0.078 IRC_S * KH: NS		

KH: Potassium humate, IRCs: Induced resistance chemicals, NS: Not-Significantly. ZnS: Zinc sulphate (6 and 12 mM), AmMo: Ammonium molybdate (0.8 and 1.6 mM), SA: Salicylic acid (3 and 6 mM), CaSi: Calcium silicate (5 and 10 mM), Score: fungicide (Difenoconazole 25% EC) (0.5 ml/L), Control (untreated).

3.4. Effect of induced resistance chemicals alone or in combination with potassium humate on sugar beet growth traits under greenhouse conditions

3.4.1. Root length and diameter

Concerning the effect of induced resistance chemicals on root length and diameter, as exhibited in **Table 8**, no significant differences were observed in all treatments. Meanwhile, ZnS-1 and SA-1 were observed to be higher values for root lengths than their counterparts, which were recorded at 26.92 and 26.17cm, respectively. Furthermore, fungicide treatment showed the highest root diameter that recorded 15cm. Similar results were obtained by **Zewail *et al*. (2020)** that the Zn foliar treatment had increased sugar beet root length**.** While foliar spray with SA caused positive and significant effects on root length, root diameter, and the sugar beet crop grown on saline soil **(Merwad 2016)**. Potassium humate effect on the root length, as shown in **Table 8** had no significant differences with or without KH. On the other hand, the root diameter with KH was significantly increased compared to the KH-untreated ones 14.22 and 12.2, respectively. Whereas, **Elgamal *et al*. (2021)** found that the application of humic had significantly affected endogenous phytohormones (gibberellins, auxins, cytokinin, and abscisic) and gave the highest values of root diameter**.**

3.4.2. Root and top fresh weight

Induced resistance chemicals had no significant effect on root and top fresh weight, the data shown in **Table 8**. Even so the insignificant effect of ZnS-2 treatment had the highest root fresh weight (0.73 kg), followed by SA-1 (0.68 kg). Moreover, CaSi-1 and CaSi-2 showed the same weight (0.63 kg). As an example, for top fresh weight, the highest treatment was observed for ZnS-2 0.45 kg, followed by AmMo-1 (0.36 kg) and SA-1(0.32 kg). **Ghazy *et al*. (2020)** had a parallel effect of Sulfur application that had led to an increase in the fresh weight of sugar beetroot. While, **Zewail *et al*. (2020)** had different results that the Mo foliar treatment had increased root fresh weight. Concerning the effect of KH, the data presented in **Table 8** show that the KH significantly decreased the root and top fresh weight (0.51 kg). While, there is no effect of using KH on neither root nor top fresh weight. Potassium humate significantly decreased root and top fresh weight, but no effect was observed with KH. Application of 15 g humic/L significantly affected and gave the highest values of fresh and foliage weights per plant **(Elgamal *et al*. 2021)**.

Table 8. Means of root length, root diameter, root and top fresh weights of sugar beet as affected with different applied treatments under artificial infection with *Cercospora beticola*

IRCs	Root fresh length (cm/plant)		Mean	Root fresh diameter (cm/plant)		Mean	Root fresh weight (kg/plant)		Mean	Top fresh weight (kg/pant)		Mean
	With KH	Without KH		With KH	Without KH		With KH	Without KH		With KH	Without KH	
ZnS-1	26.67	27.17	26.92	15.17	11.50	13.33	0.59	0.52	0.56	0.27	0.31	0.29
ZnS-2	25.00	24.67	24.83	16.50	9.33	12.92	0.88	0.57	0.73	0.48	0.42	0.45
AmMo-1	24.17	22.00	23.08	13.83	15.50	13.17	0.50	0.67	0.59	0.30	0.43	0.36
AmMo-2	23.83	22.50	23.17	12.00	13.33	12.17	0.30	0.93	0.61	0.16	0.43	0.29
SA-1	26.33	26.00	26.17	14.00	11.50	12.75	0.54	0.83	0.68	0.27	0.37	0.32
SA-2	22.17	21.17	21.67	14.00	9.33	11.67	0.48	0.32	0.40	0.28	0.24	0.26
CaSi-1	23.33	22.00	22.67	13.33	13.50	13.42	0.46	0.80	0.63	0.21	0.39	0.30
CaSi-2	22.67	26.50	24.58	13.17	15.17	14.17	0.36	0.89	0.63	0.19	0.36	0.28
Score	23.67	24.17	23.92	15.50	14.50	15.00	0.38	0.50	0.44	0.14	0.25	0.19
Control	25.67	22.00	23.83	14.67	12.33	13.50	0.62	0.40	0.51	0.28	0.27	0.27
Mean	24.35	23.82	-	14.22	12.20	-	0.51	0.64	-	0.26	0.35	-
L.S.D. at 5%	IRCs: NS Soil Amendments (KH): NS IRCS * KH: NS			IRCs: NS Soil Amendments (KH): 1.130 IRCS * KH: 3.576			IRCs: NS Soil Amendments (KH): 0.121 IRCS * KH: 0.383			IRCs: NS Soil Amendments (KH): 0.067 IRCS * KH: NS		

KH: Potassium humate, IRCs: Induced resistance chemicals, NS: Not-Significantly. ZnS: Zinc sulphate (6 and 12 mM), AmMo: Ammonium molybdate (0.8 and 1.6 mM), SA: Salicylic acid (3 and 6 mM), CaSi: Calcium silicate (5 and 10 mM), Score: fungicide (Difenoconazole 25% EC) (0.5 ml/L), Control (untreated).

4. CONCLUSIONS

CLS is one of the most important and common diseases affecting sugar beet production in Egypt. The sugar beet cultivar selection for cultivation is considered one of the most important management methods used for CLS disease. Since, all the sugar beet tested cultivars had a different sensitive reaction to the CLS infection. All the chemical inducers tested had recorded a significant decrease in disease severity and disease incidence compared to the control. The chemical fungicide recorded the highest decrease in DS and DI, followed by CaSi-2, AmMo-2, and SA-2 treatments. Among treatments, ZnS-1 showed the highest record of DS and DI. Meanwhile, the highest DS and DI were observed in the untreated plants (negative control). Adding KH to soil in greenhouses affected disease severity and incidence, with the lowest severity and incidence observed with KH, despite no significant differences between groups. The study examined sugar beet roots treated with various chemical inducers, showing slight differences in sucrose percentage. CaSi-1 and fungicide treatments showed the most significant increases in extractable sugar percentages. Also, KH's effect increased significantly with sucrose and extractable sugar percentages. Treatments of fungicide, ZnS-1, SA-2, and CaSi-1 significantly increased purity percentage showing higher purity percentages than untreated plants, while the fungicide treatment led to a significant reduction in sucrose loss to molasses percentage (SLM%), with ZnS-1 and ZnS-2 also showing reductions. No significant differences in root length, root diameter, root and top fresh weight were recorded between chemical inducers and the KH.

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