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Research Article

Evaluating the Resistance of some Sugar Beet Cultivars to Cercospora Leaf Spot

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Abstract:

Sugar beet is an important commercially cultivated root crop. It yields more than 100 million tons of sugar, predominantly sucrose, annually for global consumption. Cercospora leaf spot (CLS), caused by *Cercospora beticola* Sacc, is one of the most threatening foliar diseases to sugar beet crops and can significantly reduce sugar yield. The present study aimed to evaluate ten sugar beet cultivars for resistance to Cercospora leaf spot disease during two growing seasons. Additionally, parameters such as disease severity percentage, root diameter (cm), root length (cm), root fresh weight per plant (g), root yield per feddan (ton), and sucrose content were measured. Our findings showed that the sugar beet cultivars Clavious and Bts 8953 were highly resistant, recording the lowest disease severity during the 2021/2022 season (1.33% and 2% respectively) and the 2022/2023 season (2.67% and 4.33% respectively). In contrast, Lily and Oscarpoly were highly susceptible cultivars, recording the highest disease severity during the 2021/2022 season (18.00% and 19.33% respectively) and the 2022/2023 season (17.67% and 19.67% respectively). Other cultivars exhibited moderate resistance. Infection of sugar beet cultivars impacts root diameter (cm), root length (cm), fresh root weight per plant (g), root yield per feddan (t), and sucrose content, with notable differences observed among the cultivars. Consequently, due to the decline in several quality parameters caused by Cercospora leaf spot infection, selecting and cultivating resistant sugar beet cultivars to CLS is one of the most important control strategies that can be relied upon to reduce the losses resulting from this disease.

1. Introduction

Sugar beet (*Beta vulgaris* subsp. *vulgaris*, belonging to the Amaranthaceae family) is one of the major sugar crops in Egypt. It is the second most cultivated crop for sugar production after sugarcane and contributes approximately 2.458 million tons to the total sugar production (Hashem, 2020). The global sugar beet production was 261 million tons in 2022, with a harvested area spanning 4295160 hectares (FAOSTAT, 2023). Additionally, Egypt cultivated 253825 hectares of sugar beet achieving a yield of 53.411 tons per hectare and a total production of 13.557 million tons in the same year (FAOSTAT, 2023).

Sugar beet is highly susceptible to various phytopathogens, including fungi, bacteria, viruses, and numerous insects, all of which can significantly affect yield and reduce sucrose production (Tehseen et al., 2023). Notably, *Cercospora beticola Sacc*, the pathogen responsible for Cercospora leaf spot (CLS) disease, can lead to yields dropping by as much as 50%. CLS is particularly recognized as one of the most severe foliar diseases affecting sugar beet, damaging the shoot system and disrupting photosynthesis, which ultimately reduces root sugar production. This disease impacts approximately 44% of global sugar beet cultivation areas, with severity levels varying across different regions (Tan et al., 2023). Furthermore, sugar production can decrease by up to 42%, and increased impurity levels may result in significant economic losses (Khan and Smith, 2005; Knight et al., 2019).

CLS significantly reduced root yield, extractable sugar content, and levels of potassium (K), sodium (Na), and amino nitrogen (α-amino N), making it harder to produce crystalline sugar and lowering sugar yield during refining (Kaya, 2022). Generally, CLS symptoms appear on the primary leaves of sugar beet. As the disease progresses, primary leaves fall off, and the plant forms new leaves to maintain photosynthetic capacity, depleting root sugar reserves. This results in a marked decrease in root weight and sugar content, highlighting the critical need for effective CLS control measures in field management (Tedford et al., 2018).

Numerous control strategies are employed to control CLS in sugar beet, including crop rotation (Khan *et al.*, 2007), assessment and monitoring (Wijekoon et al., 2008), chemical fungicides (Ioannidis *et al.*, 2010), and biological control (Galletti et al., 2008). However, planting resistant cultivars is considered one of the safest and most effective strategies compared to the previously mentioned strategies (Weiland and Koch, 2004).

Planting resistant cultivars of sugar beet to CLS reduces the presence of disease inoculum in the field, leading to a slower progression of disease epidemics. Similarly, by enhancing quantitative resistance to CLS disease, the completion of the disease cycle is prevented, thereby inhibiting spore production (Mundt, 2014). Developing sugar beet cultivars with high genetic resistance is among the most effective and sustainable strategies for managing plant diseases, especially Cercospora leaf spot. Additionally, it can decrease the reliance on chemical fungicides and hinder the evolution of pathogen strains (Kaya, 2022; Tan *et al.*, 2023).

Using resistant cultivars of sugar beet is an effective way to reduce the distribution and severity of Cercospora leaf spot disease in sugar beet crops. This investigation aimed to evaluate the resistance of ten selected sugar beet cultivars to this disease under Egyptian conditions. The cultivars evaluated included BTS 8953, Clavious, BTS Smart 9830, BTS 3740, BTS 3880, LILY, Oscarpoly, Faraida, Jampol, and Ktart.

2. Materials and Methods

2.1. Field experiment design and geographical location

Two experiments were conducted during two growing seasons (2021/2022 and 2022/2023) at Sakha Agricultural Research Station, Sakha, Kafr El-Sheikh, Egypt (31.094059◦ N, 30.933899◦ E). This site was chosen because of its long history of severe CLS infestation. Experiments were conducted in a randomized complete block design with three replicates for each treatment/cultivar. The plot area was 18 m2, including 5 rows of 6.0 m long and 60 cm wide, with 20 cm apart between hills.

Moreover, in preparation of the seedbed, superphosphate (15% P2O5) was applied at 30 kg P_2O_5 per feddan. Ammonium nitrate (33.5% N) was administered at 80 kg N per feddan in two equal doses. The initial dose was given after thinning (at the four true leaf stage), and the subsequent dose was given one month later.

2.2. Plant materials and substances

These experiments were conducted under field conditions to evaluate the resistance and susceptibility of ten sugar beet cultivars to Cercospora leaf spot (CLS) caused by *Cercospora beticola* during two consecutive growing seasons, 2021/2022 and 2022/2023. Sugar beet seeds were obtained from the Sugar Crops Research Institute, Agricultural Research Center, Giza, Egypt, as shown in Table 1.

2.3. Sampling and determined traits, at harvesting time

A scale of 0 to 9 based on the development of symptoms on leaves death of older leaves and leaf spot progression to inner leaves) as described by (Shane and Teng, 1992) was used to measure the percentage of disease severity (%DS). Disease severity was recorded after 15 days of infection. Additionally, Sucrose% (pol%) was polarimaterically determined using the pol method described in (AC, 1990). Several vegetative parameters such as root diameter (cm), root length (cm), and root fresh weight/ plant (g) were evaluated 105 days post-seed planting**.** Furthermore**,** root yield per feddan (ton) sugar beet roots per plot were weighed in kg and converted into tons per feddan.

Table 1. Sugar beet cultivars used in the present study

Sugar beet cultivars		Type of seeds	Country of origin
1	BTS 8953	Poly	Germany
2	Clavious	Poly	Germany
3	BTS Smart 9830	Mono	Germany
4	BTS 3740	Mono	Germany
5	BTS 3880	Mono	Germany
6	Lily	Poly	Denmark
7	Oscarpoly	Poly	Denmark
8	Faraida	Poly	Belgium
9	Jampol	Mono	Poland
10	Ktart	Mono	French

2.4. Statistical analysis

The experiments were conducted using a completely randomized design, with three biological replicates across two consecutive seasons (2021/2022 and 2022/2023). All data underwent statistical analysis via analysis of variance (ANOVA), succeeded by the Tukey-Kramer honestly significant difference test (Tukey HSD, $p \leq 0.05$) for post hoc pairwise comparisons.

3. Results

3.1. Reaction of different sugar beet cultivars to *Cercospora beticola* Sacc

Generally, the ten tested sugar beet cultivars exhibited varying degrees of Cercospora leaf spot (CLS) disease severity during the 2021/2022 and 2022/2023 growing seasons (Table 2). In the first season (2021/2022), Clavious, BTS 8953, BTS 3880, and BTS Smart 9830 recorded the lowest disease severity percentages (% DS) at 1.33, 2.67, 3.67, and 5.67%, respectively compared with other cultivars. Similarly, in the second season (2022/2023), these cultivars again showed the lowest values at 2, 4.33, 4, and 2.33%, respectively (Table 2). Conversely, the Lily and Oscarpoly cultivars exhibited the highest CLS disease severity values, with 18.00 and 19.33% in the first season, and 17.67, and 19.67% in the second season, respectively (Table 2). The remaining sugar beet cultivars recorded CLS severity percentages ranging from 5.67 to 7.33% during the 2021/2022 season and 8.00 to 14.00% during the 2022/2023 season (Table 2).

Table 2. Disease severity of Cercospora leaf spot disease of ten sugar beet cultivars during two growing seasons 2021/2022 and 2022/2023

Sugar beet cultivars	Disease severity of CLS (%)	
	2021/2022	2022/2023
Clavious	1.33 e	2.00 d
Bts 8953	2.67 de	4.33 d
Bts smart 9830	5.67 bcd	2.33 d
Bts 3740	5.67 bcd	8.00 c
Bts 3880	3.67 cde	4.00 d
Lily	18.00 a	19.33 a
Oscarpoly	17.67 a	19.67 a
Faraida	6.33 bc	14.00 b
Jampol	7.33 b	8.00 c
Ktart	7.31 b	8.2c
LSD 5%	**3.191**	**3.412**

3.2. Root parameters of different sugar beet cultivars infected with *Cercospora beticola* Sacc

Generally, significant differences were observed in the root parameters like root length and root diameter of the tested sugar beet cultivars infected with *Cercospora beticola* Sacc (Table 3). Bts 3880, Lily and Oscarpoly cultivars recorded the highest values for root length (38.00, 37.00, and 34.33 cm respectively) in the first season, 2021/2022 and these cultivars also achieved the highest values for root length in the second season 2022/2023(30.80, 35.41 and 31.73 cm, respectively). Flowed by Bts 3740, Jampol, Ktart, and Faraida sugar beet cultivars were recorded root lengths (30.33, 31.33, 31.33, and 32.33 cm respectively) in the first season, 2021/2022. Furthermore, the same trend was observed in the second season of 2022/2023, Bts 3740, Jampol, Ktart, and Faraida sugar beet cultivars rank second after Bts 3880, Lily and Oscarpoly cultivars (29.05, 30.00, 30.99, and 31.62 cm respectively). On the other hand, Bts 8953, Clavious, and Bts smart 9830 had the lowest root length (20.67 and 21.64 cm), (27.00 and 24.95 cm) and (26.67 and 26.17 cm) respectively, during the two growing seasons 2021/2022 and 2022/2023.

Additionally, significant differences were observed in the root diameters of the studied sugar beet cultivars (Table 3). The Bts 8953, Clavious, and Bts 3880 cultivars exhibited the highest root diameters during the 2021/2022 and 2022/2023 seasons, measuring 31.67 and 28.60 cm, 18.67 and 20.05 cm, and 20.33 and 20.20 cm, respectively. Conversely, the Oscarpoly and Faraida cultivars had the lowest root diameters, measuring 14.33 and 15.30 cm, and 14.33 and 17.80 cm, respectively, over the two growing seasons. The remaining sugar beet cultivars had root diameters ranging between 15.67 and 18.67 cm, and 15.30 and 18.21 cm, respectively, during the 2021/2022 and 2022/2023 growing seasons (Table 3).

Table 3. Root lengths and root diameter of studied sugar beet cultivars infected with *Cercospora beticola* Sacc during two growing seasons

Sugar beet cultivars	Root length		Root diameter	
	2021/2022	**2022/2023**	**2021/2022**	**2022/2023**
Clavious	27.00 d	24.95 d	18.67 bc	20.05 b
Bts 8953	20.67 e	21.64 e	31.67 a	28.60 a
Bts smart 9830	26.67 d	26.17 d	16.33 d	17.60 bc
Bts 3740	30.00 cd	29.05 c	16.67 d	18.21 bc
Bts 3880	38.00 a	30.80 bc	20.33 b	20.20 b
Lily	37.00 a	35.41 a	18.67 bc	16.05 bc
Oscarpoly	34.33 ab	31.73 b	14.33 e	15.30 c
Faraida	32.33 bc	31.62 b	14.33 e	17.80 bc
Jampol	31.33 bc	30.00 bc	15.67 de	17.17 bc
Ktart	31.33 bc	30.99 bc	17.33 cd	16.03 bc
LSD 5%	**4.290**	**2.063**	**1.949**	**4.649**

3.3. Root fresh weight and root yield of studied sugar beet cultivars infected with *Cercospora beticola* Sacc during two growing seasons

The results in Table 4 reveal marked differences in root characteristics among the sugar beet cultivars studied. The Ktart cultivar had the highest fresh root weights, with values of 1.78 kg and 1.64 kg for the 2021/2022 and 2022/2023 growing seasons, respectively. Conversely, the Faraida and Jampol cultivars had the lowest fresh root weights, with Faraida at 1.25 kg and 1.16 kg, and Jampol at 1.29 kg and 1.19 kg for the respective periods. The other cultivars displayed fresh root weights ranging from 1.38 kg to 1.68 kg in the 2021/2022 season and from 1.17 kg to 1.60 kg in the 2022/2023 season (Table 4).

Table 4. Root fresh weight and root yield of studied sugar beet cultivars infected with *Cercospora beticola* Sacc during two growing seasons

Sugar beet cultivars	Root Fresh Weight (kg/root)		Root yield/fed (ton)	
	2021/2022	**2022/2023**	**2021/2022**	**2022/2023**
Clavious	1.56 abc	1.46 bc	25.26 cd	22.15 bc
Bts 8953	1.65 ab	1.55 ab	32.08 a	25.20 a
Bts smart 9830	1.38 bcd	1.34 d	22.97 ef	20.82 cd
Bts 3740	1.46 bcd	1.34 d	25.18 cd	21.21 cd
Bts 3880	1.54 abcd	1.60 a	24.19 de	21.16 cd
Lily	1.68 ab	1.43 cd	26.55 bc	20.05 d
Oscarpoly	1.49 abcd	1.17 e	24.48 de	23.23 b
Faraida	1.25 d	1.16 e	21.57 f	21.90 bc
Jampol	1.29 cd	1.19 e	22.08 f	23.39 b
Ktart	1.78 a	1.64 a	28.39 b	22.80 b
LSD 5%	**3.062**	**0.890**	**1.983**	**1.552**

3.4. Sucrose content of studied sugar beet cultivars infected with *Cercospora beticola* Sacc during two growing seasons

In general, the sucrose content of root-studied sugar beet cultivars was affected by CLS disease (Table 5). However, in the first season (2021/2022), the BTS 8953, Faraida, and Clavious cultivars exhibited the highest sucrose content, with 14.57%, 14.47%, and 14.43%, respectively. These values did not show significant differences among them. They were followed by the Jampol, Bts 3740, and Ktart cultivars, which had sucrose contents of 14.27%, 14.00%, and 13.77%, respectively. The Lily cultivar recorded the lowest sucrose content at 12.97% (Table 5). Similarly, during the second season (2022/2023), BTS 8953 again achieved the highest sucrose content among the tested cultivars, with a value of 14.51%. The lowest sucrose content in this season was also found in the Lily cultivar, which had a sucrose content of 12.15% (Table 5).

Table 5. Sucrose content of studied sugar beet cultivars infected with *Cercospora beticola* Sacc during two growing seasons

Sugar beet cultivars	Sucrose %	
	2021/2022	**2022/2023**
Clavious	14.43 a	14.51 a
Bts 8953	14.57 a	13.77 bc
Bts smart 9830	13.57 d	12.79 f
Bts 3740	14.00 bc	13.50 cde
Bts 3880	13.23 e	13.11 ef
Lily	12.97 e	12.15 g
Oscarpoly	13.97 bc	13.24 de
Faraida	14.47 a	14.17 ab
Jampol	14.27 ab	13.69 c
Ktart	13.77 cd	13.55 cd
LSD 5%	**0.311**	**0.435**

4. Discussion

Cercospora leaf spot disease (CLS), caused by the fungus *Cercospora beticola* Sacc., is a major foliar disease threatening global sugar beet production. Without effective control, it can lead to significant economic losses (Tan *et al.*, 2023). Generally, plant diseases are managed with chemical fungicides, but their overuse can result in the emergence of resistant pathogen strains (Deresa and Diriba, 2023).

Consequently, strategies for controlling CLS disease in sugar beet should incorporate alternative methods to mitigate the adverse effects of chemical fungicides. One such method is planting resistant cultivars, it is considered one of the most effective approaches for controlling many plant diseases, including CLS (Mahapatra *et al.*, 2023). In the current study, ten sugar beet cultivars were chosen to evaluate their resistance to CLS disease under Egyptian conditions.

Our results showed that Clavious, BTS 8953, BTS 3880, and BTS Smart 9830 recorded the lowest disease severity (% DS) compared with other cultivars. However, the Lily and Oscarpoly cultivars exhibited the highest values of CLS disease severity.

These findings are consistent with previous research, which also identified significant variations in the resistance of sugar beet cultivars to CLS. The earlier study utilized disease index metrics to classify cultivars as either resistant or susceptible (Rangel *et al*., 2020). Cultivars with low disease severity were identified as potentially resistant, while those with high disease severity were considered susceptible. However, further research should focus on understanding the genetic and physiological mechanisms underlying resistance to CLS. Such insights could significantly enhance breeding programs aimed at developing sugar beet cultivars with improved disease resistance. By integrating these resistant traits, it is possible to achieve more robust and resilient sugar beet crops, ultimately contributing to sustainable agricultural practices and food security.

Additionally, this study observed an increase in the severity of CLS in sugar beet cultivars during the second season compared to the first. This escalation may be attributed to variations in environmental conditions and climate changes experienced in the second season, resulting in greater disease severity. In another study, (Kaiser *et al.*, 2010) observed these differences between studied cultivars, accordingly, they suggested that the susceptible cultivars were different from resistant cultivars in the highest values of disease severity % and the greater infection area sizes based on the disease progress curve (AUDPC). Overall, sugar beet cultivars with low disease severity may be resistant to CLS, as they showed fewer spots and the diameter of the spots was smaller than their counterparts in other cultivars with high disease severity, which can be classified as susceptible to the disease (Joudi *et al.*, 2019).

Moreover, the current results showed significant differences in root measurements such as root length, diameter root fresh weight, and sugar yield. Low disease severity cultivars had longer roots and larger diameters than high disease severity cultivars which means that the disease had a significant negative effect on the mentioned root measurements, probably due to the direct effect of disease on the leaves (it is a major foliar disease). These findings are consistent with those of (Emam *et al.*, 2022) who observed that sugar beet cultivars with the least disease severity possess longer roots, greater biomass in both foliage and root (based on fresh and dry weight), and higher percentages of Total Soluble Solids (TSS) and sucrose.

Additionally, the fresh weight and yield of roots have significantly increased in certain cultivars such as Ktart, Clavious, BTS 8953, and BTS Smart 9830; however, a notable decrease has been observed in others, this might be the high level of CLS disease severity. The presence of spots on the plant leaves reduces the efficiency of photosynthesis and hence reduces food storage in the roots of sugar beet plants. In addition, disease resistance in sugar beet plants reduces damage to root yield and sugar content by slowing disease progression throughout the growing season. Thus, in severe cases, the impact of CLS on resistant cultivars is less severe than on susceptible cultivars, as observed by (Chamara *et al.*, 2022).

Thus, the present study suggests that the increase in root weight and yield was due to disease resistance of some cultivars and a significant reduction in disease severity. Recent studies have resulted in the creation of new generations of disease-resistant sugar beet cultivars. These cultivars have shown no decrease in yield when not affected by disease and have performed better than susceptible cultivars (Gummert *et al.*, 2015), stating that resistance to CLS in sugar beet can be attained by combining classical and molecular breeding methods. Cercospora leaf spot fungus causes significant reductions in photosynthesis and, consequently, root yield, leading to real economic losses (Knight *et al.*, 2019).

It should be noted that the sucrose content varied among the tested cultivars; some exhibited high sucrose levels while others showed low levels, which could be attributed to the varying degrees of disease infection. During the growth phase, sugar beet plants that are susceptible to disease exhibit reduced root yield, sugar content, and extractable sugar. Additionally, high levels of potassium (K), sodium (Na), and α-amino nitrogen (α-amino N) complicate the extraction of crystalline sugar, leading to decreased sugar production during refinement. Generally, the sugar content in sugar beet roots correlates with the plant's resistance to *C. beticola* (Rangel *et al.*, 2020).

5. Conclusions

Sugar beet (*Beta vulgaris* subsp. *vulgaris*) is a crucial strategic crop in Egypt and globally, significantly contributing to sugar production. However, it is highly susceptible to Cercospora leaf spot (CLS), a severe foliar disease that can lead to substantial economic losses by significantly reducing sugar yield. Cultivating CLS-resistant sugar beet cultivars is an essential and effective strategy for managing this disease. This approach mitigates the impact of CLS and reduces the reliance on chemical fungicides, thereby minimizing environmental and health hazards. Through selective breeding for resistance, the agricultural sector can achieve more sustainable and economically viable sugar beet production. In summary, the strategic selection and cultivation of CLS-resistant sugar beet cultivars represent a sustainable and economically prudent approach to disease management. This ensures the protection of sugar yield and quality while promoting environmental sustainability and public health by reducing the need for chemical fungicides.

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