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Research Article

Reaction of commercial sugar‑beet cultivars to beet curly top Iran virus (BCTIV)

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Abstract: Beet curly top Iran virus (BCTIV; family *Geminiviridae*, genus *Becurtovirus*, species *Becurtovirus betae*) is a widespread pathogen that reduces sugar beet yields in the Mediterranean and Middle East regions. This study aimed to investigate the reaction of seven commercial sugar beet cultivars to BCTIV to identify natural resistance to the virus. The cultivars were inoculated and maintained under greenhouse conditions. Virus accumulation was quantified at 56 days post-inoculation (dpi) through quantitative polymerase chain reaction (qPCR). The results showed that virus accumulation in Aria and Arta cultivars was lower than in other cultivars. On the other hand, Jolgeh, as a susceptible cultivar, exhibited the highest virus accumulation, which coincided with the most severe symptoms. When Jolgeh was inoculated with the virus, it exhibited the lowest greenness, photosynthesis, chlorophyll a and b, carotenoids, catalase, peroxidase, polyphenol oxidase, and proline compared to non-inoculated plants. Conversely, the Aria and Arta cultivars showed a smaller decline in the traits mentioned when inoculated with the virus. Collectively, the results of biochemical, physiological, and molecular assays revealed that the Aria and Arta cultivars were resistant to BCTIV infection. Since the virus has been reported in most sugar beet-growing areas in Iran, the Aria and Arta cultivars are recommended for cultivation in these regions.

Keywords: *Becurtovirus betae*, Biochemical, Geminiviruses, Physiological traits

Introduction

Sugar beet, *Beta vulgaris* subsp. *Vulgaris*, is a biennial, diploid plant from the family Chenopodiaceae that plays a significant role in the economy, and faces threats from pests and diseases. In Iran, the primary diseases affecting sugar beet include beet curly top disease, rhizomania, beet weariness caused by beet cyst nematode, and root rots (Harveson *et al*., 2009). Beet curly top virus (BCTV) was first reported in the late 19th century in the western United States (Bennett, 1971) and can infect more than 300 plant species, including crops, ornamentals, and weeds, from at least 44 plant families. The use of resistant cultivars, along with insecticide treatments, greatly reduces the incidence of beet curly top disease (Bennett, 1971; Velasquez-Valle *et al*., 2012). Nevertheless, infection of resistant sugar beet cultivars has been reported at

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early stages, increasing the incidence of this disease and causing heavy yield losses in recent years (Yıldırım *et al*., 2023).

Beet curly top Iran virus (BCTIV), also known as *Becurtovirus betae*, a species in the *Becurtovirus* genus of the family *Geminiviridae*, has been identified in Iran. It has been detected not only on sugar beet, but also on turnips, tomatoes, spinach, and various types of grass (Heydarnejad *et al*., 2007; Yazdi *et al*., 2008; Varsani *et al*., 2014). Recently, BCTIV has also been reported in Turkey (Yıldırım *et al*., 2022). BCTIV is naturally transmitted by the leafhopper *Circulifer haematoceps*, the dominant leafhopper species found in sugar beet fields in Iran, in a persistent-circulative manner (Taheri *et al*., 2012).

One effective way to manage this disease is to use resistant cultivars, and several studies have identified sources of resistance to BCTV. In one study, 29 commercial sugar beet hybrids were screened for resistance to the BCTV in a naturally infected field in Canyon County, and none were found to be resistant (Camp *et al*., 2005). In another study, based on visual rating, among 30 tested lines, 26 performed similarly to the resistant checks (Strausbaugh and Fenwick, 2019). Montazeri *et al.* (2016) screened 50 sugar beet lines for resistance to beet curly top virus (BCTIV, BCTV-C), and five of them were resistant to both viruses. In another study, five of 18 sugar beet cultivars were identified as tolerant, and no resistant cultivar was found against severe beet curly top virus (Fatahi *et al*., 2012). Under greenhouse conditions using infectious clones, 38 sugar beet genotypes were assessed for their susceptibility to either BCTV-Svr or BCTIV separately. As a result, ten and seven genotypes were found to be resistant to BCTV-Svr and BCTIV, respectively. Consequently, in a field experiment under natural virus infection, six genotypes were found to be resistant to BCTV-Svr and BCTIV (Saadati *et al*., 2021). Considering the broad host range and presence of BCTIV vector in most sugar beet cultivation areas of Iran, this study aimed to identify commercial cultivars resistant to BCTIV, and hypothesized that specific commercial cultivars exhibit biochemical traits associated with BCTIV resistance.

Materials and Methods

Plant growth and experimental conditions

Seven cultivars of sugar beet *Beta vulgaris* L., namely Arya, Arta, Sanetta, Bifort, Hadiya, S1_920833, and Jolgeh, were obtained from the Sugar Beet Seed Institute, Karaj, Iran. The plants were grown in an insect-free greenhouse at 25±2 °C with a 16 h of light and eight h of darkness photoperiod. All experiments were conducted in a completely randomized factorial design with two factors *i.e.* cultivars and virus inoculation, using 31 replicates. The experiment was repeated twice independently. Treatments were as follows: uninoculated control plants; inoculated plants with *Agrobacterium tumefaciens* strain LBA4404 harboring a plasmid without a virus fragment as a control; and those inoculated with the infectious clone of virus (V). The latter two were considered for all experiments.

Virus inoculation

The agroinoculation of plants was performed using the infectious clone of BCTIV [IR:Neg: B33P:-Sug:08], with the GenBank accession number JQ707949 (Heydarnejad *et al*., 2013), provided by Dr. J. Heydarnejad from Shahid Bahonar University of Kerman, Iran. Agro-inoculation was carried out using *Agrobacterium tumefaciens* strain LBA4404 harboring infectious clones of BCTIV. To perform this, it was grown in a liquid LB medium containing the antibiotics Kanamycin (50 µg/ml) and Rifampicin (50 µg/ml). Then it was kept on a shaker at 180 rpm until the OD_{600} reached 0.2-0.6 (Grimsley *et al*. 1986). Cells were precipitated by centrifugation at 6000 rpm for 10 minutes and then resuspended in sterile distilled water containing acetosyringone (50 mM). Agro-inoculation was performed by infiltrating leaves at the four-to-six leaf stage, around 40 days after sowing (Sedano *et al*., 2012). The symptoms were assessed using the method described before (Montazeri *et al*., 2016).

Quantitative PCR analysis (qPCR)

At 56 dpi, DNA was extracted from plant leaf tissue using the CTAB method (Doyle and Doyle, 1987). To evaluate virus accumulation in inoculated plants, specific primers targeting a 127 bp segment of the BCTIV were used in quantitative polymerase chain reaction (qPCR). The qPCR mixture (10 µl) contained the following components: 5 µl RealQ SYBR Green PCR master mix (Amplicon, Denmark), 2 µl distilled water, 1 µl of each primer (10 pmol/µL), and 1 µl (50 ng/µl) of DNA template, and the reactions were performed on an ABI StepOne Real-Time PCR System (USA), with four biological replicates, each having two technical replicates. The negative control contained all components used in the PCR reaction, except that the DNA template was replaced with distilled water. The qPCR data were analyzed using the relative quantification method, with SSU rDNA of *B. vulgaris* as the reference gene (Table 1). The results were analyzed using the $2^{-\Delta\Delta CT}$ method (Livak and Schmittgen, 2001).

Fresh and dry weight measurements

At sixty dpi of BCTIV, the aerial parts of the plants were cut off to measure the fresh weight. The plants were subsequently placed in paper envelopes and dried in an oven at 105 °C for two days, and their dry weights were measured.

Phytochemical measurement

Proline content was measured at 35 dpi (5 weeks after inoculation) as described by Carillo and Gibon (2011) and Astaraki and Shams-Bakhsh (2023) using a microplate reader (Epoch BioTek, USA), and the following formula was used to calculate proline.

$$proline = (X/0.0049) \times (2000/200) \times (1/50)$$
$$X = (sample - blank)$$

Flavonoid content was assessed at 35 dpi according to the method described by Chang *et al.* (2002). Polyphenol oxidase (PPO), peroxidase (POX) (Siguemoto and Gut, 2017), and catalase (CAT) activities (Maehly and Chance, 1954) were estimated at 420, 470, and 240 nm, respectively, using a microplate reader (Epoch BioTek, USA). For each sample, 100 mg of leaf plant tissue was used to assess enzyme activity. All the measurements were performed in five biological replicates and three technical replicates.

Physiological parameters

The chlorophyll content of the leaves, indicative of greenness, was quantified using a SPAD device following calibration. For measuring photosynthesis, the Li-Cor instrument (Li-3000, USA) was utilized. The chlorophyll a, chlorophyll b, and carotenoid contents were estimated at 35 dpi Astaraki *et al.* (2020) using the methods of Warren (2008), at 665 nm, 652 nm, and 470 nm, respectively, using a microplate reader (Epoch BioTek, USA). The following formula was used to calculate the chlorophyll a, chlorophyll b, and carotenoid contents.

$A_{652,} = (A_{652} - \text{blank})$

$A_{665,} = (A_{665} - \text{blank})$

$A_{470} = (A_{470} - \text{blank})$

Chl a (µg/mL) = $16.72\ A_{665} - 9.16\ A_{652}$

Chl b (µg/mL) = $34.09\ A_{652} - 15.28\ A_{665}$

Carotenoid = $(1000\ A_{470} - 1.63\ \text{Chla} - 104.96\ \text{Chlb})/221$

Statistical analysis

All statistical analyses were conducted using SAS 9.2 (SAS Institute Inc., Cary, NC). Analysis of variance (ANOVA) was performed using the GLM procedure, and tests of residual normality were conducted with the UNIVARIATE procedure. Categorical and ordinal data underwent rank transformation (e.g., the severity of virus symptoms). They were analyzed using the nonparametric methods developed by Shah and Madden (2004) via the GLM procedure in SAS. Means were differentiated via the least significant difference (LSD) test at a significance level of $P \leq 0.05$. Analysis of the combined experiments was carried out using Minitab (Minitab 18.1).

Results

Symptom severity assessment

Symptoms were scored at 56 dpi, and among the seven examined cultivars, mild symptoms, including bright veins and slight vein swelling and crumpling, were observed on Aria, and Arta cultivars, while severe symptoms, including severe stunting, vein swelling, and crumpling of most leaves, severe leaf curling were observed on Hadiya and Jolgeh cultivars (Figs. 1 and 2). Results showed that the incubation period, from inoculation to symptom appearance, ranged from 13 to 29 days depending on the cultivar (Fig. 3), and a correlation was observed between the incubation period and symptom severity at 56 dpi.

Table 1 Primers used to quantify beet curly top Iran virus accumulation using qPCR.

Primer name and function	Forward (5′-3′)	Reverse (5′-3′)	Product size	Reference
DNA-BCTIV- (target)	CGCATCCCTCCTAATCCGAT	TGGCTAGTGGTGCATTTTGG	127bp	This study
SSU rDNA *B. v ulgaris* (reference)	CGTTCTTAGTTGGTGGAGCG	AAGATTACCCGGACCTGTCG	245bp	This study

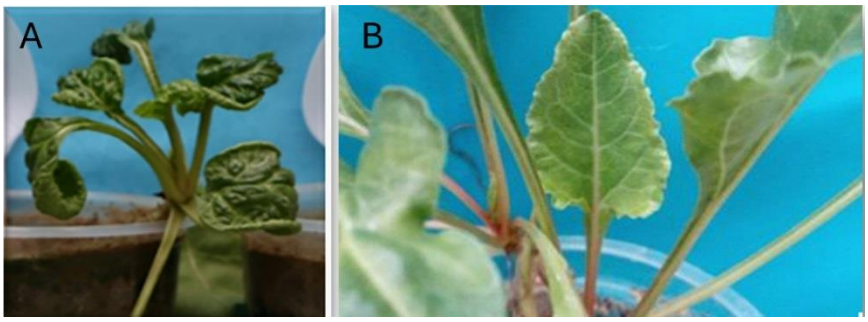

Figure 1 Symptoms of beet curly top Iran virus on leaves of susceptible and resistant cultivars of sugar beet to beet curly top Iran virus. A: cultivar Jolgeh as susceptible cultivar with clear symptoms of severe curling, B: Cultivar Arya as resistant cultivar with no visible symptoms.

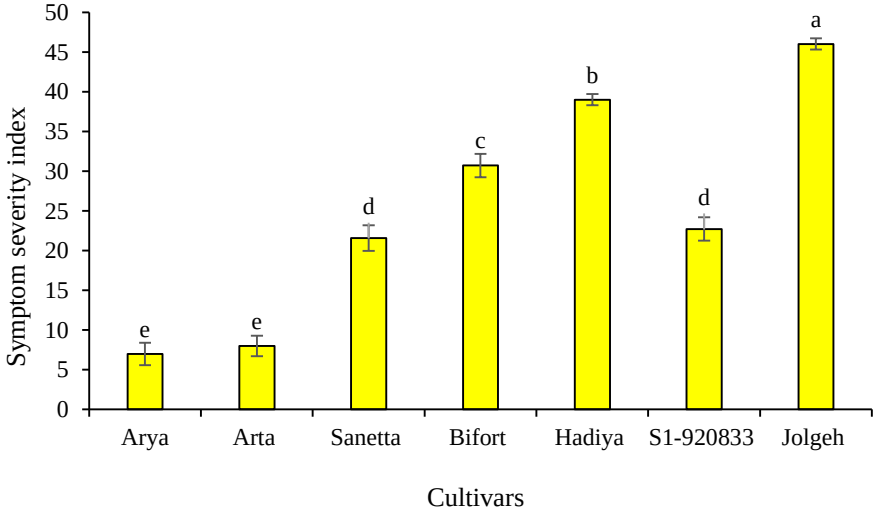

Figure 2 Comparison of the symptom severity index of seven sugar beet cultivars inoculated with the beet curly top Iran virus 56 days post-inoculation under greenhouse conditions. The graph is based on the average of 31 replicates. Error bars indicate standard error (SE). Different letters represent significant differences (LSD test, $P < 0.05$).

Photosynthesis pigments, greenness, and photosynthesis

The data shown in Fig. 4 indicate that the levels of chlorophyll a, b, total chlorophyll, carotenoid, chlorophyll index, and photosynthesis in cultivars Arya and Arta were not significantly decreased except for total chlorophyll, chlorophyll index, and photosynthesis level in Arta upon inoculation with BCTIV. In cultivar Jolgeh, as the susceptible cultivar, all the mentioned parameters were significantly decreased. In other cultivars, including Sanetta, Bifort, Hadiya, and S1_920833, all parameters were significantly reduced upon inoculation with BCTIV, as observed in the susceptible cultivar Jolgeh.

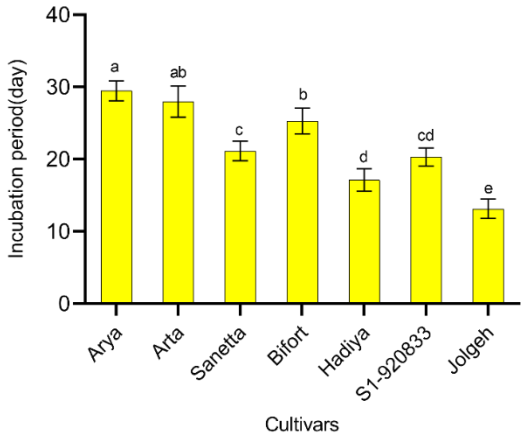

Figure 3 Incubation period in seven sugar beet cultivars inoculated with the beet curly top Iran virus under greenhouse conditions. The graph is based on the average of 31 replicates. Error bars indicate standard error (SE). Different letters represent significant differences (LSD test, $P < 0.05$).

Enzyme activity measurements

To investigate the defense responses of different cultivars after virus inoculation, biochemical assays for photosynthetic pigments, greenness, and photosynthesis were performed at 35 dpi. A notable decrease in POX, PPO, and CAT was observed in the Jolgeh cultivar for all three enzymes. Conversely, the resistant cultivars, Arta and Arya, exhibited a general trend toward increased accumulation of the abovementioned defense-related enzymes following infection by BCTIV. The rest of the cultivars either showed suppression of defense-related enzymes or remained unaffected after virus inoculation (Fig. 5A). The cultivars Arya and Arta showed significantly higher proline and flavonoid contents than their control samples (Fig. 5B and 5C).

Growth parameters

Growth parameters, including total fresh and dry weights of shoots and roots, were evaluated. The Jolgeh cultivar exhibited the greatest reductions in both fresh and dry weight compared to the other cultivars (Fig. 6).

Replication of BCTIV

Accumulation of BCTIV in different cultivars

The results obtained from the qPCR showed a significant difference in BCTIV accumulation among the cultivars (Fig. 7). The titer of BCTIV DNA was highest in the Jolgeh cultivar, and lowest in the Arya and Arta cultivars. No significant difference was observed between the Arya and Arta cultivars in accumulation of virus. The four other cultivars, however, showed different levels of virus accumulation, where Hadiya exhibited the highest accumulation compared to Sanneta, Bifort, and S1_920833.

Discussion

Among all approaches to managing plant disease, the use of resistant cultivars, particularly for viral diseases, is of great importance. Most other methods, particularly the commonly used chemical treatments, are ineffective against viruses except in cases where viral control is achieved indirectly by targeting insect vectors. The initial step in applying resistant cultivars is identifying the source of resistance. In this study, seven sugar beet cultivars were screened for resistance against BCTIV, and the underlying biochemical mechanisms were investigated. The morphological observations revealed that Arya and Arta exhibited fewer symptoms of virus infection. In contrast, the remaining cultivars, particularly Jolgeh, showed bright veins, minor vein swelling, and crumpling symptoms. In line with morphological observations, measurements of virus accumulation

in the examined cultivars showed that Arta and Arya had lower virus accumulation than the others, indicating lower susceptibility to infection. In BCTIV-inoculated plants of the cultivars Arta and Arya, symptoms such as leaf curling, vein swelling, and reduced plant growth developed more slowly, with severe symptoms persisting for up to two months post-inoculation, as observed in previous studies (Soleimani *et al*., 2013; Jahanbin *et al*., 2015; Saadati *et al*., 2021).

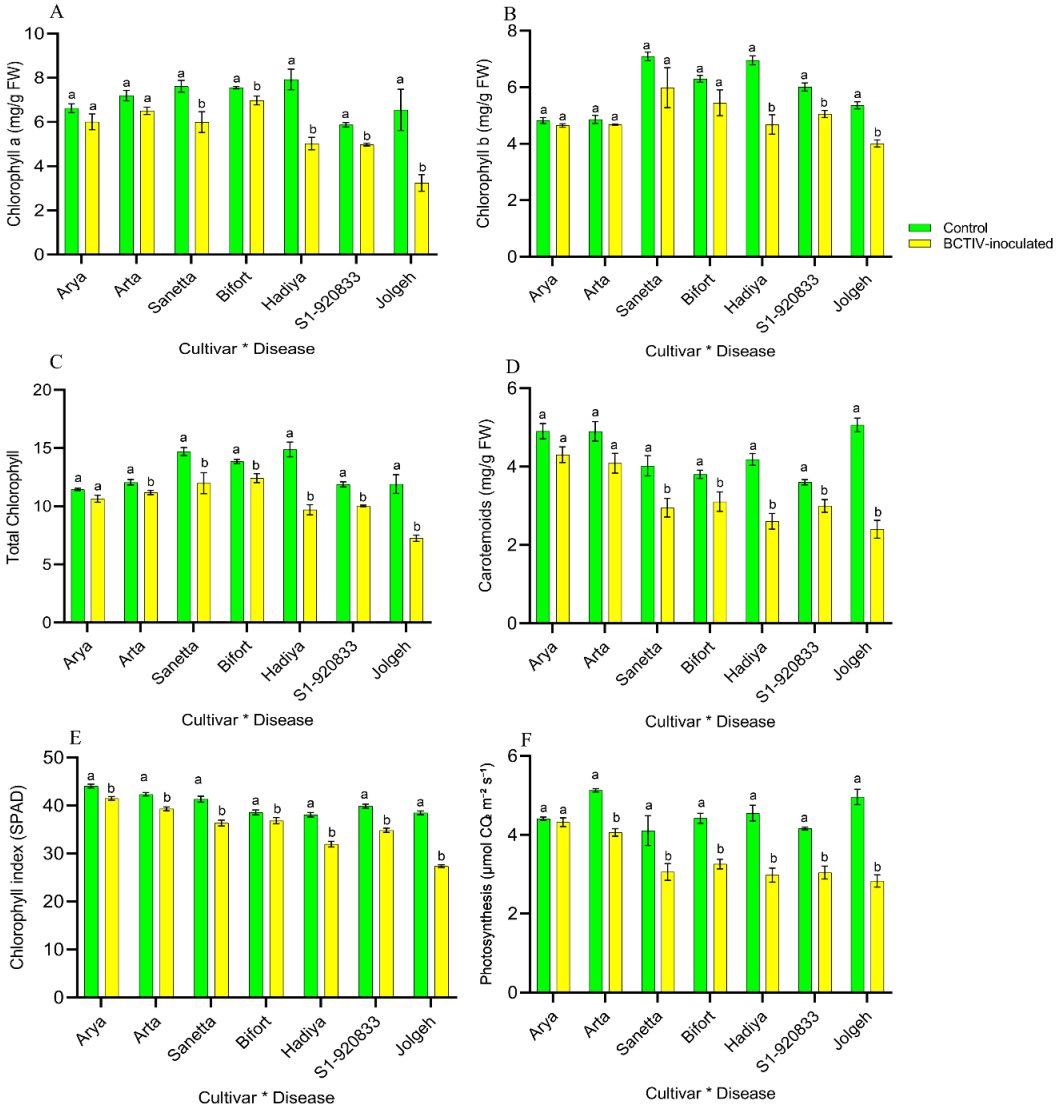

Figure 4 Chlorophyll a, b, total chlorophyll, carotenoid, chlorophyll index, and photosynthesis level in seven sugar beet cultivars in plants inoculated with the beet curly top Iran virus under greenhouse conditions in comparison with their respective non-inoculated control plants. Plants were inoculated with *A. tumefaciens* harboring a plasmid with a virus fragment as virus-inoculated plants and without a virus fragment as control plants. Plants were harvested at 35 dpi. (A), chlorophyll a, (B), chlorophyll b content, (C), total chlorophyll, (D), Carotenoids, (E), Chlorophyll index, and (F), photosynthesis level. The graphs are based on the average of three biological replicates, each consisting of a pool of three plants. Error bars indicate standard error (SE). Different letters represent significant differences (LSD test, $P < 0.05$).

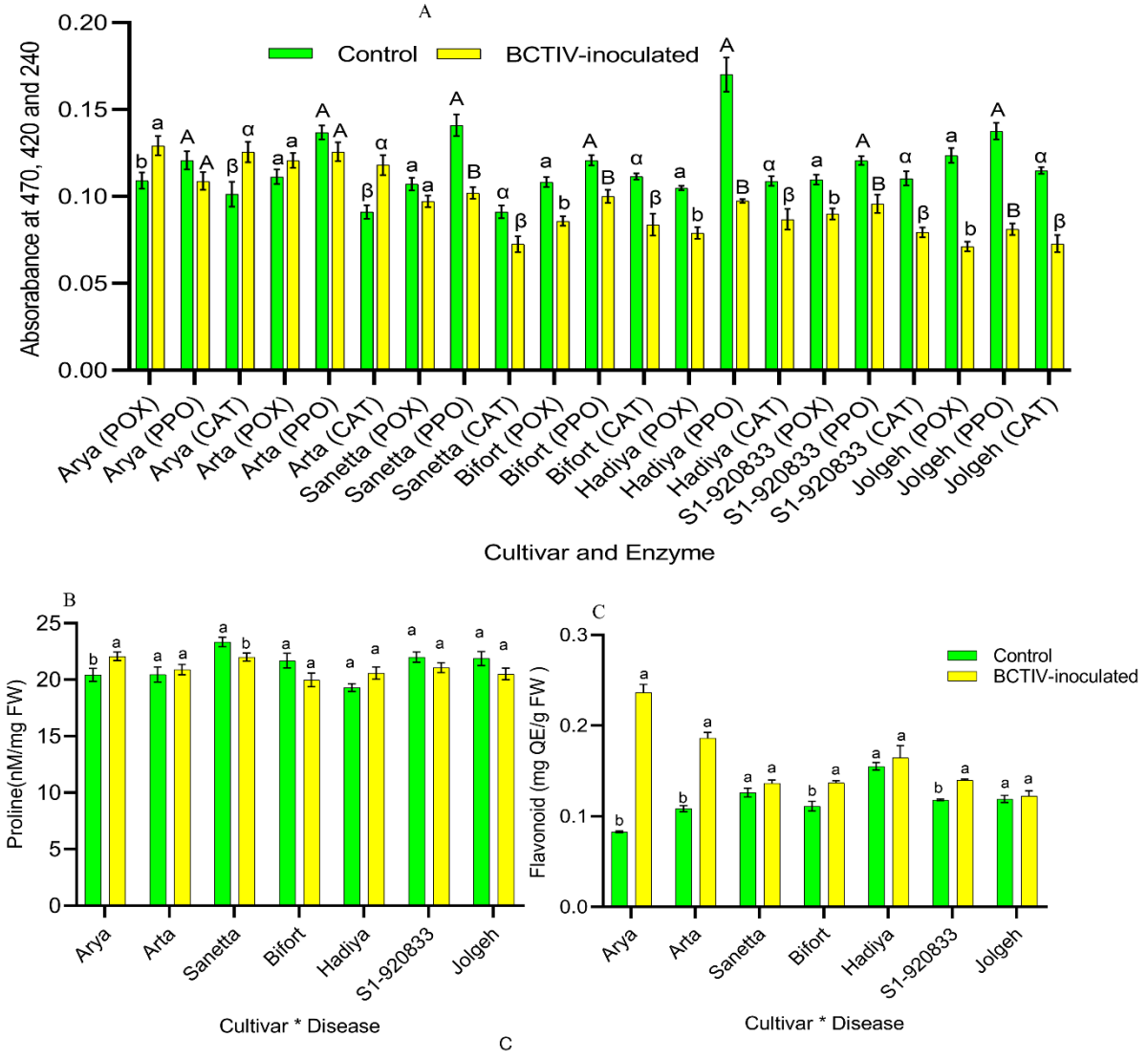

Figure 5 Defense-related enzymes, including peroxidase (POX), polyphenol oxidase (PPO) and catalase (CAT) levels as well as proline and flavonoids in seven sugar beet cultivars in plants inoculated with the beet curly top Iran virus under greenhouse conditions in comparison with their respective non-inoculated control plants. Plants were inoculated with *Agrobacterium tumefaciens* harboring a plasmid without a virus fragment as a control and with a virus fragment in inoculated plants, plants were harvested at 35 dpi. (A), POX, PPO and CAT levels (B), proline level (C), flavonoids. The graphs are based on the average of three biological replicates, each consisting of a pool of 3 plants. Error bars indicate standard error (SE). Different letters represent significant differences (LSD test, $P < 0.05$).

The extent of virus accumulation in plant tissue is a critical factor in assessing plant resistance. Lower virus build-up in plant tissues signifies greater resistance, while higher accumulation indicates increased susceptibility. The findings of present study are consistent with the results of previous studies (Lapidot, 2002; Fatahi *et al*., 2012; Majidi *et al*., 2017; Saadati *et al*., 2021). The qPCR results aligned with symptom severity outcomes, indicating that

cultivars with more severe symptoms exhibited greater viral accumulation than those with mild symptoms (Mehetre *et al*., 2021). Other methods yielded the same results, with a direct, positive correlation between symptom severity and ELISA uptake rate at each rank (Montazeri *et al*., 2016). In the current study, viral infections in plants resulted in significant alterations in photosynthesis and photosynthetic pigments across infected cultivars. The Jolgeh cultivar exhibited the most substantial decrease in photosynthesis and photosynthetic pigments, correlating with a relatively high symptom severity. In contrast, the Aria and Arta cultivars experienced a much lower rate of reduction in photosynthesis and photosynthetic pigments. This feature has been reported in the responses of other host plants to this virus or other plant viruses too. For instance, in common bean, pepper, and sugar beet plants infected with BCTIV and BCTV-Svr, a decrease in the photosynthesis rate and the content of chlorophyll a and b has been observed (Astaraki *et al*., 2020). Susceptible bean cultivars exhibited significant decreases in photosynthetic pigments following pathogen infection, resulting in impaired photosynthesis (Lobato *et al*., 2010).

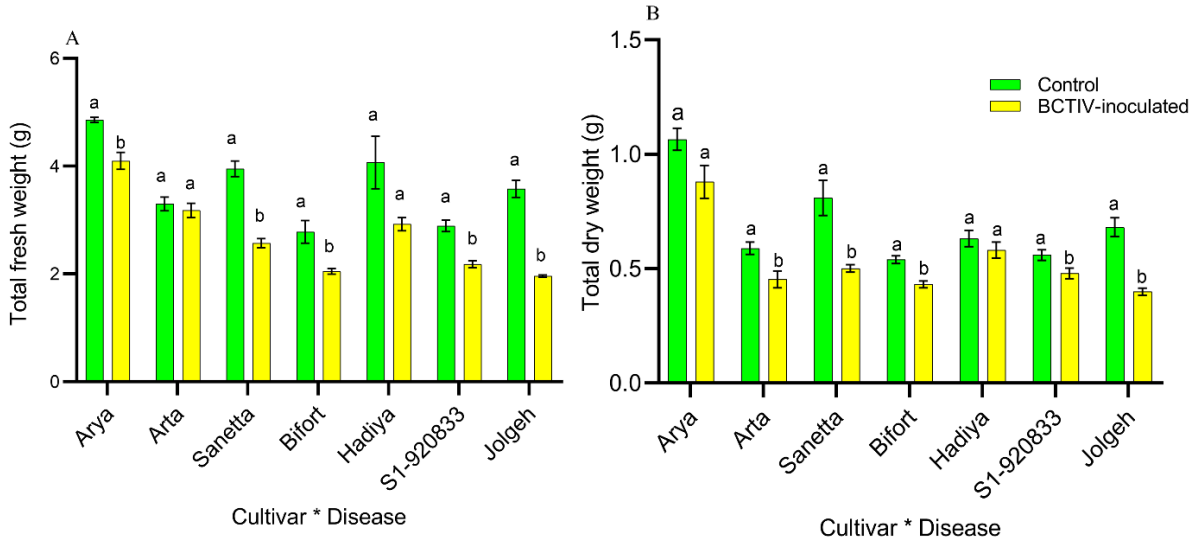

Figure 6 Growth parameters including total fresh and dry weight of shoots and roots of seven sugar beet cultivars in plants inoculated with the beet curly top Iran virus under greenhouse conditions in comparison with their respective non-inoculated control plants. Plants were inoculated with *Agrobacterium tumefaciens* harboring a plasmid without a virus fragment as a control and with a virus fragment in inoculated plants. Plants were harvested at 60 dpi. (A), total fresh weight of shoots, (B), total dry weight of shoots. The graphs are based on the average of 31 plants. Error bars indicate standard error (SE). Different letters represent significant differences (LSD test, $P < 0.05$).

Moreover, various studies have shown that viral infection damages chloroplast structure, decreases the number of chloroplasts per cell, and increases the activity of enzymes involved in chlorophyll breakdown, leading to reduced chlorophyll levels and photosynthesis rates (Zhang *et al*., 2014; Wang *et al*., 2020). When two sugar beet lines—one susceptible (Z-10) and one resistant (9BB6090)—were inoculated with two isolates (CHF and Logan) of BCTV, the rate of photosynthesis decreased in both lines, with the susceptible line experiencing a greater reduction than the resistant line. Similarly, chlorophyll content was affected by viral disease, with a greater reduction observed in the susceptible line (Swiech *et al*., 2001). During the infection period, a decrease in photosynthetic pigments was also reported in rice cultivars infected with rice tungro virus. In this study, photosynthetic pigments in resistant lines were

5.8%, while in susceptible lines they were 82.5% compared to their respective controls (Patel *et al*., 2018). This decrease is a strategy employed by resistant plants to enhance their ability to mitigate damage caused by infection. Resistant genotypes have a more effective protective system against pigment damage caused by the infection (Chen *et al*., 2015; Cheaib and Killiny, 2025).

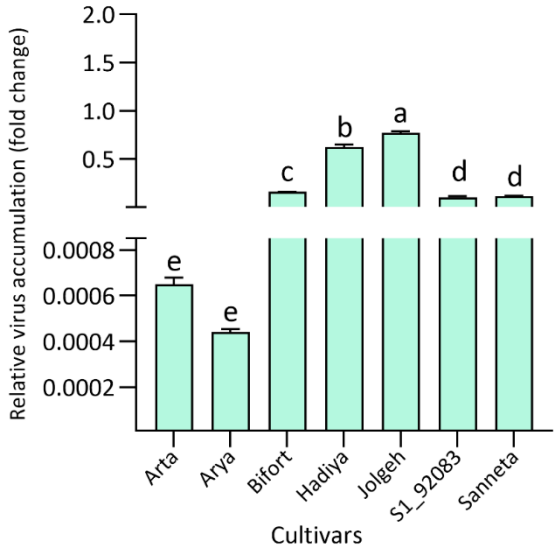

Figure 7 Assessment of relative virus accumulation in different cultivars upon inoculation with BCTIV using qPCR at 56 dpi. The data represent the average of four biological replicates, each with two technical replicates. Relative expression was calculated using the $2^{-\Delta\Delta CT}$ method and statistically analysed using the LSD test at the 5% significance level. Different letters denote statistical differences.

In this study, proline levels were significantly increased in the resistant cultivar Arya, remained unaffected in other cultivars, and decreased in Sanetta. These findings are in line with previous studies, as proline has been shown to have a higher content in resistant cultivars (Saadati *et al*., 2022; Astaraki *et al*., 2023). Proline is a crucial component of plant defense mechanisms, functioning as a vital osmolyte and a potent non-enzymatic antioxidant (Ahmed *et al*., 2017). It helps maintain cellular integrity by balancing osmotic pressure under stressful conditions (Dar *et al*., 2016). Numerous studies have documented an increase in proline content in host-pathogen interactions, and the increase observed here following viral inoculation aligns with these findings (Gupta *et al*., 2020; Mahfouze *et al*., 2020; Sofy *et al*., 2020; Singh *et al*., 2021; Soni *et al*., 2022). In the case of flavonoids, the resistant cultivars Arya and Arta showed accumulation upon BCTIV infection, while other cultivars remained unaffected. Flavonoids primarily act as antioxidants, preventing viral attachment and entry into cells while bolstering cellular defense mechanisms (Friedman, 2007; Zakaryan *et al*., 2017). In watermelon, flavonoids were found to be significantly increased in resistant cultivars against cucumber green mottle mosaic virus (CGMMV), indicating their role in enhancing resistance through metabolic pathways (Liu *et al*., 2023).

Except for Aria and Arta, all cultivars experienced a decrease in total fresh and dry weights in BCTIV-inoculated plants compared to non-inoculated control plants. Pathogens impair plant growth by diverting resources from growth to defense mechanisms (Lee *et al*., 2016). Resistant onion plants exhibited less symptom appearance and growth defects comparing susceptible cultivars upon onion yellow dwarf virus infection (Corrado *et al*., 2024).

Upon pathogen attack, reactive oxygen species (ROS) are generated to activate defense signaling pathways and directly kill pathogens through toxic effects. To maintain ROS balance, plants have developed antioxidant systems that mitigate excess ROS accumulation through enzymatic and non-enzymatic reactions (Mittler, 2002). Peroxidase, one of the first enzymes to respond to plant pathogens (Sulman *et al*., 2001), plays a crucial role in lignin and suberin biosynthesis. Pathogen infections induce peroxidase activity in plant tissues, with greater increases observed in resistant plants than in susceptible ones (Retig, 1974). In wheat cultivars infected by *Pyricularia oryzae*, higher antioxidant enzyme activities, such as catalase and peroxidase, have been observed in resistant plants compared to susceptible ones (Debona *et*

al., 2012). Consistent with previous studies, the resistant cultivars Arta and Aria exhibited higher antioxidant activity than susceptible cultivars. The ability of plants to resist pathogens depends significantly on increased accumulation and activity of defense-related enzymes. Research has shown that oxidative enzymes, such as PPO and POX, play a crucial role in enhancing plant disease resistance (Srivastava, 1987). PPOs catalyze the oxygen-dependent oxidation of phenols to quinones, which act as antibiotics and toxic agents against pathogens (Dahlem Junior *et al*., 2022). Quinones also participate in signal transduction by activating leucine-rich repeat receptor-like kinases (Laohavisit *et al*., 2020). In this study, resistant cultivars exhibited elevated PPO activity upon viral infection. The increase in defense enzyme activity observed in this study aligns with previous findings (Madhusudhan *et al*., 2009; Papaiah and Narasimha, 2014; Siddique *et al*., 2014; Soni *et al*., 2022; Mafakheri *et al*., 2024). The activity of POX, PPO, and phenylalanine ammonia-lyase enzymes increased in bean plants infected by the tomato leaf curl Palampur virus (Astaraki *et al*., 2023). Similarly, the activity of POX and PPO enzymes increased in sugar beet plants treated with fungal and bacterial antagonists against the beet curly top virus‑Sever (Mafakheri *et al*., 2024). Additionally, an examination of chemical changes in susceptible and resistant mung bean cultivars infected with mung yellow mosaic virus revealed a significant increase in PPO activity in resistant cultivars, whereas a decrease was observed in susceptible cultivars (Madhumitha *et al*., 2020).

Conclusion

In conclusion, the present study highlights the use of the resistant varieties Aria and Arta for controlling BCTIV in sugar beet cultivation. They remained resistant, with decreased viral accumulation, reduced symptom expression, and preserved photosynthetic capacity, all of which contribute to increased plant vigor and yield. In addition, they exhibited enhanced biochemical defense responses, including increased proline and flavonoid contents, as well as increased antioxidant enzyme activities as the underlying mechanism of resistance. They are advised to be tested for natural infection under field conditions before cultivation in most areas where BCTIV infection has been reported. Resistance resources are crucial in breeding programs. Therefore, the resistant sugar beet cultivars mentioned in this study have potential for use in sustainable disease management programs.

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واکنش ارقام تجاری چغندرقند به ویروس پیچیدگی برگ چغندر (BCTIV)

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چکیده: ویروس ایرانی پیچیدگی برگ چغندرقند (BCTIV) خانواده *Geminiviridae*، جنس *Becurtovirus*، گونه *Becurtovirus betae* بیمارگری است که عملکرد چغندرقند را در مناطق مدیترانه و خاورمیانه کاهش می‌دهد. این مطالعه با هدف بررسی واکنش هفت رقم تجاری چغندرقند به BCTIV برای شناسایی مقاومت طبیعی در برابر ویروس انجام شد. ارقام مایه‌زنی شده در شرایط گلخانه نگه‌داری شدند. تجمع ویروس در ۵۶ روز پس از مایه‌زنی (dpi) از طریق واکنش زنجیره‌ای پلیمراز کمی (qPCR) اندازه‌گیری شد. نتایج نشان داد که تجمع ویروس در ارقام آریا و آرتا کم‌تر از سایر ارقام بود. از سوی دیگر، جلگه، به‌عنوان یک رقم حساس، بیش‌ترین تجمع ویروس و شدت علائم را نشان داد. هم‌چنین رقم جلگه کاهش بیش‌تری در سبزینگی، فتوسنتز، کلروفیل a و b، کاروتنوئیدها، کاتالاز، پراکسیداز، پلی فنل اکسیداز و پرولین را بعد از آلودگی به ویروس در مقایسه با گیاهان شاهد نشان داد. برعکس، ارقام آریا و آرتا کاهش کم‌تری در صفات ذکر شده بعد از آلودگی با ویروس در مقایسه با گیاهان شاهد نشان دادند. درمجموع، نتایج سنجش‌های بیوشیمیایی، فیزیولوژیک و مولکولی نشان داد که ارقام آریا و آرتا در برابر آلودگی به BCTIV مقاوم هستند. از آن‌جایی که این ویروس در اکثر مناطق چغندرکاری ایران گزارش شده است، ارقام آریا و آرتا برای کشت در این مناطق توصیه می‌شوند.

واژگان کلیدی: *Becurtovirus betae*، بیوشیمیایی، Geminiviruses، صفات فیزیولوژیک