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The effect of spraying with growth regulator (Atonic) and *Trichoderma viride* in improving the physical properties of Buckthorn fruits (*Ziziphus mauritiana L. cv. Tufahi*) infected with *Alternaria alternata*

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Abstract

Objective

The aim of this study was to evaluate the effects of the plant growth regulator Atonic and the biocontrol fungus *Trichoderma viride* on reducing *Alternaria alternata* infection, both individually and in combination. The goal was also to improve the physical properties of bitter elderberry (*Ziziphus mauritiana* L. cv. Tufahi) fruits. The study focused on increasing fruit quality as well as providing an environmentally friendly method for disease control.

Materials and Methods

The location of this study was a commercial garden of bitter elderberry located south of Nasiriyah city, Dhi Qar province, Iraq. The time of the study coincided with the growing season in 2023-2024. Six-year-old buckthorn trees naturally infected with *A. alternata* were used. Standard mycological techniques were used to isolate and identify pathogens from infected fruits. In vitro antagonism tests were conducted on potato dextrose agar (PDA) to assess the inhibitory effect of *T. viride* against *A. alternata*. Then assess the Atonic effect on the growth of both fungi was performed under laboratory conditions. In the field experiment, trees were treated with Atonic alone, *T. viride* alone, a combination of both, and an untreated control.

Results

Our laboratory results showed that *T. viride* has a high inhibitory effect on the growth of *A. alternata*. It indicates that it has high potential to act as a biological control agent. In contrast, we did not observe any direct inhibitory or stimulatory effects of Atonic on any of the fungi in vitro. These results suggest that its role is mainly physiological. Based on field results, it was found that the combined use of Atonic and ***T. viride*** was more effective than individual treatments and control. This treatment significantly increased vegetative growth, fruit length and diameter, fresh and dry fruit weight, pulp weight, seed weight, and pulp-to-seed ratio. In addition, the treated fruits showed a significant reduction in the severity and extent of *A. alternata* infection.

Conclusions

The results of this study showed that the interaction between Atonic and *T. viride* is synergistic. The physiological stimulation provided by Atonic, combined with the biocontrol and growth-promoting effects of *T. viride*. This resulted in improved physical fruit quality and effective suppression of *A. alternata*. Therefore, we can recommend this hybrid method as a safe and effective approach to improve the quality of bitter buckthorn fruit and manage fungal diseases in field conditions.

Keywords: *Atonic*, biocontrol, disease severity, fruit quality, plant growth regulator

Paper Type: Research Paper.

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Introduction

Buckthorn (*Ziziphus mauritiana* L.) is an important fruit tree that is widely grown in subtropical and semi-arid regions due to its high tolerance to drought, salinity, and poor soil conditions. The plant is valued not only for its adaptability but also for the high nutritional quality of its fruits, which are rich in carbohydrates, vitamin C, minerals, and several bioactive compounds. Buckthorn fruits are commonly consumed fresh and are also used in various processing industries. Despite its tolerance to harsh environmental conditions, fruit yield and quality are often reduced by biotic stresses, especially fungal diseases that occur during fruit ripening and the postharvest period (Ekir San & Yildirim, 2010). Among fungal pathogens, *Alternaria alternata* is considered one of the most destructive fungi affecting buckthorn fruits. This pathogen causes fruit rot, black spots, and surface blemishes, which greatly reduce fruit appearance and market value. Infection by *A. alternata* negatively affects fruit size, weight, firmness, and shelf life, leading to serious economic losses for growers. Previous studies have reported that the incidence and severity of Alternaria fruit rot increase under warm and humid conditions, making disease management more difficult (Meena et al., 2017; Larran et al., 2022). Therefore, developing effective and sustainable strategies to control this disease while maintaining fruit quality is highly necessary. In recent years, plant growth regulators have received increasing attention as tools to enhance plant growth, improve fruit quality, and reduce the negative effects of stress. Atonik is a commercial plant growth regulator composed of nitrophenolate compounds. It has been reported to stimulate several physiological processes, including photosynthesis, nutrient uptake, enzyme activity, and cell division. Foliar application of Atonik has shown positive effects on vegetative growth, yield, and fruit quality in several horticultural crops, particularly under stress conditions. These findings suggest that Atonik may help improve fruit development even when plants are exposed to biotic stresses such as fungal infections (Di Sario et al., 2025; Głąb et al., 2021). At the same time, biological control agents have emerged as environmentally safe alternatives to chemical fungicides. *Trichoderma viride* is widely known for its strong antagonistic activity against many plant pathogenic fungi, including *Alternaria* species. The mechanisms of action of *T. viride* include mycoparasitism, competition for nutrients and space, production of antifungal metabolites, and induction of systemic resistance in host plants. Several studies have shown that the application of *Trichoderma* spp. can reduce disease severity while enhancing plant growth and yield in fruit crops (Harman et al., 2021; Yao et al., 2023). In addition, *Trichoderma* species are natural components of agricultural soils and play an important role in improving soil health and plant immunity. Recent research has provided greater insight into *Trichoderma*-plant interactions in the rhizosphere, endosphere, and phyllosphere, revealing diverse colonization patterns and functional roles in plant growth and defense (Guzmán-Guzmán et al., 2025). Combining plant growth regulators with biological control agents represents a promising approach to simultaneously improve plant performance and disease resistance. The combined use of Atonik and *T. viride* may enhance plant physiological activity while suppressing fungal infection, leading to improved physical characteristics of buckthorn fruits under *A. alternata* stress. However, information on the combined effects of Atonik and *T. viride* on buckthorn (*Ziziphus mauritiana* L. cv. Tufahi) is still limited. Therefore, the objective of this study was to evaluate the individual and combined effects of foliar application of Atonik and *T. viride* on improving the physical properties of buckthorn fruits and reducing *A. alternata* infection under field conditions

Materials and methods

Molecular isolation and identification of *Trichoderma viride:* The isolate of *Trichoderma viride* used in this study was obtained from agricultural soil samples. The fungus was cultured on potato dextrose broth and incubated for five days at 25 ± 2°C to obtain sufficient mycelial growth. Genomic DNA was extracted from fresh mycelium using the Genomic DNA Mini Kit (Geneaid Biotech, Taiwan), following the manufacturer's instructions. The extraction procedure was performed in the laboratory of the University of Basra. The quality and integrity of the extracted DNA were evaluated according to the protocol described by Williams et al. (1990), and the isolate was confirmed as *T. viride* based on molecular characteristics.

Isolation and identification of *Alternaria alternata:* Naturally infected buckthorn fruits (*Ziziphus mauritiana* L. cv. Tufahi) showing black spot symptoms were collected from an orchard located in the Al-Husayniyah region, south of Nasiriyah City. The infected fruits were placed in sterile plastic bags and transported to the Plant Pathology Laboratory, College of Agriculture and Marshes, Thi-Qar University. Small sections from the diseased tissues were surface sterilized, placed on potato dextrose agar (PDA) medium, and incubated at 25 ± 2°C. The fungus was identified as *A. alternata* based on colony morphology and microscopic characteristics, following standard mycological methods. The plant growth regulator Atonic (Japanese origin) was purchased from authorized agricultural suppliers.

Pathogenicity test of the isolated fungus: The pathogenicity of the isolated *A. alternata* was evaluated using the method described by Park et al. (2024). A fungal disc (0.5 cm in diameter) taken from the margin of a 7-day-old colony grown on PDA was placed in the center of Petri dishes containing water agar supplemented with tetracycline (250 mg L^{-1}). The inoculated plates were incubated at 25 ± 2°C for three days. Surface-sterilized garden cress (*Lepidium sativum* L., local variety) seeds were arranged around the fungal colony, with 25 seeds per plate and four replicates. Control plates contained seeds without fungal inoculation. Plates were incubated until complete germination of control seeds. Infection percentage was calculated using the following formula:

$$\text{Infection percentage (\%)} = \frac{\text{Number of infected seedlings}}{\text{Total number of seedlings}} \times 100$$

Assessment of infection severity: Infection severity was assessed using a numerical scale (Table 1 and Figure 1) and calculated using the Mickenny (1923) equation, as cited in Pondkule (2018).

$$\text{Infection severity (\%)} = \frac{[\Sigma\ (\text{Number of plants} \times \text{Severity score})]}{\text{Total plants} \times 5} \times 100$$

Table 1. Infection severity scale used for pathogenicity evaluation

Severity score	Description
0	No infection
1	Slight infection
2	Mild infection
3	Severe infection
4	Very severe infection

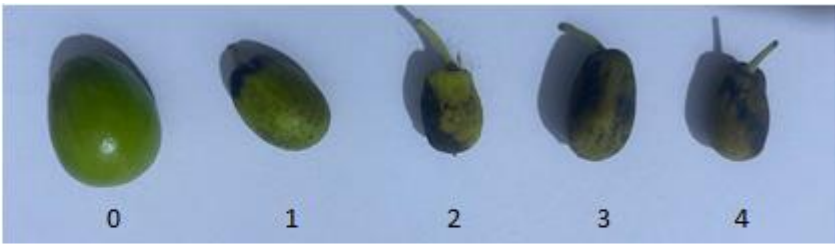

Figure 1. Diagrammatic representation of infection severity scale

Evaluation of antagonistic activity of *T. viride* against *A. alternata:* The antagonistic potential of *T. viride* against *A. alternata* was assessed using the dual culture technique, as described by Bell et al. (1982). Both fungi were inoculated on opposite sides of PDA plates and incubated at 25 ± 2°C. The degree of inhibition was recorded after seven days.

Effect of Atonic on the growth of *T. viride* and *A. alternata:* To evaluate the effect of Atonic on fungal growth, PDA medium was prepared and supplemented with Atonic at a concentration of 1 mL L^{-1} before solidification. The medium was poured into Petri dishes and inoculated separately with *T. viride* and *A. alternata*. Each treatment was replicated three times, and control plates without Atonic were included. Fungal growth inhibition was recorded after six days of incubation.

Preparation of *Trichoderma viride* suspension: The *T. viride* inoculum was prepared by culturing the fungus in potato dextrose broth for one week. The mycelium was washed with sterile distilled water, and spore concentration was determined using a hemocytometer, reaching 7.2×10^6 spores mL^{-1}. Foliar spraying was carried out at a concentration of 1 mL L^{-1}, following the method described by Minaxi & Saxena (2011) and Yadav et al. (2019).

Field treatments and measurement of fruit physical properties: Field spraying was conducted in the early morning using a 15-L backpack sprayer. Trees were sprayed until full leaf wetting, one day after irrigation to ensure open stomata. Spraying started on 1 October 2024, followed by three additional sprays at 30-day intervals. Treatments included Atonic, *T. viride*, Atonic + *T. viride*, and Control (untreated). Each treatment consisted of three replicates with four trees per replicate. At the fruit development and full ripening stages, ten fruits per replicate were randomly harvested. Fruit length and diameter were measured using a Vernier caliper. Fresh weight of fruit, pulp, and seed was measured using a digital balance. Dry weight was determined after oven-drying samples at 70°C until constant weight. The following equations were used:

$$\text{Average fruit weight (g)} = \frac{\text{Total fruit weight}}{\text{Number of fruit}}$$

$$\text{Pulp weight (g)} = \text{Average fruit weight} - \text{Average seed weight}$$

$$\text{Pulp} - \text{to} - \text{seed ratio} = \frac{\text{Pulp weight}}{\text{Seed weight}}$$

Results and discussion

Molecular identification of *Trichoderma viride:* The molecular identification of *Trichoderma viride* confirmed the accuracy of the isolate used in the present study. As shown in Table 2, the obtained sequence was successfully registered in the National Center for Biotechnology Information (NCBI) under the accession number PQ325356.1. The amplified fragment length was 540 bp and showed a very high similarity (99.63%) with the reference isolate MF094442.1, which originated from India. The query coverage of 99% further confirms the reliability of the molecular identification, indicating that the isolate used in this experiment belongs to *T. viride*. Such high sequence similarity supports the use of this isolate as a biological control agent, as genetically confirmed strains are essential for reproducibility and scientific validity.

Table 2. Molecular identification of *Trichoderma viride* based on NCBI registration

Name	Accession number	Fragment length (bp)	Matching accession	Matching length (bp)	Identity (%)	Query cover (%)	Country
T. viride	PQ325356.1	540	MF094442.1	610	99.63	99	India

Effect of treatments on fruit length: The effect of Atonic, *T. viride*, and their interaction on the average fruit length of buckthorn is presented in Table 3. Fruit length was significantly influenced by both treatments and developmental stage. At the growth completion stage, the combined Atonic + *T. viride* treatment produced the highest mean fruit length (2.75 cm), followed by Atonic alone (2.61 cm) and *T. viride* alone (2.53 cm). The lowest fruit length (1.74 cm) was observed in the control treatment, indicating poor growth under natural conditions without stimulatory inputs. At the final ripening stage, fruit length increased markedly in all treatments, with the maximum value (3.80 cm) recorded under the combined Atonic + *T. viride* treatment. This was followed by Atonic alone (3.71 cm), while the control still showed the smallest fruit length (2.07 cm). These results clearly demonstrate a synergistic effect between Atonic and *T. viride*, particularly at the final ripening stage when fruit growth reaches its peak.

Table 3. Effect of Atonic and *T. viride* on average fruit length (cm)

Treatment	Growth completion	Final ripening
Atonic	2.61	3.71
T. viride	2.53	3.42
Atonic + *T. viride*	2.75	3.80
Control	1.74	2.07
LSD (0.05)	0.12	0.14

Effect of treatments on fruit diameter: Fruit diameter followed a similar trend to fruit length, as shown in Table 4. The combined Atonic + *T. viride* treatment resulted in the largest fruit diameter at both growth stages, reaching 3.82 cm at the final ripening stage. Atonic alone also significantly increased fruit diameter (3.21 cm), while *T. viride* alone showed moderate improvement. The control treatment consistently produced the smallest fruits, especially at the growth completion stage (1.07 cm). These findings indicate that both Atonic and *T. viride* enhance cell expansion and tissue development, with the strongest effect observed when both are applied together.

Table 4. Effect of spraying with Atonic, *Trichoderma viride*, and their interaction on the average fruit diameter (cm) of buckthorn (*Ziziphus mauritiana* L. cv. Tufahi) infected with *Alternaria alternata* at growth completion and final ripening stages

Treatments	Growth completion stage	Final ripening stage
Growth regulator (Atonic)	2.50	3.21
T. viride	2.31	3.17
Atonic + *T. viride*	2.72	3.82
Control	1.07	2.51
LSD (0.05)	0.15	0.21

Effect on fruit dry weight: Data presented in Table 5 show that fruit dry weight was significantly affected by treatments and ripening stage. The highest dry weight (26.73 g) was obtained under the combined Atonic + *T. viride* treatment at the final ripening stage, followed by Atonic alone (25.31 g). The lowest dry weight (8.01 g) was recorded in the control treatment at the growth completion stage, indicating limited assimilate accumulation in untreated fruits.

Increased dry weight reflects enhanced photosynthetic efficiency and assimilate translocation, which are commonly associated with biostimulant application.

Table 5. Effect of spraying with Atonic, *Trichoderma viride*, and their interaction on the average fruit dry weight (g) of buckthorn (*Ziziphus mauritiana* L. cv. Tufahi) infected with *Alternaria alternata* at growth completion and final ripening stages

Treatments	Growth completion stage	Final ripening stage
Growth regulator (Atonic)	12.64	25.31
T. viride	10.63	22.02
Atonic + *T. viride*	12.70	26.73
Control	8.01	16.07
LSD (0.05)	0.74	0.92

Effect on pulp weight, seed weight, and pulp-to-seed ratio: Soft pulp weight increased significantly with biostimulant application (Table 6). The combined treatment produced the highest pulp weight (26.21 g) at final ripening, whereas the control showed the lowest value (7.10 g) at growth completion. Seed weight also increased slightly under treated conditions (Table 7), with the maximum value (1.63 g) recorded under Atonic + *T. viride*. As a result, the pulp-to-seed ratio was highest (17.13) under the combined treatment at final ripening (Table 8), which is a desirable trait for fruit quality and consumer acceptance. Lower ratios in control fruits indicate poor pulp development and inferior fruit quality.

Table 6. Effect of spraying with Atonic, *Trichoderma viride*, and their interaction on the average soft pulp weight (g) of buckthorn (*Ziziphus mauritiana* L. cv. Tufahi) infected with *Alternaria alternata* at growth completion and final ripening stages

Treatments	Growth completion stage	Final ripening stage
Growth regulator (Atonic)	11.83	24.35
T. viride	9.30	21.72
Atonic + *T. viride*	11.42	26.21
Control	7.10	13.71
LSD (0.05)	0.19	0.36

Effect on dry matter percentage of fruit pulp: The percentage of dry matter in fruit pulp is a key indicator of fruit quality. As shown in Table 9, the combined Atonic + *T. viride* treatment significantly increased dry matter content, reaching 27.10% at the final ripening stage. The lowest dry matter percentage (17.30%) was observed in the control treatment, indicating diluted fruit tissues and reduced quality. Higher dry matter content is often associated with increased sugars, fibers, and storage compounds, which improve taste, texture, and processing quality (Vojnović et al., 2023).

Table 7. Effect of spraying with Atonic, *Trichoderma viride*, and their interaction on the average seed weight (g) of buckthorn (*Ziziphus mauritiana* L. cv. Tufahi) infected with *Alternaria alternata* at growth completion and final ripening stages

Treatments	Growth completion stage	Final ripening stage
Growth regulator (Atonic)	1.27	1.45
T. viride	1.31	1.43
Atonic + *T. viride*	1.52	1.63
Control	0.97	1.12
LSD (0.05)	0.01	0.01

Table 8. Effect of spraying with Atonic, *Trichoderma viride*, and their interaction on the pulp-to-seed ratio of buckthorn (*Ziziphus mauritiana* L. cv. Tufahi) infected with *Alternaria alternata* at growth completion and final ripening stages

Treatments	Growth completion stage	Final ripening stage
Growth regulator (Atonic)	6.76	15.10
T. viride	6.87	15.36
Atonic + *T. viride*	8.79	17.13
Control	6.22	11.96
LSD (0.05)	0.21	0.31

Table 9. Effect of spraying with Atonic, *Trichoderma viride*, and their interaction on the dry matter percentage (%) of fruit pulp of buckthorn (*Ziziphus mauritiana* L. cv. Tufahi) infected with *Alternaria alternata* at growth completion and final ripening stages

Treatments	Growth completion stage	Final ripening stage
Growth regulator (Atonic)	21.41	23.10
T. viride	21.68	24.33
Atonic + *T. viride*	24.94	27.10
Control	17.30	18.45
LSD (0.05)	2.83	2.61

Effect on infection percentage and disease severity: The percentage of fruit infection by *A. alternata* was strongly affected by treatments (Table 10). The control treatment showed the highest infection rates, reaching 72.34% at the final ripening stage, which reflects the natural susceptibility of fruits during maturation. The combined Atonic + *T. viride* treatment significantly reduced infection, with values of 19.71% and 24.82% at growth completion and final ripening, respectively. Disease severity followed the same trend (Table 11). The control showed the highest severity (60.64% after the third spray), while the combined treatment recorded the lowest severity (12.18%). These results confirm the strong antagonistic and protective role of *T. viride*, especially when supported by the physiological stimulation provided by Atonic.

Table 10. Effect of spraying with Atonic, *Trichoderma viride*, and their interaction on the infection percentage (%) of buckthorn fruits (*Ziziphus mauritiana* L. cv. Tufahi) infected with *Alternaria alternata* at growth completion and final ripening stages

Treatments	Growth completion stage	Final ripening stage
Growth regulator (Atonic)	55.09	64.58
T. viride	36.42	47.67
Atonic + *T. viride*	19.71	24.82
Control	63.04	72.34
LSD (0.05)	6.23	7.06

Table 11. Effect of spraying with Atonic, *Trichoderma viride*, and their interaction on disease severity (%) of buckthorn fruits (*Ziziphus mauritiana* L. cv. Tufahi) infected with *Alternaria alternata* after the first and third sprays

Treatments	After first spray	After third spray
Growth regulator (Atonic)	35.44	40.45
T. viride	25.32	30.31
Atonic + *T. viride*	10.15	12.18
Control	45.50	60.64
LSD (0.05)	5.07	6.44

The present results clearly demonstrate that the combined application of Atonic and *Trichoderma viride* significantly improves fruit growth, quality, and resistance to *Alternaria alternata* in buckthorn. Biostimulants are known to enhance plant physiological processes, including nutrient uptake, hormonal balance, and stress tolerance, leading to improved fruit size and quality. The increased fruit length and diameter observed in this study reflect enhanced cell division and expansion, which are promoted by growth regulators and beneficial microorganisms. Similar findings were reported by Gonçalves et al. (2025), who showed that *Trichoderma* species positively influence fruit development through hormonal modulation and improved nutrient availability. The higher dry weight, pulp weight, and pulp-to-seed ratio obtained under the combined treatment indicate better assimilate allocation to fruit tissues, resulting in superior fruit quality. Liu et al. (2025) reported comparable improvements in melon fruits treated with *T. viride*, attributing these effects to enhanced metabolic activity and fruit filling. Dou et al. (2024) also demonstrated that *T. viride* improves fruit size, weight, and quality by stimulating root growth and nutrient assimilation. The increase in dry matter percentage observed in the present study further supports the role of biostimulants in enhancing metabolic efficiency, leading to higher concentrations of sugars and structural compounds (Vojnović et al., 2023). Conversely, the minimum values in the control treatments at the stage of growth completion support the contribution of external stimulatory inputs to the promotion of fruit development. Plants that are not treated usually exhibit low fruit growth and measures of fruit quality since they are only left to be at the mercy of natural physiological activities that are not enhanced by growth regulators or helpful microorganisms. Similar studies on plant growth regulators and biostimulants have also achieved comparable lower performance of the control plants, which highlights the role of applied treatments in maximizing the size and makeup of fruits (Loeza-Lara et al., 2024). The strong reduction in infection percentage and disease severity confirms the biocontrol potential of *T. viride*, which acts through mycoparasitism, competition, and induction of systemic resistance. Atonic alone showed moderate disease reduction, likely by improving plant vigor and defense responses, but the combined treatment provided the highest level of protection, demonstrating a clear synergistic effect. These findings are consistent with previous reports on integrated biostimulant strategies, which combine chemical and biological agents to enhance plant performance and disease resistance (Rouphael & Colla, 2020; du Jardin, 2015). Overall, the integration of Atonic and *T. viride* represents an effective, sustainable, and environmentally friendly approach to improving buckthorn fruit quality while reducing *A. alternata* infection.

Conclusion: The results of this study demonstrated that foliar application of the growth regulator Atonik and the biocontrol fungus *Trichoderma viride* had a clear and positive effect on the physical quality of buckthorn (*Ziziphus mauritiana* L. cv. Tufahi) fruits infected with *Alternaria alternata*. All applied treatments reduced the negative effects of the pathogen on fruit characteristics when compared with the untreated control. However, the combined application of Atonik and *T. viride* was the most effective treatment, as it resulted in the greatest improvement in fruit size, weight, pulp quality, and dry matter content, while also significantly reducing disease incidence and severity. The enhanced performance observed under the combined treatment suggests a synergistic interaction between Atonik and *T. viride*. Atonik likely improved plant physiological activity and vigor, while *T. viride* contributed to disease suppression through its antagonistic and growth-promoting effects. This integrated approach not only improved fruit quality but also provided effective control of *A. alternata* under field conditions. Overall, the findings indicate that the combined use of a plant growth regulator and a biological control agent is a practical, safe, and environmentally friendly strategy for improving buckthorn fruit quality and managing fungal diseases. This approach can reduce reliance on chemical fungicides and may be recommended for sustainable buckthorn production in similar agro-climatic conditions.

Author contributions

All activities were performed by auther. The final document was examined, debated, and approved by the author.

Data availability statement

The corresponding author can provide data supporting this study's conclusions upon reasonable request.

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Ethical approval

Not applicable.

Conflict of Interest

The author affirm that they have no financial conflicts of interest or competing interests in this study.

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تأثیر محلول‌پاشی با تنظیم‌کننده رشد (Atonic) و قارچ *Trichoderma viride* در بهبود صفات فیزیکی میوه کنار (*Ziziphus mauritiana L. cv. Tufahi*) آلوده به *Alternaria alternata*

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چکیده

هدف: هدف از این پژوهش، ارزیابی تأثیر تنظیم‌کننده رشد گیاهی آتونیک (Atonic) و قارچ کنترل زیستی *Trichoderma viride* در کاهش آلودگی به *Alternaria alternata* به‌صورت جداگانه و توأم، و همچنین بهبود صفات فیزیکی میوه کنار (*Ziziphus mauritiana* L. cv. Tufahi) بود. این مطالعه با تمرکز بر افزایش کیفیت میوه و ارائه روشی سازگار با محیط زیست برای کنترل بیماری انجام شد.

مواد و روش‌ها: این تحقیق در یک باغ تجاری کنار واقع در جنوب شهر ناصریه، استان ذی‌قار، عراق و در فصل رشد ۲۰۲۴-۲۰۲۳ انجام شد. درختان شش‌ساله کنار که به‌طور طبیعی به *A. alternata* آلوده بودند، مورد استفاده قرار گرفتند. جداسازی و شناسایی عامل بیماری‌زا از میوه‌های آلوده با استفاده از روش‌های استاندارد قارچ‌شناسی انجام شد. آزمون‌های تضاد درون‌شیشه‌ای روی محیط کشت PDA برای بررسی اثر بازدارندگی *T. viride* بر *A. alternata* انجام گرفت. همچنین اثر آتونیک بر رشد هر دو قارچ تحت شرایط آزمایشگاهی بررسی شد. در آزمایش مزرعه‌ای، درختان با آتونیک به‌تنهایی، *T. viride* به‌تنهایی، ترکیب هر دو تیمار و شاهد بدون تیمار مورد بررسی قرار گرفتند.

نتایج: نتایج آزمایشگاهی نشان داد که *T. viride* دارای اثر بازدارندگی بالایی بر رشد *A. alternata* است که بیانگر پتانسیل بالای آن به‌عنوان عامل کنترل زیستی می‌باشد. در مقابل، آتونیک در شرایط درون‌شیشه‌ای هیچ اثر مستقیم بازدارنده یا تحریک‌کننده‌ای بر رشد قارچ‌ها نشان نداد که حاکی از نقش عمدتاً فیزیولوژیک آن است. نتایج مزرعه‌ای نشان داد که کاربرد توأم آتونیک و *T. viride* نسبت به تیمارهای منفرد و شاهد مؤثرتر بود. این تیمار باعث افزایش معنی‌دار رشد رویشی، طول و قطر میوه،

وزن تر و خشک میوه، وزن گوشت میوه، وزن بذر و نسبت گوشت به بذر شد. علاوه بر این، شدت و گسترش آلودگی به *A. alternata* در میوه‌های تیمار شده به‌طور معنی‌داری کاهش یافت.

نتیجه‌گیری: نتایج این پژوهش نشان داد که برهم‌کنش بین آتونیک و *T. viride* دارای اثر هم‌افزایی است. تحریک فیزیولوژیک ناشی از آتونیک همراه با اثرات کنترل زیستی و تحریک رشد *T. viride* منجر به بهبود کیفیت فیزیکی میوه و مهار مؤثر *A. alternata* شد. بنابراین، این روش تلفیقی می‌تواند به‌عنوان رویکردی ایمن و کارآمد برای بهبود کیفیت میوه کنار و مدیریت بیماری‌های قارچی در شرایط مزرعه‌ای توصیه شود.

کلمات کلیدی: آتونیک، تنظیم‌کننده رشد گیاهی، شدت بیماری، کنترل زیستی، کیفیت میوه

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