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MANAGEMENT OF CUCUMBER (*CUCUMIS SATIVUS* L.) IN INTEGRATION WITH BIOSTIMULANT ATONIK BASED ON PHYSICAL AND BIOCHEMICAL PROPERTIES

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SUMMARY

The following experiment on cucumber (*Cucumis sativus* L.) took place in the fall of 2021–2022 at the unheated greenhouse of the Ministry of Agriculture, Iraq. The experiment included two coefficients and three replications consisting of compatibility between two cucumber cultivars, Sayff and Fito, and four Atonik concentrations (0, 2.5, 3.5, and 4.5 ml L^{-1}). The research aimed to know the effect of Atonik on the cucumber's physical and biochemical properties for cultivation in the Southern Region, Dhi-Qar Governorate, Iraq. The cultivar Sayff emerged considerably superior in plant height, stem diameter, the number of leaves, and fruits' total soluble carbohydrates from the leaves (156.86 cm, 0.486 mm, 40.825 leaves $plant^{-1}$, and 6.511 mg g^{-1}, respectively), except in the fruit content of vitamin C, which was highest in the cultivar Fito (91.25 mg 100 g^{-1} fresh weight). The foliar application of Atonik (4.5 ml L^{-1}) considerably improved the morphological traits and biochemical composition of cucumbers. It provided the supreme rates of plant height, stem diameter, the number of leaves, total soluble carbohydrate content in fruits, and vitamin C (158.04 cm, 0.491 mm, 41.049 leaves, 6.818 mg g^{-1}, and 96.19 mg 100 g^{-1} in fresh weight, respectively), as compared with the control treatment.

Keywords: Cucumber (*C. sativus* L.), cultivars, Atonik, morphological traits, physical and biochemical properties

Key findings: In cucumber (*C. sativus* L.), the foliar application of Atonik (4.5 ml L^{-1}) considerably improved the morphological traits and biochemical composition and provided the highest rates of plant height, stem diameter, the number of leaves, total soluble carbohydrate content in fruits, and vitamin C.

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INTRODUCTION

The cucumber (*Cucumis sativus* L.) plants belonged to the cucurbit family (Cucurbitaceae), which is important in countries around the world, including Iraq, as it includes 90 genera and 750 species (Abu-Dahi and Muayad, 1988). Its use is either fresh or pickled cucumbers. Given its economic and nutritional importance and its various uses in many recipes, it is due to cucumber fruits containing 96.3% water by the weight of the fruit. Each 100 g of fruit includes 0.7 mg of protein, 14 calories, 24 mg of calcium, 20 international units of vitamin A, 0.075 mg of riboflavin, and 0.3 mg of niacin. Cucumber contains numerous vitamins, the most essential of which are A and C, with a small percentage of vitamin B. It also has a good percentage of mineral elements, such as iron, manganese, iodine, and copper (Al-Bayati *et al.*, 2012). One of the most critical reasons for the use of foliar fertilization using stimulants is the possibility of loss of these stimuli or their incompatibility with the degree of soil pH interaction. There, they undergo adsorption, precipitation, and the formation of compounds unfit for the plant and difficult to absorb by the roots (Abu-Dahi and Muayad, 1988). Cucumber growing can be in two seasons (spring and fall), but the fall crop is the basis. Its planting can also succeed inside greenhouses or glass houses and plastic tunnels, which helps to extend its harvest period and protect it from unsuitable environmental conditions and from various pests.

Cucumber fruits have many medicinal uses, as they help relieve pain resulting from skin irritation, reduce bloating (Sumathi *et al*., 2008), and balance high blood pressure (Waseem *et al*., 2008). The cultivated area in Iraq in 2017 amounted to about 5,210 ha (52,100 dunums), a yield of 856 kg/0.1 ha, and a total production of 156,300 t/ha (Annual Statistical Collection, 2017).

Notably, the productivity of this crop is still below the required level. It is crucial to focus on agricultural service operations, such as fertilization, irrigation, and pest and weed control, as well as planting high-yielding and high-quality genetic constructs or hybrids to increase its productivity. Increasing the yield for quantity and quality is necessary to meet the growing needs of the population through various types of services, including fertilization.

Moreover, cucumber is a crop with high nutritional needs. Nutrient deficit weakens its field performance, reducing yield, causing fruit deformation, and bitterness. For its continued output, leaves require nourishment to suit crop needs. Organic or inorganic biostimulants can increase agricultural productivity by 50% if other growth factors are available. In fixing this, the use of chemical fertilizers is necessary. However, volatilization and leaching below the root zone pollute groundwater and reduce the performance and efficiency of most soil fertilizers, notably nitrogen fertilizers. Hence, it has become essential to determine the concentration of nitrates and nitrites in food due to concerns about these compounds that pose a health risk. Therefore, one of the main ways to reduce these problems is to spray the leaves with biostimulants. These materials are distinct for their content of nitrogen, phosphorus, potassium, and micronutrients for the healthy growth of plants.

Organic matter improves the physical, chemical, and fertility features and delivers nutrients to plants. Organic colloids' large specific surface area helps them retain water, ions, and nutrients more than their weight. Most scientific investigations show biostimulant spraying boosts plant growth and productivity. More prolific types require development while providing the plant with its nutrient needs, either through mineral or organic fertilizers and biostimulants that boost production. They offer N, P, and K for growth and production, increasing output and quality. They contain all the important elements for plant growth and maturity, including micronutrients and rare elements, in addition to providing plants with these elements continuously throughout the growth period (Al-Rakabi, 2021).

Catalysts are among the chief pillars used to organize production, protect the environment, and produce crops. They help give vegetative and laboratory indicators with high content for increasing flowering, knots, and raising vegetative indicators. Some companies have begun to manufacture fertilizers for use as liquid solutions, which are applicable for spraying through the leaves (Alsadon *et al.*, 2006). One of the manufactured fertilizers that is substantially a growth stimulator, benefiting the plant and giving similar results and more than other stimuli and increasing the percentage of knots, carbohydrates, and vegetative and flowering production, is Atonik. It stimulates growth significantly, especially in the early stages, and boosts flowering, size, and hardness of fruits (Aktas *et al.*, 2009).

Given the lack of study on the effect of the Atonik biostimulant on cucumber yield and the importance of this crop for increased productivity and improved quality in greenhouses, this study had the following objectives: to know the extent of Atonik's effect on cucumber hybrids and study the interaction between them to achieve the highest yield in production. The presented study also sought to identify the most suitable cucumber hybrid that can grow in the environmental conditions of the Southern Region, specifically Dhi-Qar Governorate, Iraq.

MATERIALS AND METHODS

The experiment, held in the fall of 2021–2022 at the unheated greenhouse, Ministry of Agriculture, Iraq, determined the Atonik biostimulant's effect on two cucumber (*C. sativus* L.) cultivars' physical and biochemical characteristics and their bilateral interactions under protected cultivation. This experiment used a randomized complete block design (RCBD). After preparing the land in the plastic house (9 m × 50 m), applying the agricultural service operations, such as loosening, patching, and hoeing, and all other treatments proceeded. Afterward, the scaling process succeeded after the plant reached the sixth true leaf. Placing the climbing thread commenced from the bottom, then wrapped along the length of the plant, tied, and fixed to a carrier wire in the plastic house (Al-Sahhaf, 1989).

Studied attributes

Plant height measurement (cm plant^{-1}) used a metric tape from the stem's soil contact to the developing peak. The stem diameter (cm plant^{-1}) for selected plants: the Vernier measured the stem diameter at 1 cm from the main stem's soil contact and according to its rate. The number of total leaves (leaf plant^{-1}) resulted in counting at the end of the season for each of the selected plants, with the average calculated. Total carbohydrates in fruits (mg g^{-1}) reached estimation using the phenol method with sulfuric acid (Al-Sahhaf *et al.*, 2011). Steps comprised taking 0.5 g of dried and ground fruits and placing it in a volumetric flask with a 100-ml capacity and adding 75 ml of distilled water to it before tightly closing the flask. The samples attained heating in a water bath at a temperature of 70 °C for an hour. Leaving it to cool at the laboratory temperature and then filtering the solution with filter paper acquired 5 ml of the filtrate. Adding 25 ml of distilled water to it, we took 1 ml and added 1 ml of 5% phenol and 5 ml of 95% concentrated sulfuric acid. A spectrophotometer measured the absorbance at 490 nm, and then estimating the carbohydrates used the standard curve of glucose.

For the 5% vitamin C concentration in fruits (mg 100 g^{-1} fresh weight), the procedure is as follows: the direct leaching method calculated vitamin C (Qubeissi, 2007), using a dye (2-6, Dichlorophenolindophenol), 5 g of the pureed fruits sustained mixing with 100 ml of 6% oxalic acid. Taking 10 ml from the filtrate of the filtered mixture and increasing its volume to 100 ml continued by adding 3% oxalic acid. Taking 10 ml from the last solution had the above dye dissolved with it, whose strength before washing was equal to 0.1 mg vitamin C until reaching the neutralization point (appearance of scarlet or pink color). Vitamin C estimation in fruits depended on the number of milligrams per 100 g fresh fruit weight, as in the following equation:

$$\text{Vitamin C (mg. 100 gm}^{-1}) = \frac{x * y * mitigation}{Sample\ weight\ (gm)}$$

Where:

x: The number of millimeters of dye used in the correction.

y: The strength of the dye (which is the number of milligrams of vitamin C that is equal to 1 ml of the dye).

An analysis of variance ensued for each of the studied traits based on the randomized whole block design, applying the least significant differences (LSD) test at a 0.05 probability level (Al-Mohammadi, 1990).

RESULTS AND DISCUSSION

Plant height

The Atonik foliar application and cultivars considerably affected the plant height in cucumber (Table 1). The cultivar Sayff grew taller than cultivar Fito, reaching 156.86 cm versus 153.58 cm. The Atonik spraying made a big difference because its 4.5 ml L^{-1} concentration was substantially greater than the comparison's 158.04 cm. With the cultivar and Atonik spraying, the Sayff cultivar had the highest average plant height at 159.25 cm $plant^{-1}$ at 4.5 ml L^{-1}. Compared with the Fito cultivar, it gave the lowest average plant height at 149.41 cm^{-1}.

Stem diameter

The Atonik spraying and cultivars influenced the cucumber's stem diameter (Table 2). The Sayff cultivar had the broadest rate at 0.486 cm $plant^{-1}$, surpassing cultivar Fito's 0.478 cm. Using the 4.5 ml L^{-1} concentration, Atonik spraying had a greater impact than the control treatment's 0.491 mm $plant^{-1}$. The comparative treatment yielded the Fito cultivar with the lowest average plant diameter (0.470 cm $plant^{-1}$), while cultivar Sayff had the largest (0.485 cm $plant^{-1}$ at 4.5 ml L^{-1}).

Leaves per plant

Atonik foliar application and cultivars modified cucumber's leaf count (leaf $plant^{-1}$), as shown in Table 3. The Sayff cultivar had the topmost rate of 40.825 leaves $plant^{-1}$, compared with 38.528 for the Fito cultivar. In the same table, Atonik spraying had a substantial effect, with the dose of 4.5 ml L^{-1}, as compared to 41.049 leaves $plant^{-1}$ for the control treatment. The Sayff cultivar produced the most plant leaves, reaching 42.587 leaves $plant^{-1}$ at 4.5 ml L^{-1}, while the Fito cultivar received the comparison treatment. However, the lowest leaf mean was 37.541 leaves $plant^{-1}$.

Total carbohydrates in fruits

The spraying of Atonik and cultivars influenced fruit total carbohydrates (mg g^{-1}, Table 4). The Sayff cultivar had the maximum rate at 6.511 mg g^{-1}, whereas the Fito cultivar had 5.497 mg g^{-1}. The same table shows Atonik spraying at 4.5 ml L^{-1}, produced much higher than the comparative treatment of 6.818 mg g^{-1}. In the interaction between study components, cultivar and Atonik spraying had a significant influence, with the Sayff cultivar giving the highest rate (7.424 mg g^{-1}) at 4.5 ml L^{-1}, while the Fito cultivar gave less (4.814 mg g^{-1}).

Vitamin C content in fruits

The results revealed how Atonik foliar application and cultivars influence the fruit's vitamin C (mg 100 g^{-1} fresh weight) (Table 5). The Fito cultivar has 91.25 mg 100 g^{-1} fresh weight, while the Sayff had 83.99 mg 100 g^{-1}. In the same table, Atonik spraying's 4.5 ml L^{-1} concentration was substantially greater than the control treatment's 96.19 mg 100 g^{-1} fresh weight. In the comparative treatment, the Fito cultivar yielded the most vitamin C content (97.87 mg 100 g^{-1} fresh weight) at an Atonik dose of 4.5 ml L^{-1}. Sayff had the lowest average at 78.31 mg 100 g^{-1} fresh weight.

It is clear from the results of vegetative growth characteristics that the effect of hybrids, Atonik spray treatments, and their interactions have significantly affected some vegetative growth indicators of cucumber plants (plant height, stem diameter, and the number of leaves) (Tables 1, 2, and 3). The cultivars differed among themselves. The reason for this refers to the genetic factors specific to the hybrid, which are responsible for some traits and the magnitude of their environmental response. This is consistent with what Al-Sahhaf *et al*. (2011) found. The reason for this may be due to genetic differences between cultivars resulting from different genetic factors (Sudre *et al*., 2010).

Table 1. Effect of Atonik foliar application and cultivars on the plant height in cucumbers.

Cultivars	Atonik (ml L^{-1})				Means (cm)
	0	2.5	3.5	4.5	
Sayff	155.21	156.30	156.71	159.25	156.86
Fito	149.41	152.34	155.74	156.84	153.58
Average Atonik	152.31	154.32	156.22	158.04	
$LSD_{0.05}$	Cultivar		Atonik		Cultivar by Atonik interaction
	1.254		1.011		1.414

Table 2. Effect of Atonik foliar application and cultivars on the stem diameter in cucumbers.

Cultivars	Atonik (ml L^{-1})				Means (cm)
	0	2.5	3.5	4.5	
Sayff	0.480	0.482	0.485	0.498	0.486
Fito	0.470	0.475	0.482	0.485	0.478
Average Atonik	0.475	0.478	0.483	0.491	
$LSD_{0.05}$	Cultivar		Atonik		Cultivar by Atonik interaction
	0.004		0.004		0.011

Table 3. Effect of Atonik foliar application and cultivars on the number of leaves in cucumbers.

Cultivars	Atonik (ml L^{-1})				Means (#)
	0	2.5	3.5	4.5	
Sayff	39.111	40.251	41.354	42.587	40.825
Fito	37.541	38.321	38.741	39.512	38.528
Average Atonik	38.326	39.286	40.047	41.049	
$LSD_{0.05}$	Cultivar		Atonik		Cultivar by Atonik interaction
	1.128		0.854		2.098

Table 4. Effect of Atonik foliar application and cultivars on total carbohydrates in cucumber fruits.

Cultivars	Atonik (ml L^{-1})				Means (mg g^{-1})
	0	2.5	3.5	4.5	
Sayff	5.990	6.121	6.510	7.424	6.511
Fito	4.814	5.121	5.841	6.212	5.497
Average Atonik	5.402	5.621	6.170	6.818	
$LSD_{0.05}$	Cultivar		Atonik		Cultivar by Atonik interaction
	0.444		0.488		0.941

Table 5. Effect of Atonik foliar application and cultivars on the vitamin C content in cucumber fruits.

Cultivars	Atonik (ml L^{-1})				Means (mg 100 g $^{-1}$ fresh weight)
	0	2.5	3.5	4.5	
Sayff	75.31	80.34	85.81	94.51	83.99
Fito	85.12	89.54	92.47	97.87	91.25
Average Atonik	80.21	84.94	89.14	96.19	
$LSD_{0.05}$	Cultivar		Atonik		Cultivar by Atonik interaction
	6.550		6.111		4.512

Atonik works to improve the characteristics of vegetative growth, as it led to an increase in the height of the plant in cucumbers, which is one of the indicators of the plant's strength. It occurs either by increasing the number of nodes or by boosting the height of the internodes of the plant. It raises the vegetative and floral growth and enhances the diameter because Atonik activates several enzymes. Hormones that increase growth and the expansion in diameter may be a reason for the buildup and accumulation of dry matter in the plant (Al-Rikabi, 2021).

This may be because biostimulants (Atonik) limit nutrient availability in the soil solution, which helps create an efficient root system to absorb nutrients. Plants absorb more nutrients when soil solution nutrients abound. Nutrients play an important role in regulating the activity of plant hormones that control growth and meristematic cell division and activate vital processes. This showed a positive reflection in the number of manufactured nutrients needed to build plant tissues and thus increases plant height, the number of leaves, and stem diameter.

Similarly, Atonik contains many essential nutrients for the plant. Spraying with Atonik, given the high availability of these stimulants, has led to an increase in their absorption by the plant, as reflected in the formation of an efficient root system in absorbing nutrients from the soil. It may also be due to the increase in nitrogen and its importance in the composition of nucleic acids, proteins, some vitamins, and many enzymes, helping complete the vital processes that occur in cells. Moreover, the contribution of some plant hormones and the role of chlorophyll necessary for photosynthesis reflected positively in increasing plant height, the number of leaves, and stem diameter (Havlin *et al*., 2005). Another reason that explains the significant superiority of using biostimulants is that Atonik may contribute to boosting the amount of nutrients absorbed by the plant, which encourages the absorption of nutrients, including nitrogen and phosphorus. These, then, work with potassium to increase the size of the vegetative system and raise the nutrients manufactured inside the plant, and thus the dry weight of plant parts increases (Eifediyi and Remison, 2009; Al-Bayati, 2012; Al-Khafaji and Miftin, 2013).

The cultivar Sayff has better fruit content, total carbs, and vitamin C as compared with the cultivar Fito (Tables 4 and 5). As many features may be genetically different, the cultivar's influence on ambient conditions and weather factors may explain the growth. Genetic makeup determines their inheritance (Al-Zaidi, 2002). Genetic variables may have caused the hybrids to respond differently to this feature (Aktas *et al*., 2009; Sudre *et al*., 2010; Rasool *et al*., 2009; Al-Ibrahim, 2017).

As for the effect of biostimulants on increasing the above traits, an explanation may be with the importance of Atonik, as it contains about half the amount of nitrogen, in addition to high potassium, phosphorus, and micronutrient contents. The mineralization and nitrification process increases soil organic matter, ammonium, and nitrates, making Atonik better at increasing plant leaf nitrogen. In general, the absorption of biostimulants is rapid at first and slows down over time. Moisture, climatic circumstances, and potassium's capacity to increase the plant's nitrogen use and absorption rate affect absorption rates. The amount of Atonik added to biostimulants influences the percentage of phosphorus in the leaves of plants fertilized with organic fertilizers, especially when fertilized with Atonik (Al-Rakabi, 2021). Atonik also contains organic acids and natural chelating agents that increase potassium availability (Selim *et al*., 2009). Biostimulants also improve soil chemical and physical qualities, increase element availability, and provide an appropriate environment for root growth, which strengthens root systems (Havlin *et al*., 2005).

Biostimulants sprayed on plants and soil also have an effect on increasing the cation exchange capacity. This causes an increase in the holding and release of positive ions K^+, and by the process of exchange with other ions, it prevents their fixation and increases their availability. The cation exchange capacity, or CEC, comes from the fact that it prevents or shortens the washing of fertilizer components, such as potassium, ammonium, magnesium, calcium, and other positive ions. The exchange of positive ions is the means by which the soil can store potassium and other positive ions, such as calcium and magnesium, in soil colloids and can be known as the exchange of positive ions. The added biostimulants work to lower the soil pH, which increases the dissolution of minerals and releases potassium (Saleh *et al*., 2003).

Past findings further indicated Atonik increases the availability of potassium and nitrogen (Al-Saeedi, 2017; Al-Rakabi, 2021). Their results also pointed to the role of Atonik in enhancing vegetative growth, which helps improve plant nutrition and the transfer of carbohydrates from the manufacturing centers, which are the leaves, to the consumption sites, which are the fruits. This makes them meet the growth requirements, which leads to an increase in the fruit content of carbohydrates. The reason for this may be due to the rise in the leaf content of chlorophyll in the Atonik treatment preparing large amounts of nitrogen to enter into the chlorophyll formation. Moreover, the production of amino acids enters into the formation of chloroplasts. In turn, it increases the leaf content of chlorophyll in addition to the role of biostimulants enhancing carbon fixation, which boosts the plant's ability to prepare the required carbon skeletons in the biosynthesis of the chlorophyll molecule.

The N and Mg, which are at the center of the chlorophyll, are likewise heightened by organic matter. The chlorophyll molecule's formation depends on the plant's nitrogen content (Gutierrez-Micelli *et al*., 2007). As Atonik improves the soil's physical and chemical properties, nitrogen release increases, which penetrates the chlorophyll molecule (Pang and Letey, 2006). Biostimulants have a high nutrient content compared with other media, especially nitrogen, and boost the availability of nutrients, mainly nitrogen, which determines the relative chlorophyll content of the leaves because most nitrogen concentration is in the leaves.

When treating fruits with a growth regulator, their carbohydrate content increases, making them more like atonic. Atonik increases the chlorophyll content of the leaves, which improves photosynthesis and elevates synthetic materials in the leaves, increasing fruit carbohydrates. Total dissolved solids accumulate in fruits. These results match the findings of Al-Rikabi (2021). Atonik may boost the fruit's vitamin C content by activating metabolic pathways that raise glucose, which affects the fruit's ascorbic acid levels. Thus, its presence stimulates vitamin C production. Similar results came from Al-Jubouri (2009), Szot *et al*. (2014), and Al-Saeedi (2017), where spraying Atonik on *Fragaria* plants increased the vitamin C content of one cultivar of such fruits.

CONCLUSIONS

Based on the results, cultivar Sayff was significantly superior to cultivar Fito in most of the characteristics. Spraying Atonik at 4.5 ml L^{-1} significantly improved the measured traits, including the highest rates of plant height, stem diameter, the number of leaves, total soluble carbohydrate, and vitamin C content in fruits. This suggests that Atonik serves as an effective biostimulant for enhancing cucumber plant growth and fruit quality. The results emphasize the importance of selecting suitable hybrids and optimizing biostimulant application to achieve high productivity and fruit quality under controlled conditions.

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