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REVIEW ARTICLE

Significance of chitosan foliar spraying on the growth and yield of vegetable crop under protected cultivation: A review

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Abstract

Chitosan is a naturally occurring substance that is manufactured industrially from crab shells. It has been used as a better material for improving vegetable growth and yields, as well as a protective mechanism against fungi, bacteria and viruses. Because of its excellent biocompatibility, biodegradability and bioactivity, the biopolymer "Chitosan" has generated a lot of interest for its potential wide application in agriculture. Chitosan acts as an inducer in many species of plants. It not only works by triggering the immune system of plants, but it also enhances crop yields. Chitosan increased plant efficacy in reducing the negative effect of adverse circumstances as well as plant growth. The main objective of this review paper is to synthesize the most recent literature on the influence of chitosan foliar spraying on the development and yield properties of various vegetables, as well as to foster academic collaboration.. For instance, 100 ppm level of foliar spraying of chitosan have effects on the average plant height, medium number of leaves, area of leaves, the content of chlorophyll and fruits weight of tomato plant growth parameters, whereas chitosan at 4 mL per litre improved the minerals situation in cucumber and this substance also significantly lowered the damaging Powdery mildew in okra. This study demonstrates the beneficial effect of foliar spraying chitosan in conjunction with other chemical substances on plants. The current research has been done for future studies aimed at improving the foliar application of chitosan for horticultural production, particularly vegetable yield and growth.

Keywords

Chitosan, foliar spraying, growth, vegetables, yield

Introduction

The use of new technology has resulted in significant breakthroughs in agriculture, making it easier to meet agricultural output targets. However, in order to maintain agricultural productivity gains, new environmentally friendly production technology must be implemented (1). Plant growth regulators are among the most significant aspects in intensifying vegetable yield. Growth regulators have a good management consequence on vegetable plant growth and yield. Hormones control physiological processes, and synthetic growth regulators may strengthen field crop growth and development, resulting in increased total dry matter of a field crop (2). Chitin, which is found in the exoskeletons of crustaceans and insects as well as the cell walls of certain fungi, is the second-most common polymer in nature. Chitosan is a deacetylated chitin derivative mostly consisting of glucosamine units and 2- amino-2 deoxy—D-glucose (3). Chitosan (pronounced Kite-O-San) was recognized in 1811 by Henri Braconnot, who was the executive of the Botanical Gardens at the Academy of Sciences in Nancy, France. He discovered fungine, a mushroom produce that does not breakdown in Sulphuric acid (4). Chitosan was authorized as a feed additive by the Food and Drug Administration in the United States in 1983. Chitosan is commonly used in functional foods, protection of the environment and biotechnology (5). Chitosan's foundation possesses three types of functional groupings that boost its affinity for ions and contaminants: amino/acetamido groups, principal and secondary hydroxyl groups. Chitosan is a natural, reduced, renewable, environmentally benign, long-term, and cost-effective substance with multiple agricultural applications (6). Chitosan is not common in nature, but it is synthesized from chitin, mostly from crab shells, shrimp shells, squid pens and in rare circumstances, filamentous fungus via a heterogeneity deacetylation process (7).

Chitosan has many beneficial biological properties, including biodegradability, biocompatibility and non-allergenicity, in additional to its low expense of production Chitosan is destroyed by both particular and nonspecific enzyme and is mostly nontoxic to humans. Today, chitosan utilized in industrial applications is mostly obtained from crustaceans, specifically crab, prawn and shrimp shells, whose exoskeletons are easily available as food processing industrial wastes. However, it is rapidly becoming accessible as a by-product of protein extraction from insects for food/animal feed sectors and fungal fermentation.. Depending on certain estimates, 1012-1014 tons of chitosan from crustaceans are generated each year, and the global market for chitin and its derivatives was estimated at US$2900 million in 2017, with a compound annual growth rate (8). Furthermore, polysaccharides are widely used in food product creation and processing to impart desirable functional qualities such as thickening, gelling, emulsification and whipping. Chitosan, without exception, has been shown to have various different qualities (9).

Besides that, the shells of crustaceans are the primary source of chitin (shrimp, prawn, crab and lobster). Chitin, proteins, minerals and carotenoids are the main components of crustacean exoskeletons. Shrimp cultivation and processing is the world's largest fishing sector, accounting for around 45 % of all seafood consumed globally. The present shrimp output is predicted to be close to 5.03 million tons per year, with demand expected to rise further in the following years (10).

All of these characteristics combine to make Chitosan unique and very helpful in a variety of industries, including cosmetology, food, biotechnology, pharmacology and medicine (11). Chitosan contains potent antibacterial and antifungal properties that might help to minimize fruit rot. It could readily create a coating on fruit and vegetables and by changing the permeability of carbon dioxide and oxygen, the respiration rate of fruit and vegetables was lowered (12). Chitosan has been proven to reduce the systemic proliferation of viruses, viroids and bacterial growth all throughout plant, as well as to improve the host's hypersensitive reaction to infection (13). Chitosan has the following characteristics: it can damage cell walls, resulting in electrolyte leakage and pathogen death; it can invade a pathogen's nuclei, preventing protein and Ribonucleic acid synthesis; it can form an exterior film over a plant's surface, reducing nutrient availability for microorganisms; it can alter fungal growth and toxin production and it can induce the host plant's defense systems, including the activation of the salicylic acid (14).

Furthermore, chitosan not only stimulates the cells, but it also helps improve disease and insect resistance in the field and during storage. Chitosan application in agriculture, even without chemical fertilizer, can greatly increase the bacterial load (15). Despite this, foliar chitosan application resulted in greater plant growth and improved fruit quality in pepper, radish and cucumber. The beneficial effect of chitosan, on the other hand, is generally dependent on its concentration, preparation methods, environmental factors and growth condition (16). The new point of this review is that until today there are no published articles related to significance of Chitosan foliar spraying on the growth and yield of vegetable crop under protected cultivation. Hence The current novel study looks at the sources of chitosan, application of chitosan and the influence of foliar spraying chitosan and other chemical components on the growth, yield of Chilli, Tomato, Okra, Cucumber, Spinach, Sugar beet and potato under protected cultivation

Sources of chitosan

Chitin and chitosan are the world's second most prevalent naturally biopolymers. These polysaccharides, biopolymers feature a long linear chain-like structure that is linked to the functionalizable surfactant molecules through -d glucosideslinkage (17). Chitosan is a linear electrostatic polysaccharide generated from chitin (obtained from crustacean exoskeletons) by a deacetylation mechanism discovered in insect, fungi and algae (18). Although current research plan to use chitin from insects as a novel source of chitosan, the primary sources of commercial chitosan are fungi, crustaceans and squids. Indeed, the exoskeleton of insects is a plentiful byproduct of protein manufacturing for food utilizing this basic material (19). Chitosan is produced by the chemical or enzyme-mediated deacetylation of chitin, the material of which ranges from 44% for the exoskeleton of arthropods (crabs), 40% for the endoskeleton of cephalopods (squid) and 42% for the chassis of fungus. Chitin to chitosan conversion necessitates many preliminary stages, including demineralization with Hydrochloric Acid, microbial degradation, Sodium hydroxide and finally color removal (20).

According to one report, recent studies have discovered that chitosan and its substitutes under specific conditions employed oxidized microcrystalline cellulose grafted chitosan to make a novel and chitosan film dressing (21). In comparison to Hydrochloric Acid and Sodium hydroxide, the use of organic acids and enzymes in chitin extraction does not necessitate the use of specific reactor materials, lowering investment costs. The cost of producing chitosan using the environmentally friendly technique is 28% less than that of the traditional process (22). Chitosan is a moderately polysaccharide that is commercially accessible and inexpensive. It is most typically soluble in mild organic acids such as lactic, acetic, formic, citric, tartaric and malic acids. Because of its special characteristics, such as significant adsorption capacity, cationicity, macromolecular structure, low price and abundance, chitosan has received a great deal of attention in applications of water treatment (23).

Furthermore, while shrimp shells have a low economic value due to their use as animal feed, they are high in protein, minerals, and chitin. This waste could be used to make chitin and its derivative, chitosan, which have a significant economic value while having low manufacturing costs.. One of the economically advantageous possibilities is the extraction of chitosan from shrimp shells, which transforms shrimp shells from worthless trash into economic value represented by chitosan as a commercially important commodity with several applications. (24)

Application of chitosan

Chitosan in diverse concentration levels aids in the growth, yields and effectiveness of a variety of vegetables, including tomato, okra, cucumber, potato, spinach and artichoke. Incorporating Chitosan with added chemicals like potassium sorbate and potassium bicarbonate, as well as yeast, can enhance vegetable growth, yields and preservative levels in food. Immune system enhancement, microorganism inhibition, plant reaction stimulation, physiological properties such as growth and vegetative characteristics such as yield, biodegradability and biocompatibility are all great qualities found in this one-of-a-kind substance. According to one report, Chitosan boosted the content of capsaicin in jalapeo pepper by 51% (25). Found that Ceria nanoparticles applied to the soil at a concentration of 250 mg kg $^{-1}$ resulted in the greatest levels of total antioxidant properties in the tuber and leaves of *Raphanus sativus* L. It was revealed that chitosan-infused seeds and foliar spraying boosted plant height and leaf area in Chinese cabbage plants. Plant height and leaf number rose as Chitosan content increased (26).

Chitosan foliar application during the early stages of growth enhanced plant height, branching number, and leaf area plant, as well as nitrate reductase activity in leaves, resulting in higher total dry mass plant (27). Foliar chitosan treatment on tomato development (number of leaves per plant, number of branches per plant and plant height) and quality attributes (chlorophyll content, dry matter content, total nitrogen content and total phosphorus content) were shown to be considerably greater (28). Chitosan foliar spray at 100 mg $^{L-1}$ resulted in highest mean plant height, median number of leaves, leaf area, total chlorophyll, relative water content, excised leaf moisture retention, fruit plant, average fruit weight and yield (29). Chitosan foliar treatment resulted in increased vegetative growth and enhanced pepper quality of the fruit (30). All of the chilli characteristics such as plant height, branch per plant, fruits per plant, fruit length, fruit breadth and chilli weight all showed a positive connection with oligochitosan levels (31). Chitosan spraying at 0.10 $^{g-l}$ considerably boosted plant growth characteristics, yield and its components, total soluble solid %, nitrogen and phosphorus (32). Spraying plants with 0.10 $^{g-l}$ chitosan resulted in the greatest levels of plant growth, yield and its constituents, nitrogen and phosphorus content in summer squash fruits (33). The most efficient chitosan doses for increasing leaf number, leaf area, plant biomass and stomatal conductance were 0.75 and 1 mg mL^{-1}.

Furthermore, Chitosan, a natural, antibacterial, nontoxic, antioxidant, renewable and biocompatible molecule, has found widespread application in agriculture, food, medicine and cosmetics. Many studies have shown that chitosan is a bio-fungicide, resistance inducer and growth promoter that can be used to control plant diseases and promote plant growth (34). Chitosan has gained favor in recent years as an ecologically benign method of crop disease prevention. Chitosan's strong antibacterial action against a wide range of microorganisms, including fungus, bacteria, viruses and nematodes, is one of its most well-documented features (35). Chitosan-treated plants had fewer galls and less nematode proliferation than controls. The only fungus found parasitizing nematode eggs in chitosan-treated soils was *Pochonia chlamydosporia*. Soils containing naturally occurring *P. chlamydosporia* that have been treated with chitosan are expected to show increased colonization of plant roots and increased parasitism of eggs by the fungus. This strategy has the potential to reduce the population of plant-parasitic nematodes in agroecosystems indefinitely (36).

Chitosan's antifungal effect is primarily related to its suppression of mycelial development and spore germination. Chitosan restricts spore germination, budding tube elongation and radial growth by sequestering metals, minerals, trace elements, or nutrients required for fungal growth, according to early research. It has also been shown that chitosan’s suppression of pathogenic fungi in fruits may be connected to its ability to stimulate increase in the production of polyphenol oxidase and peroxidase stimulate (37). Another study found that chitosan-based covering surrounding the fruit reduced the penetration of the fungal germ tube and blocked the passage of nutrients to the outside, restricting the proliferation of harmful microorganisms. Chitosan and mint essential oil hindered mycelial growth and sporulation in *Aspergillus niger*, *Botrytis cinerea*, *Penicillium expansum* and *Rhizopus stolonifer* (38).

The mechanism behind this synergistic effect of chitosan combinations is unknown. However, synergism is more likely to occur when the individual components of a mixture act in different ways on their respective targets. This supports the previously reported process of extracellular membrane disruption by chitosan polymers, which leads to intracellular metabolic disruption by chitosan oligomers. Even though we do not completely understand the mechanism of antifungal synergism of chitosan mixtures, this result highlights the relevance of evaluating the molecular weight dispersity of a chitosan solution as a potentially important factor of its biological activity (39). The most likely mechanism for chitosan's antibacterial activities consists of the interaction of positive charges chitosan molecules with negatively charged bacterial cell surface byproducts, resulting in the leakage of proteinaceous and other intercellular components (40). According to (41), the effect of chitosan on fungal biological systems is well understood in terms of molecular weight (low, medium, or high). Chitosan with a low molecular weight may be more effective against mycelial development. Furthermore, additional investigations have revealed that concentration may be a component in the generation of different defensive responses in fungi.

The impact of Chitosan on the growth and yields of some vegetables crops

Chili

A study was conducted to find out how chitosan affects the development and production of chili seeds. They needed to use 20 ppm of chitosan with three different mass levels, such as lowing level 80 up to 100 kDa, medium level 200 up to 300 kDa and high level 600 up to 900 kDa consistent with MS medium Murashige Skoog and completely randomized design was used in this investigation, and the seedling has been grown within the greenhouse. As a consequence, they discovered that the seedling that was cultivated with 1% of Molecular weight (MW) has been observed with the maximum compounds chlorophyll and a good level of development, besides that, the seedling that was cultivated within the soil consistent with 1% MW of chitosan was evaluated greatest vegetative parameter such as the plant height and also the number of leaves, as well as the constituents of chlorophyll. This is because chitosan has really been identified as a high-potential biomolecule that promotes plant growth and yield. It has a wide range of applications in agriculture (42). According to one report, chitosan spray at 50 ppm increased vegetative development such as plant height, fruit size and chilli pepper production (43). So this is consistent with the previously mentioned experiment (44). Foliar treatments of chitosan-poly (acrylic acid) complexes had a responsible for the biological impact on the habanero pepper crop, boosting total plant dry biomass and the quantity of fruits of the 2 varieties (Chichen Itza and Jaguar). In addition, Chitosan could play a direct function in reducing Phytophthora pathogenicity, implying a possible role for chitosan as an alternative to traditional fertilizer and fungicide in the chili pepper plant (45). Hence, this is in agreement with the above mentioned experiment.

Tomato

An experiment has applied regarding the influence of chitosan on the efficiency of tomato (*Lycopersicon esculentum* L.) under water stress condition. They need used different levels of chitosan 0, 50, 100, 150 mg/L in keeping with a completely randomized design with 3 replications in check of glasshouse condition. They reported that various amounts of chitosan and level of the strain situations act influences on all characteristics and also they showed that level of 100 mg per litre of chitosan and interval of 6 days' water stress have good effects on the average plant height, medium number of leaves, area of leaves, the content of chlorophyll and fruits weight of tomato. This is due to Chitosan foliar spray decreased the influence of water stress on photosynthetic rate, which has the potential to boost endogenous cytokinins, which play an important role in increasing chlorophyll content in leaves. Chitosan in various concentrations increased chlorophyll content in tomato leaves and foliar application of chitosan reduced exchange of gases and transpiration from the leaves, lowering the demand for water and delivering water to biomass and yield during periods of low availability of water to the plant and improving photosynthetic machinery as well. Water stress treatment at 6-day intervals, blended with foliar spray of chitosan at level of 100 mg/L, is recommended for improving tomato performance under water stress conditions (46). The methods as well as combinations has been organized in Table 1. According to one study, foliar application of oligo-chitosan at rates of 60 or 100 ppm may increase plant height, flower number and yields and is recommended for tomato and eggplant (47). A study was designed to look into the effect of chitosan on the growth

Table 1. This table shows the Growth condition, Methodology, Function, of chitosan and other chemical compounds on growth and yield of the various crops

Crop	Growth condition	Dose and Methodology	Function	References
Chilli	Greenhouse	Chitosan: 20ppm, Foliar spraying	Plant height, Canopy diameter, Leaf number, Leaf width, Leaf length, Chlorophyll content, Fruit number, Fruit weight, Seed, Seed weight	42
Tomato	Glasshouse	Chitosan: 0, 50, 100, 150 mL Per litre, foliar spraying	Plant height, number of leaf, Leaf area, chlorophyll content, Water content	46
Okra	Greenhous	Chitosan: 0.5, 0.75%, Potassium salt: 1, 2%, Potassium bicarbonate: 2%, 3%, Foliar spraying	Plant height, number of branches, number of pod, pod length, pod weight, powdery mildew	49
Cucumber	Greenhous	Chitosan: 1, 2, 3, 4 mL per litre, Yeast: 1, 2, 3, 4 mL per litre, Foliar spraying	Plant height, number of leaf, Fresh weight, dry weight, weightof stem, dry weight stem, Fruit weight, fruit length, TSS, Total yield	52
Spinach	Greenhous	Chitosan: 0.1, 0.05, 0.01, 0.005, 0.001 mL, Foliar spraying	Total phenolic, flavonoid,phenolic, Protein, peroxidase, catalase	56
Potato	Greenhous	1, 0.1, 0.01, 0.001, 0.0001 per litre, Foliar spraying	Fresh weight, dry weight, shoot, Length, leaf length, leaf width, Leaf shape, tuber number, tuber yield	62

and yield of tomato (Cv. Rio Grande) plant under water stress condition, (Glass house) environment condition and they discovered that 100 mg^{L-1} chitosan usage along with 6 days water interval had a beneficial affect on tomato growth and quality. Hence these are in agreement with the above experiment undertaken to investigate the influence of various chitosan treatment techniques on tomato growth, yield and quality (*L. esculentum* Mill.) (15). They discovered that the treatment of soil application of chitosan 80 ppm and foliar application of chitosan 60 ppm produced the maximum tomato yield, whereas the control treatment produced the lowest. This is as a result of during drought stress, foliar chitosan application reduces water loss from the leaves by including stomatal type closing compounds, which are capable of reducing water loss from the leaf by enhancing plant biomass or crop yield. Furthermore, an experiment was conducted to determine the influence of chitosan and Cu nanoparticles (Cu NPs) on tomato plant development, antioxidant capacity, mineral content and saline stress (48). The current study shows that chitosan and Cu nanoparticles NPs both promoted vegetative and reproductive growth in tomato plants without causing saline stress.

Okra

A research has done to pursuit the influence of chitosan, potassium sorbate and potassium bicarbonates on the antioxidant compounds and physiological activities of Okra (*Abelmoschus esculentus* L.) that caused resistance against mildew. They utilized chitosan at rates of 0.5, 0.75 %, plus P sorbate at 1.0 %, 2.0 %, P bicarbonate at 2.0 % or 3.0 % as the most effective treatments and also the P sorbate at levels of 2 and 3 %, which were arranged in accordance with randomized completely block design under greenhouse conditions Egypt. As a result, single treatments of Chitosan, P sorbate and P bicarbonate at high concentrations 0.75 %, 2.0 % and 3.0 % had significant effects. As a result, foliar applications of Chitosan and potassium salts as pure and chemical stimulants can be used to control powdery mildew disease at early stages of growth, resulting in the highest fruit yield in okra plants (49). The combination as well as the methods has been shown in Table 1 (50). A study was carried out to look into the influence of foliar application of chitosan, a growth promoter, on the morphological, growth, biochemical, yield characteristics and fruit yield of okra cv. BARIdherosh -1. As a result, foliar applications of chitosan at 100 or 125 ppm may be employed to maximize fruit output in okra during an early development stage. In addition (51) In 2 consecutive seasons, 2013 and 2014, researchers conducted research in the Experimental Farm, Desert Research Center, Ras Sudr Region, South Sinai Governorate, Egypt. Okra plants cultivated with 200 ppm chitosan had the greatest height, number of leaves, fresh and dry weight per plant, leaf minerals (nitrogen, phosphorus), fruit number/plant, mean fruit fresh weight and plant yield. Hence, these are in harmony with above experiment.

Cucumber

An experiment has been conducted regarding the effect of foliar spraying of chitosan and also yeast on cucumber. They need used different levels of chitosan 1, 2, 3, 4 mL/L and also yeast at levels of 1, 2, 3, 4 g/L during two seasons 2010 and 2011 on growth and efficiency of cucumber crops under greenhouse condition. In consequence, he reported that level 4 mL/L of chitosan improved the compounds percent of potassium and phosphorus for the 2 seasons, finally, he demonstrated that foliar components of chitosan at the level of 4 mL/L resulted in the most effective parameters vegetative and reproductive of cucumber. According to the findings of this study, foliar application of active chitosan resulted in higher total yield and quality of cucumber plants. Under the laboratory conditions, it is possible to conclude that chitosan is much more efficient than yeast as a bio-stimulant for cucumber yield and quality. This is because the stimulating effects of vegetative growth may be attributed to the fact that chitosan treatment increased the availability and absorption of water and critical minerals by changing cell osmotic pressure (52). The combination as well as methods have been organized in Table 1 (53), has conducted research on the effects of viral infection on potato plant growth factors and metabolism, as well as the consequences of using chitosan and phosphorus to prevent Potato virus Y infection in these plants. Chitosan and Phosphorus enhanced plant resistance to Potato virus Y (PVY) and lowered sickness severity. Furthermore, 1.0% Chitosan might be utilized as a fungicide alternative in sustainable agriculture to inhibit Rhizoctonia canker and southern blight and increase carrot output (54). According to one report, Bitter melon plants have been grown at three sodium chloride (NaCl) salinity levels (0, 50 and 100 mM) with a foliar spray of Chitosan-Selenium Nanoparticles (Cs-Se NPs) (0, 10 and 20 mg L^{-1}) (55). At harvest, some important morphological, biochemical and physiological characteristics in leaf samples and essential oil from fruit have been measured. Treatment with 20 mg L^{-1} Chitosan-Selenium Nanoparticles (Cs-Se NPs) resulted in the greatest improvement in measured parameters under saline conditions, significantly increasing salinity tolerance in bitter melon plants.

Spinach

A research has done to pursuit the influence spraying of chitosan on the various levels of phytochemicals and antioxidant activities of Spinach. They need to utilize the chitosan at levels of 0.1, 0.05, 0.01, 0.005, 0.001 mg per mL. In the present experiment, Chitosan was used as a growth regulator molecule in this study to increase the phytochemical substance of the spinach plant. Chitosan, when applied as a foliar spray at a dosage of 0.01 mg for each mL, enhanced the enzymatic (peroxidase, catalase and phenylalanine ammonium lyase and non-enzymatic (total phenolic, flavonoids and proteins) defensive metabolites, as well as the antioxidant properties of spinach leaves and this is because of Chitosan has been demonstrated to activate the pathway that leads to the creation of flavonoids such as antioxidants, radical scavengers, antimutagenic, anti - inflammatory, anticarcinogen and depressive chemicals (56). The chitosan combination as well as the methodology have been tabulated in Table 1. Furthermore, 4 chitosan treatments (25, 50, 75 and 100 ppm) were sprayed as a foliar spray on spinach cultivars (All Pure Green, Desi Local and Lahori Palak) in contrast to the control (non-treated with chitosan). The outcomes of the study demonstrated that foliar treatment of chitosan had a substantial effect on characteristics under heat stress. Chitosan at 100 ppm produced the best results (57). In addition, a study was conducted to investigate the effect of chitosan foliar application on lettuce growth under drought conditions (58). In this study, three chitosan concentrations (0.2, 0.4 and 0.6 g/L) were tested. Chitosan application at 0.2 g/L was able to mitigate the effects of drought stress while maintaining lettuce growth. So these are in agreement with the above experiment.

Sugar beet

A research has done to pursuit the influence of multilateral efficacy of chitosan and trichoderma on the growth and antifungal effect on sugar beet (*Beta vulgaris*). The have used Commercial and preparedness of crustacean chitosan with various molecular weights, including low-molecular-weight (50-190 kDa), high-molecular-weight (310-375 kDa) and practical-grade (190–375 kDa).

According to the experiment, repeated foliar application of either high-molecular-weight and low-molecular-weight promoted growth, triggered defense responses and reduced the incidence of Cercospora leaf spot disease in *B. vulgaris*, based on the experiment Both agents are ideal candidates for reducing or complementing frequently used fungicides, according to our findings. Chitosan induced disease resistance and acted as a biocide. Additionally, covering *B. vulgaris* sp. *vulgaris* seeds with chitosan boosted germination efficiency and commencement. Our findings demonstrate that coating *B. vulgaris* seeds and foliar application of chitosan promotes growth, resistance and defense gene expression while decreasing Cercospora leaf spot (CLS) incidence. These findings might be explained by chitosan's position as a major enzyme in nitrogen metabolism (nitrate reductase, glutamine synthetase and protease) and its influence on photosynthesis, which increased plant growth (59). Chitosan coverings, both industrial and commercial, used as a foliar spray showed successful in keeping the quality of minimally processed lettuce at 4 °C for 15 days. The use of 12.5 g $^{L-1}$ significantly decreased all microbial populations, enhancing hygienic quality during post-harvest storage (60). In addition, A study was conducted to determine the effect of chitosan and Gibberlic acid on artichoke yield and quality (*Cynara scolymus* L.). The study contained twelve treatments: four levels of Gibberlic acid at 0 and 25 ppm, sprayed once, twice, or 3 times with a 1-month gap between treatments and 3 levels of chitosan at 0, 150 or 300 ppm. As a consequence, spraying chitosan at 300 ppm considerably improved plant growth parameters, head production and components. Spraying of high quality, we can conclude that these studies are in harmony with the above experiment (61).

Potato

The purpose of this study was to see if using soluble chitosan at concentrations of 1, 0.1, 0.01, 0.001, 0.0001 g/L in potato micro propagation can strengthen micro plant quality *in vitro*, aid in acclimatization *ex vitro* and increase yield and seed quality of mini tubers. Micro plants were treated *in vitro* with different concentration of dissolved chitosan added to semisolid tissue culture medium. Following that, the micro plants were moved to the greenhouse and sprayed with chitosan solutions. The chitosan concentration that was most beneficial to the *in vitro* growth of micro plants changed over time. Mini tuber number and yield in the greenhouse enhanced in treatments with the best *in vitro* growth. The application of foliar chitosan during the acclimatization phase stabilized the effect of *in vitro* treatment on yield parameters. Increases in yield lay between 5.8 and 89.1 % and mini tuber number between 21.4 and 52.2 % were observed in the preferred treatment, 0.1 g/L chitosan *in vitro* 1 g/L at acclimatization, increasing the effectiveness of mini tuber production as a large scale operation. This is because of Chitosan was discovered to boost secondary metabolite synthesis in cell suspensions and callus from different species. The seed quality of mini tubers derived from *in vitro* chitosan treatments alone and in mixture with foliar treatment was evaluated (62). The methodology and chitosan combination has been tabulated in Table 1. According to one report, under greenhouse circumstances, the effect of chitosan treatment on fruit yield and quality was investigated (63). Chitosan activated yield and secondary metabolite generation in tomato according to the results. Furthermore, Nano-chitosan was evaluated in a research to suppress root-knot nematodes, Meloidogyne incognita and Tobacco mosaic tobamovirus in greenhouse-grown tomato (64). The results showed that nano-chitosan reduced Meloidogyne incognita densities by 45.89 to 66.61 % whether used alone or in the presence of Tobacco mosaic tobamovirus (TMV). Tomato plant morphogenesis, such as shoot and root systems was much enhanced.

Conclusion

Chitosan is gaining popularity in agricultural protection cultivation as an antimicrobial agent, plant growth promoter and edible film for vegetable covering. And because of its potential physiological effects, this substance attracted attention of people in recent years. One of the main point of this review is that ther are no published articles related to significance of Chitosan foliar spraying on the growth and yield of vegetable crop under protected cultivation. Hence, present new studies have been evaluated to investigate the influence foliar spraying of chitosan in order to improve the growth and yield of vegetables. Such products can be employed alone or in combined effect with other chemical additives such as potassium sorbate, potassium bicarbonate, yeast and etc to reduce disease levels and prevent pathogen growth and spread, thereby preserving both quality and yield. The result of present study indicated that foliar application of chitosan combined with other chemical compounds have superior effect on the vegetative characteristics (plant height, leaf size, number of flowering, Fruit length, fruit diameter, fruit weight, total yield) also the chemical compounds like (Total soluble solid, Vitamin C, Phenolic compound, sugar, amino acid) of vegetables.

Ultimately, It could be concluded that, foliar spraying of chitosan is more effective than other bio-stimulant and chemical additive for the growth and yield attributes of vegetables and has a hopeful future in terms of crop productivity that is both sustainable and environmentally friendly under protection cultivation.

Authors contributions

All the authors have participated and cooperated for preparation of this manuscript like designed the data, acquired the data, reviewed and have approved the final manuscript for submission.

Compliance with ethical standards

Conflict of interest: We the authors do not have any conflict of interest to be declared.

Ethical issues: None.

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