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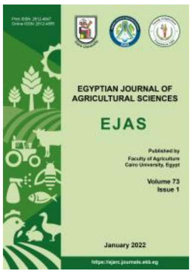

Response of *Phaseolus vulgaris* Plants to Foliar Spray and Soil Drenching by Silver Nanoparticles (Ag^+NPs)

By

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ABSTRACT

This study was conducted to evaluate the response of common bean (*Phaseolus vulgaris* L.), Paulista cv., to silver nanoparticles (Ag^+NPs) levels *i.e.*, 0, 50, 100, and 150 ppm as foliar spray or soil drenching. The results showed that superiority values of plant vegetative growth characteristics (plant length, number of branches/plants, and plant fresh weight) as well as leaf chlorophyll content, total green pods yield and pod traits (pod length, pod diameter, and pod fresh weight) were pronounced at 50 ppm foliar spray treatment followed by 100 ppm concentrates as soil drenching. However, silver nanoparticles at the high dose of 150 pp, particularly foliar spray, obviously causes decreases in plant vegetative characteristics, total green pods yield (ton/fed) and pod chemical contents of protein and carbohydrates. It can be concluded that silver nanoparticles can be used in low concentrations to improve the growth, productivity, and pod chemical contents of *Phaseolus vulgaris* plants.

Keywords: *common bean, silver nanoparticles, Phaseolus vulgaris, quality, productivity*

1. INTRODUCTION

Snap bean/ common bean (*Phaseolus vulgaris* L.) is one of the most important members of leguminous crops in Egypt for local consumption and/ or exportation. It is an essential source of protein, vitamins, minerals and dietary fibers (Jackson *et al*., 2012). Nanotechnology is an innovative approach that turned materials to nano-scale at dimensions of 1-100nm. The nanoparticles are synthesized by different approaches *i.e.*, chemical, physical, photochemical, top-down and bottom-up, as well as biological methods. The nanoparticles have a large surface area in relation to their volume and have unique physical properties (Pradhan *et al*., 2017), and play essential roles in various fields like biotechnology, food security, industry, and crop production. Using nanoparticles in agricultural development is a recent innovation that is still progressive, and their interactions with plants have not been clarified and understood in detail (Gogos *et al*., 2012). Silver nanoparticles (Ag^+NPs) offer a rather promising response for agriculture. They have been shown to enhance seed germination, plant growth, photosynthetic efficiency and chlorophyll content, while also act as safe and effective nano-pesticides and nano-fertilizers (Zheng *et al.*, 2005). The uptake process and response of Ag^+NPs within the plants is associated with a number of determinants related to the physical properties of nanoparticles (size, surface coating, concentration, functionalization, and morphology), soil components, symbiotic microorganisms, plant species (monocotyledons and dicotyledons), and the exposure time (Khan *et al*., 2023). It was reported that plant leaves can absorb Ag^+NPs

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through cuticle and stomata pathways and particles below 2 nm in size can penetrate directly through the cuticle into plant tissues. For larger particles, the uptake through stomatal openings may be feasible (Avellan *et al*., 2019; Eichert and Goldbach, 2008). Most of the leaves can absorb Ag^{+}NPs with sizes in the range of 10–40 nm (Huang *et al*., 2022). After reaching the root surface, small Ag^{+}NPs (<40 nm) can directly pass through the structure of the cell wall (Castro-González *et al*., 2019), while larger Ag^{+}NPs may enter the cytoplasm through endocytic uptake, pore formation or wounds (Schwab *et al*., 2016). The details of the mechanisms of transformation and translocation of Ag^{+}NPs in plants are still limited (Huang *et al*., 2022). Previous studies confirm that foliar Ag^{+}NPs treatment at 20, 40, and 60 mg/L maintained growth parameters, photosynthetic pigments such as chlorophyll a, and chlorophyll b, and improved seed's chemical contents *i.e.*, carbohydrate and protein percentage of fenugreek plants (Sadak, 2019). It enhances cowpea dry weight and length at concentration of 50 mg/l, also brassica shoot within 75 mg/l concentrate (Abou El-Nour *et al*., 2010). Ag^{+}NPs produced a higher percentage of dry mass and root growth of lettuce, radish and oat when used as soil drenching (Tomacheski *et al*., 2017). Most studies revealed that low levels of Ag^{+}NPs induced plant growth, while higher concentrations caused inhibition (Mandal *et al*., 2006 and Khatami *et al*., 2018).

The aim of this study is to evaluate the response of *Phaseolus vulgaris* L. plant–growth and pod yield per feddan (1 hectare *= 2.380952* feddan) and characteristics with respect to using silver nanoparticles in different concentrations and applying methods.

2. MATERIALS AND METHODS

This study was conducted at the experimental farm, Elkassasein, Research Station, Ismailia Governorate, Egypt during the summer seasons of 2020 and 2021. Seeds of *Phaseolus vulgaris* L., Paulista cv., purchased from Makka, Co., Cairo. Silver nanoparticles at (10-20 nm size) were synthesized by microbial method, and the used concentrates were *i.e*., 50, 100, and 150 ppm of Ag^{+}NPs were prepared in Geological Isotopes, Nuclear Materials Authority, Kattamia, Cairo, Egypt, as described by Salama (2012).

2.1. Field cultivation

Seeds of *Phaseolus vulgaris* L. were sown during the summer seasons of 2020 and 2021, on the 10th and 15th of November in the two growing seasons, respectively, at 5 cm apart between plants on one side of the ridge. The experimental unit area was 10.5 m^2 which contained 5 ridges with 3.5 m length and 60cm width for each. Plants (25 days old from seeds sowing), were treated with different concentrates (0.0, 50, 100, and 150 ppm) as foliar spraying or soil drenching at once-a-week intervals till the first harvest. All agricultural methods were applied according to the recommendation of the Egyptian Ministry of Agriculture for snap beans. The experiment was arranged in a randomized complete block design with three replicates including 7 treatments. The farm soil texture; physical and chemical analyses are shown in Table (1).

Table (1): Soil physical and chemical analysis.

Parameter	Quantity
Sandy loam	
Sand (%)	80.3
Silt (%)	2
Loam (%)	17.6
pH	8.4
E.C. (dSm^{-1})	0.2
$CaCo_3$ (%)	5.2
Soluble cations (mL)	
Ca^{+2}	1
Mg^{+2}	0.5
Na^{+}	0.3
K^{+}	0.2
Macro elements(ppm)	
N	40
P	66
K	40
Microelements (ppm)	
Fe	3
Cu	0.8
Zn	1
Mn	1.5
Soluble anions (mL)	
HCO^{-3}	0.2
Cl^{-2}	0.5
SO_4^{-2}	1.3

2.2. Data recorded

2.2.1. Vegetative growth parameters and chlorophyll content

A sample of five plants was taken randomly from each plot at the flowering stage in order to determine vegetative growth parameters *i.e.*, plant length (cm), branches per plant as well as plant fresh weight (g/plant). The total leaf chlorophyll content at the fourth upper leaves was recorded using Minolta Chlorophyll Meter, SPAD-501 was recorded as SPAD unit (Spectrum Technologies, Inc., Aurora, IL, USA).

2.2.2. Total green pods yield and characters

A sample of ten fresh green pods at the marketable stage of Paulista cv., were randomly taken from each plot at the second picking to determine the following data: pod length (cm), pod diameter (cm), average pod weight (g) and total green pods yield (ton/fed) were estimated (the weight of all pickings).

2.2.3. Chemical components of pods

Ten fresh green pods at the marketable stage were dried in an oven at 70 Co till a constant weight was achieved, then grounded to reach powder case. A sample of 0.2 g from a fine dry powder of green pods was digested in a mixture of sulfuric and perchloric acids according to Piper (1947) to estimate protein and carbohydrate content (%) according to A.Q.A.C. (1990).

2.3. Statistical Analysis

All data were subjected to statistical analysis according to Snedecor and Cochran (1980) using M-stat program, and the means were compared by L.S.D multiple range tests at the 5% level of probability in the two seasons of the experiment.

3. RESULTS

3.1. Vegetative growth parameters and chlorophyll content

Presented data in Table (2) showed that vegetative growth parameters differed according to the applications methods involved foliar spray (FS) or soil drenching (SD) and levels of silver nanoparticles. Whereas, silver nanoparticles at the low level (50 ppm) have the potential to improve the vegetative characters expressed as plant length (PL), plant fresh weight (FW), and the number of branches/plant (NB) as well as leaf chlorophyll content (Ch). Thus, he results were maximized to this level when used as foliar spray (FS) which cause an increment percentage by 33, 26, 20, and 23%, respectively, as average of two seasons followed by using 100 ppm, SD that had an increased ratio 20, 16, 8 and 14%, respectively, over the control treatment (Fig. 1). No significant differences were observed between 100 and 50 ppm Ag^{+}NPs Soil drenching (SD) for Plant fresh weight and number of branches in both seasons and plant length in 1st one. The negative impact has occurred with 100 ppm as FS and 150 ppm as FS or SD. The inhibition percentage (as the average of the two seasons) reached to 7.6, 6.9, 7 and 6.6% at 100 ppm FS and 15, 20, 19 and 13% at 150 ppm FS, and 3, 6, 10 and 2% at 150 ppm, SD on PL, FW, NB and Ch, respectively. It was noted that the severe deficiency was due to using Ag^{+}NPs at the high level (150 ppm, FS), (Fig. 1).

3.2. Total green pods yield and characters

The significant values obtained for yield component in terms of pod length (L), pod diameter (PD), pod fresh weight (PFW), and total green pods yield (TGY) were established through foliar application at 50 ppm concentration in both seasons (Table 3). This resulted in an increment by 14, 11, 16 and 10%, respectively, as an average of two seasons, followed by using 100 ppm (Fig. 2). It was obvious that no significant differences were observed between 50 ppm Ag^{+}NPs foliar application (FS) and 100 ppm soil drenching (SD) for pod diameter and total green pods yield in both seasons as well as pod length and pod fresh weight in 1st season. Also, the results of the medium level (100 ppm) used as SD related to all previous parameters were significant except in traits PFW and TGY which was insignificant with control treatment in 2nd season. On the other hand, data in Table (3) indicated that all the other concentrations of either FS or SD applications had harmful effects on the pod and yield characteristics in both seasons except total green yield and pod diameter in the first and second seasons, respectively.

It was observed that both concentrates 100 ppm as FS and 50 ppm as SD they had a very similar effect on pod length, pod diameter, pod fresh weight, and total green yield that they cause a close level of deficiency, thus the decrease (average of two seasons) reached 8, 4, 15 and 3% using 100 ppm (FS) and 9, 4, 15 and 3% using 50 ppm (SD), respectively. On the contrary, the most negative impact on previous parameters obviously was coupled with using Ag^{+}NPs at the high levels (150 ppm) whether spraying or drenching was applied. The average percentage of inhibition reached 11 and 13% for pod length; 9 and 11% for pod diameter; 30 and 30% for pod fresh weight and 8 & 8% for total green yield as a result of foliar spray and soil drenching, respectively (Fig 2).

Table (2): Vegetative growth traits as affected by silver nanoparticles treatments during the two growing seasons of 2020 and 2021.

Treatments		Plant length (cm)	Plant fresh weight (g)	No. of branches/ plant	Chlorophyll (SPAD)	Plant length (cm)	Plant fresh weight (g)	No. of branches/ plant	Chlorophyll (SPAD)
Concentrate (ppm)		1st season				2nd season			
Control	0.0	35.47	51.47	5.75	45.96	34.72	55.84	5.38	43.53
Ag+NPs Foliar spray (FS)	50	45.64	71.69	6.68	54.46	47.93	63.92	6.63	55.47
	100	32.49	49.25	5.16	42.45	32.33	50.50	5.18	41.03
	150	30.43	40.27	4.73	40.17	28.90	45.71	4.34	37.79
Ag+NPs Soil drenching (SD)	50	39.22	59.94	5.85	47.59	38.09	57.13	5.90	46.87
	100	41.13	62.70	6.02	51.36	43.08	61.57	6.04	50.46
	150	33.66	48.51	5.14	44.92	34.17	52.80	4.83	42.97
L.S.D at 5%		2.18	3.40	0.22	2.95	4.29	5.29	0.39	2.70

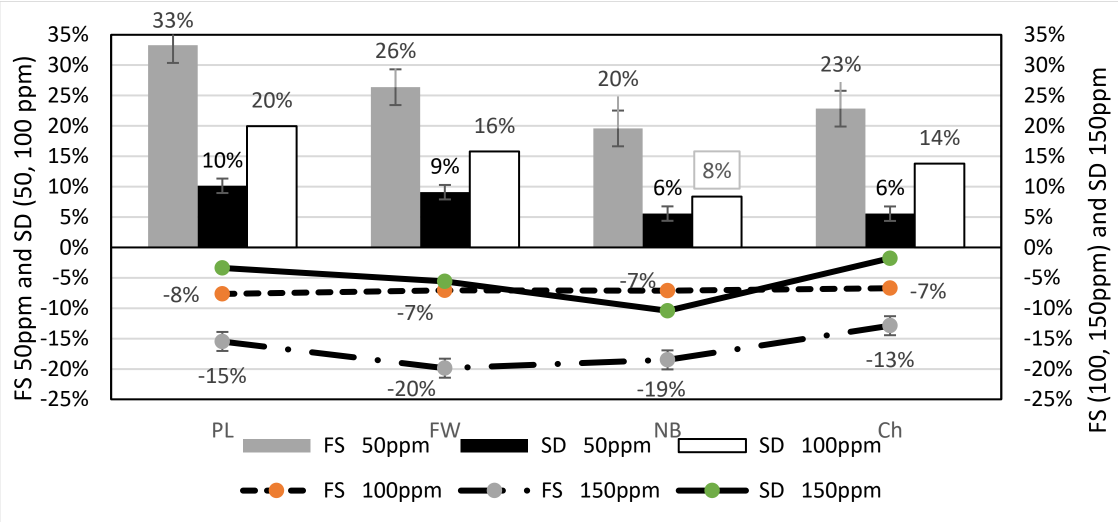

Fig. (1): The increasing or decreasing percentage (average of two seasons) overall the control treatment with respect to Ag$^+$NPs levels on *Phaseolus vegetative* parameters and leaf chlorophyll content.
FS= Foliar spray SD= Soil drenching.

Table (3): Total green pods yield and pod characters with respect to silver nanoparticles treatments during the two growing seasons of 2020 and 2021.

Treatments		Pod length (cm)	Pod Diameter (cm)	Pod fresh weight (g)	Total green Yield (ton/fed)	Pod length (cm)	Pod Diameter (cm)	Pod fresh weight (g)	Total green Yield (ton/fed)
Concentrate (ppm)		1st season				2nd season			
Control	0.0	11.71	0.59	3.66	3.08	11.44	0.64	3.50	3.22
Ag+NPs Foliar spray (FS)	50	13.20	0.65	4.27	3.47	13.19	0.72	4.06	3.49
	100	10.66	0.54	3.10	3.07	10.61	0.64	2.99	3.02
	150	10.47	0.51	2.58	2.95	10.12	0.61	2.46	2.85
Ag+NPs Soil drenching (SD)	50	10.46	0.54	3.10	3.07	10.61	0.64	2.99	3.02
	100	12.83	0.63	4.11	3.29	12.24	0.71	3.62	3.38
	150	10.07	0.50	2.58	2.95	10.10	0.60	2.46	2.85
L.S.D at 5%		0.83	0.03	0.25	0.21	0.61	0.03	0.17	0.19

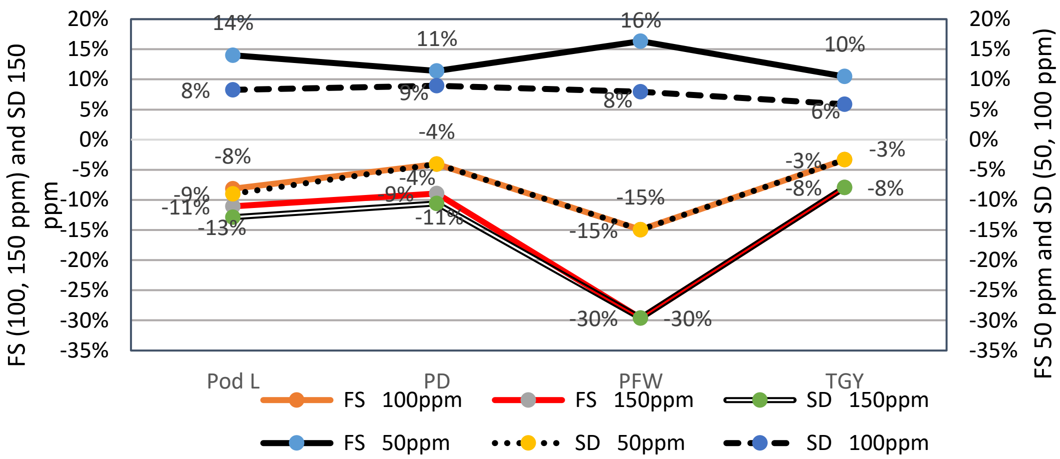

Fig. (2): The increasing or decreasing percentage (average two seasons) overall the control treatment with respect to Ag^{+}NPs levels on phaseolus yield and pod attributes FS= Foliar spray SD= Soil drenching.

3.3. Chemical components in pod

The effects of silver nanoparticles' different concentrations and applying methods are presented in Table (4). Low-dose (50 ppm) as foliar spray significantly recorded the highest pod content of protein and carbohydrate (CarbH) followed by a higher dose (100 ppm) as soil drenching which has a significant effect on protein only in two growing seasons. The average increase of pod protein content over the control due to the low-dose (50 ppm) reached 12%, and for carbohydrate was 11%. However, the percentage reached (10%) for pod protein and (6%) for carbohydrate by the high level (100 ppm) as shown in Fig. (3). The decrease in both parameters were observed when using high dose (100 ppm) as FS and 150 ppm, either spray/or soil application. Hence, the average decline due to using 100 ppm foliar spray was estimated at 3% for pod protein and 6% for pod carbohydrates content overall the control treatment. Meanwhile, Ag^{+}NPs at highly level of 150 ppm cause acute deficiency especially in the carbohydrate parameter its average percentage reached 33% and 21%, while it reached 11% and 3% for pod protein content for foliar spraying and soil drenching, respectively (Fig. 3).

4. DISCUSSION

The positive results obtained in our study might be attributed to the silver nanoparticles having a potential effect on plant growth through changes in biochemical, physiological, and molecular aspects, so it is considered as an excellent growth stimulator for plants as reported by Nowack and Bucheli (2007) and Sharon *et al*. (2010). It improves plant morphological growth parameters (Salama, 2012). The favorable effect due to the 50 ppm foliar spray of Ag^{+}NPs, which was obtained in this study, was compatible with those found byseveral researchers, where it was documented that Ag^{+}NPs at low concentrations significantly increases plant vegetative growth parameters, e.g. Sharma *et al*. (2012) on *brassica juncea*, Pallavi *et al*. (2016) on cowpea, Vishwakarma *et al*. (2017) on brassica spp, Al-Huqail *et al*. (2018) on *Lupinus termis* L, Adil *et al*. (2022) on wheat and Bsoul *et al*. (2023) on spinach. Improving plant growth as a result of using nanoparticles (NPs) might be attributed to increasing several physiological processes such as photosynthetic pigments and Indole-3-Acetic Acid (IAA), which enhance plant growth (Sadak, 2019). In this respect, Wagi and Ahmed (2019) proposed that nanoparticles might interact with plant hormones and antioxidants and promote plant growth. They also suggested that Ag^{+}NPs promote root exudates production that may facilitate plant microbes' interactions, which in turn improve plant growth. Photosynthetic pigments are the basis for absorbing and transferring light energy (Ruiz-Espinoza *et al*., 2010). Chlorophyll is the main pigment in photosynthesis. In our study, silver nanoparticles were increased chlorophyll content in leaves as result of foliar spray at 50 ppm (Table 2). The ability of silver nanoparticles to boost chlorophyll leaf content in treated plants was attributed to the metal nanoparticles which induced the efficiency of chemical energy production in photosynthetic

Table (4): Pod chemical content as affected by silver nanoparticles treatments during the two growing seasons of 2020 and 2021.

Treatments		Protein (%)	Carbohydrate (%)	Protein (%)	Carbohydrate (%)
	Concentrate (ppm)	1[st]season		2[nd] season	
Control	**0.0**	17.80	8.91	17.88	9.06
Ag+NPs Foliar spray (FS)	**50**	20.00	9.82	19.90	10.10
	100	16.93	9.10	17.58	7.87
	150	15.19	6.00	16.40	6.02
Ag+NPs Soil drenching (SD)	**50**	19.00	9.40	18.20	9.43
	100	19.37	9.48	19.78	9.62
	150	17.04	7.15	17.48	7.00

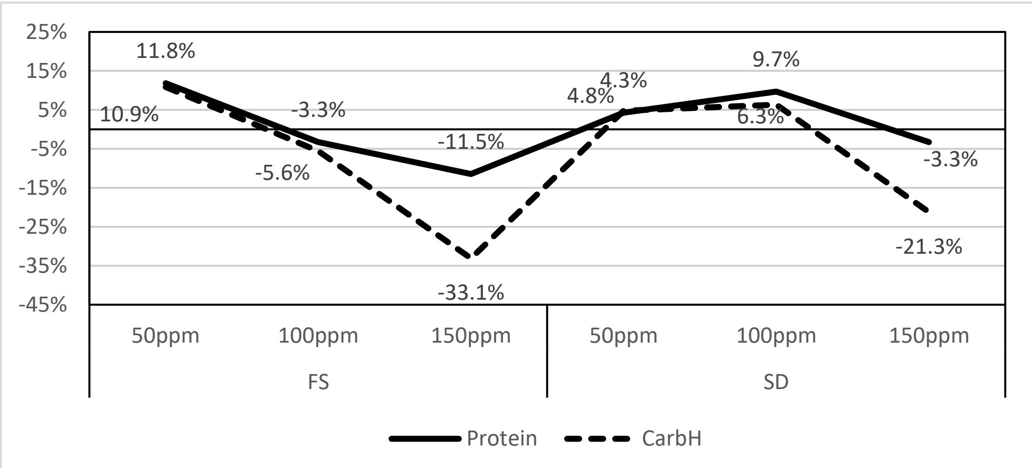

Fig. (3): The increasing or decreasing percentage (average of two seasons) overall the control treatment with respect to Ag^{+}NPs levels on pod content of protein and carbohydrates. FS= Foliar spray SD= Soil drenching

systems leading to higher content of photosynthetic pigments, *i.e.*, chlorophyll a; chlorophyll b that led to increase the rate of photosynthesis and resulted in plant vigor Govorov and Carmeli (2007). This is in line with the results obtained by Najafi and Jamei (2014) on mung bean, Farghaly and Nafady (2015) on tomato and wheat, Pallavi *et al*. (2016) and Verma *et al*. (2020) on common bean. Latif *et al*. (2017) reported that Ag^{+}NPs significantly promote photosynthesis. In our study, the foliar spray in low doses was produced the best vegetative values, followed by the higher dose (100 ppm) as soil drenching. The potential of silver nanoparticles as foliar spray, as mentioned above, is confirmed by Adrees *et al*. (2021) who revealed that metal nanoparticle (NPs) as foliar application is most effective for plant growth compared to direct soil application. The highest depressed values, which was shown in this study by highly concentrated 150 ppm whether as foliar spray (FS) or soil drenching (SD) might be due to the fact that NPs have the capability to penetrate cell walls and plasma membranes of epidermal layers upon exposure of plants, thereafter a series of events reached the vascular tissues (xylem). Therefore, NPs can be translocated to the leaves (Yan and Chen, 2019), shoot (Ma *et al*., 2010) and root meristem, or other organs through long-distance transport (Geisler-Lee *et al*., 2013). After the accumulation of Ag^{+}NPs, phytotoxicity symptoms at several levels, *i.e.*, morphological, physiological, cytotoxicity and Geno toxicity are well observed on plants. The decrease in plant biomass and inhibited shoot growth were considered as morphological level (Hong-Sheng *et al*., 2012). However, the physiological level is predicted by reduction of chlorophyll and nutrient uptake, thus affect the photosynthetic system of the plants (Tripathi *et al*., 2017), and reduce the transpiration rate, and alteration of hormone (Budhani *et al*., 2019). Meanwhile, the cytotoxicity and genotoxicity level involved damage of cell morphology and structure, reduction of cell turgidity and size of vacuole (Pokhrel and Dubey, 2013 and Mirzajani *et al*., 2013). Moreover, it increased the chromosomal aberrations and micronuclei, and decreased the mitotic index (MI) in cells (Patlolla *et al*., 2012).

It is noteworthy to mention that the main mechanism of Ag^{+}NPs phytotoxicity is the production of excess reactive oxygen species (ROS) resulting in induced oxidative stress in plant cells (Nair *et al.*, 2010). It was reported that the induced oxidative stress was positively correlated with the increasing concentration of Ag^{+}NPs (Oukarroum *et al*., 2013). Similarly, Cvjetko *et al*. (2017) found that Ag^{+}NPs induced oxidative stress and exhibited phytotoxicity only when applied in higher concentrations. The phytotoxicity of Ag^{+}Nps were proven in numerous studies such as Stampoulis *et al*. (2009) on *Phaseolous radiates* and *Sorghum bicolor,* Ma *et al*. (2010) on rice, Lee *et al*. (2012) on zucchini plants and Salama (2012) on common bean and corn. Nevertheless, Ag^{+}NPs significantly affect the membrane fluidity and permeability consequently influences the uptake of water and nutrients (Xalxo*, et al*., 2021). Indeed, a signal for decreasing was received by the high level of Ag^{+}NPs, where the decline in leaf chlorophyll content might be due to replacement of Mg^{+} with heavy metals in chlorophyll structure as reported by Küpper *et al*. (1998), and consequently inhibiting the enzymes activity in Calvin cycle, and reduce chlorophyll synthesis (Baryla *et al*., 2001), and Benavides *et al*. (2005) reported a diffusion in photosynthesis processes and plant growth parameters compared with control treatment as appear in this study. Silver NPs can affect photosynthesis adversely by disturbing the synthesis of chlorophyll (Xalxo *et al*., 2021). It was documented that the higher concentration of NPs caused a reduction in the total chlorophyll, dehydrogenases and assimilates supply (Nhan, 2015 and Li *et al*., 2022). Previous results were confirmed by Râcuciu and Creanga (2007) who reported that the chlorophyll content of maize leaves increased with a low concentrate of 10-50 $\mu l\, l^{-1}$ Ag^{+}NPs, whereas it was found to be low in high concentrations.

The potential effects of Ag^{+} NPs at low-dose 50 ppm in promoting plant production and enhancing yield component, were explained by several views. It was documented that silver is an excellent growth regulator effective in plant yield (Sharon *et al.,* 2010). Ag^{+}NPs improve the efficiency of electron transport pathway and prevent the formation of ROS that leads to a higher yield of plant (Sharma, 2012), Ag^{+}NPs improve plant yield by blocking the action of ethylene (Rezvani *et al.*, 2012). Metal in nanoparticles form possess a high surface area, solubility and penetration capacity being practiced to modulating plants' physiological response thereby improve plant health and productivity (Jurkow *et al*., 2020). Ag^{+}NPs act as nano-fertilizers and nano-pesticides promote plant growth and increase productivity of crops (Khan *et al*., 2023). Also, as mentioned above, Ag^{+}NPs play an imperative role in photosynthetic activity of plants and also increases production of growth promoter Indole acetic acid (IAA), therefore improving plant yield and yield component (Razzaq *et al*., 2016). Our results are in line with those found by to Najafi and Jamei (2014), who deduced that 50 ppm treatment of Ag^{+}NPs resulted in greater improvement in mung bean production. Sadak (2019) on fenugreek and Verma *et al*. (2020) on *Phaseolus vulgaris* and Wasaya *et al.* (2020) who suggested that foliar application of silver and zinc nano-particles significantly affected yield and yield related traits of mung bean. Similar results were reported by Janmohammadi *et al.* (2016) on barley, Jalali *et al*. (2017) on maize, Mehmood and Murtaza (2017**)** on pea, Dapkekar *et al.* (2018) and Adil *et al.* (2022) on wheat.

The decrease in yield and pod characters obtained in our study as related to Ag^{+}NPs different levels and applications particularly with using the high concentrations (150 ppm) as spray or soil applied could be reflected of phytotoxicity happened resulting from the accumulation of Ag^{+}NPs in plant tissue which led to generation of ROS and induced oxidative stress as confirm by Feigl *et al.* (2015) and (Singh *et al*., 2021). To protect the cells from oxidative stress and scavenge ROS the plants activate both of enzymatic and non-enzymatic antioxidant defense systems moreover modifies metabolism and synthesis of phenolic compounds (Xu and Rothstein, 2018) in addition to suppression in photosynthesis (Budhani *et al.*, 2019) resulting in decreasing plant yield and pods quality. Also, our results are confirmed by Krishnaraj *et al*. (2012) who reported that Ag^+NPs induced the synthesis of protein and carbohydrates in treated plants. Mehmood and Murtaza (2017) deduced that Ag^+NPs improved pea seeds' contents of carbohydrates and protein. Sadak (2019) reported that silver nanoparticles at low doses supported the content of carbohydrate and protein percentages in fenugreek seeds. Tomaszewska-Sowa *et al*. (2018) on water hyacinth, and Jahangir *et al*. (2020) in their study on onion bulb stated that Ag^+NPs exhibited maximum increase in protein content. The enhancement of the plant's biochemical attributes by the nanoparticles was documented by Salama (2012), Sharma *et al*. (2012), Latif *et al*. (2017) and Sorahinobar *et al*. (2023). In this study, there was a correlation between a high dose of silver nanoparticles and deficiency in both protein and carbohydrates it could explain these results thought that once silver nanoparticles enter into plant cells behave as metal ions causing oxidative damage, which led to harmful effects such as decrease in protein content (Yadu *et al*., 2018).

Conclusion

It could be concluded that silver nanoparticles at 50 ppm foliar spray treatment were worthy to improve plant vegetative growth and pod characteristics as well as total green pods yield (ton/fed). Furthermore, pods chemical components of protein and carbohydrates followed by a high-level 100 as soil drenching. The deficiency in growth parameters or pod yield and chemical contents of both protein and carbohydrate were related to high-dose 150 ppm, especially foliar spraying.

Authors' contributions

The authors have direct contributed in planning, conceptualization, execution, methodology, software, validation, formal analysis of data, investigation, resources, data curtain, writing the original draft preparation, writing, reviewing, editing, supervision and funding acquisition for this study. Authors of this manuscript have read and approved the final submitted version.

Competing interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript.

5. REFERENCES

Abou El-Nour, K. M., Eftaiha A., Al-Warthan A. and Ammar R.A.A. (2010) Synthesis and applications of silver nanoparticles. Arab. J. Chem. 3(3): 135–140.

Adil, M., Bashir S., Bashir S., Aslam Z., Ahmad N.,Younas T., Muhamad R., Asghar A., Alqahtani J., Dwiningsih Y., and Elshikh M.S. (2022). Zinc oxide nanoparticles improved chlorophyll contents, physical parameters, and wheat yield under salt stress. Front. Plant Sci. 13:1-9.

Adrees, M., Khan Z. S., Hafeez M., Rizwan M., Hussain K., Asrar M., Alyemeni M. N., Wijaya L. and Ali S. (2021). Foliar exposure of zinc oxide nanoparticles improved the growth of wheat (*Triticum aestivum* L.) and decreased cadmium concentration in grains under simultaneous Cd and water deficient stress. Ecotoxicol Environ Saf. 15, 208: 111627.

Al-Huqail, A. A., Hatata M. M., and Ibrahim M. M. (2018). Preparation, characterization of silver phyto nanoparticles and their impact on growth potential of *Lupinus termis* L. seedlings. Saudi J. Biol. Sci. 25: 313–319.

A.Q.A.C. (1990). Association of official analytical chemist's methods of analysis. Washington, D. C. 2004.

Avellan, A., Yun J., Zhang Y., Spielman-Sun E., Unrine J. M., Thieme J., Li J., Lombi E., Bland G. and Lowry G. V. (2019). Nanoparticle size and coating chemistry control foliar uptake pathways, translocation, and leaf to rhizosphere transport in wheat. ACS Nano. 13(5): 5291–5305.

Baryla, A., Carrier P., Franck F., Coulomb C., Sahut C. and Havaux M. (2001). Leaf chlorosis in oilseed rape plants (*Brassica napus*) grown on cadmium-polluted soil: causes and consequences for photosynthesis and growth. Planta. 212**:** 696–709.

Benavides, M. P., Gallego S. M. and Tomaro M. L. (2005) Cadmium toxicity in plants. Braz. J. Plant Physiol. 17(1): 21-34.

Bsoul, E. Y., Othman S. A., Al-Ghazawi A. A., and Massadeh M. I. (2023). Effect of silver nanoparticles on growth and physiological responses of spinach (*Spinacia oleracea* L.) under salt stress. Jordan J. Biol. Sci. 16 (1):1-6

Budhani, S., Egboluche N.P., Arslan Z., Yu H. and Deng H. (2019). Phytotoxic effect of silver nanoparticles on seed germination and growth of terrestrial plants. J. Environ. Sci. Health Part C Environ. Carcinog. Ecotoxicol. Rev. 37(4): 330–355.

Castro-González, C. G., Sánchez-Segura L., Gómez- Merino F. C. and Bello-Bello J. J. (2019). Exposure of stevia (*Stevia rebaudiana* B.) to silver nanoparticles in vitro: transport and accumulation. Sci. Rep. 9:10372.

Cvjetko, P., Milošic A., Domijan A. M., Vinkovi´C., Vrˇcek I., Toli´c S., Peharec Štefani´c P., Letofsky-Papst I., Tkalec M. and Balen B. (2017**)**. Toxicity of silver ions and differently coated silver nanoparticles in *Allium cepa* roots. Ecotoxicol. Environ. Saf. 137:18–28.

Dapkekar, A., Deshpande P., Oak M. D., Paknikar K. M. and Rajwade J. M. (2018). Zinc use efficiency is enhanced in wheat through nano-fertilization. Sci. Rep. 8,6832: 1-7.

Eichert, T. and Goldbach H. E. (2008). Equivalent pore radii of hydrophilic foliar uptake routes in stomatous and astomatous leaf surfaces further evidence for a stomatal pathway. Physiol. Plant.132(4): 491–502.

Farghaly, F. A. and Nafady N. A. (2015). Green synthesis of silver nanoparticles using leaf extract of Rosmarinus officinalis and its effect on tomato and wheat plants. J. Agric. Sci. 7(11):277-287.

Feigl, G., Lehotai N., Molnar A., Ördög A., Rodriguez-Ruiz M., Palma J. M., Corpas F. J., Erdei L. and Kolbert Z. (2015). Zinc induces distinct changes in the metabolism of reactive oxygen and nitrogen species (ROS and RNS) in the roots of two *Brassica* species with different sensitivity to zinc stress. Ann. Bot. 116(4):613–625.

Geisler-Lee, J., Wang Q., Yao Y., Zhang W., Geisler M., Li K., Huang Y., Chen Y., Kolmakov A. and Ma X. (2013). Phytotoxicity, accumulation and transport of silver nanoparticles by Arabidopsis thaliana. Nanotoxicology.7(3): 323–337.

Gogos, A., Knauer K. and Bucheli T. D. (2012). Nanomaterials in Plant Protection and Fertilization: Current state, foreseen applications, and research priorities. J. Agric. Food Chem. 60(39): 9781−9792.

Govorov, A. O. and Carmeli, I. (2007). Hybrid structures composed of photosynthetic system and metal nanoparticles: plasmon enhancement effect. Nano Lett.7(3):620–625.

Hong-Sheng J., Li M., Feng-Yi C., Li W. and Li-Yan Y. (2012). Physiological analysis of silver nanoparticles and AgNO3 toxicity to *Spirodela polyrhiza*. Environ. Toxicol. Chem. 31(8): 1880–1886.

Huang, D., Dang F., Huang Y., Chen N. and Dongmei Zhou D. (2022). Uptake, translocation, and transformation of silver nanoparticles in plants. (Critical review) Environ Sci.: Nano. 9(1): 1-28.

Jackson, J., Kinabo J., Mamiro P., Mamiro D. and Jideani V. (2012). Utilization of dry beans and pulses in Africa: In Dry Beans and Pulses Production, Processing and Nutrition; Siddiq, M., Uebersax, M.A., Eds.: Blackwell: Oxford, UK, 261–282.

Jahangir, S., Javed K. and Bano A. (2020). Nanoparticles and plant growth promoting rhizobacteria (PGPR) modulate the physiology of onion plant under salt stress. Pak. J. Bot. 52(4):1473-1480.

Jalali, M., Ghanati F., Modarres-Sanavi A. M., Khoshgoftarmanesh A. H. (2017) Physiological Effects of Repeated Foliar Application of Magnetite Nanoparticles on Maize Plants. J. Agro. Crop Sci. 203: 593–602.

Janmohammadi, M., Amanzadeh T., Sabaghnia N. and Dashti S. (2016). Impact of foliar application of nano micronutrient fertilizers and titanium dioxide nanoparticles on the growth and yield components of barley under supplemental irrigation. Acta Agric. Slov. 107: 265- 276.

Jurkow, R., Pokluda R., Sekara A. and Kalisz A. (2020). Impact of Foliar Application of Some Metal Nanoparticles on Antioxidant System in Oakleaf Lettuce Seedlings. BMC Plant Biol. 20,290: 1-12.

Khan, S., Zahoor M., Sher Khan R., Ikram M., Islam N. and Islam D. (2023). The impact of silver nanoparticles on the growth of plants: The agriculture applications. Heliyon, 9,16928: 1-16.

Khatami, M., Sharifi I., Nobre M.A.L. and Zafarnia N., Aflatoonian M. R. (2018). Aflatoxin, Waste-grass-mediated green synthesis of silver nanoparticles and evaluation of their anticancer, antifungal and antibacterial activity, GCLR. 11: 125–134.

Krishnaraj, C., Jagan E. G., Ramachandran R., Abirami S. M., Mohan N., and Kalaichelvan

P. T. (2012). Effect of biologically synthesized silver nanoparticles on *Bacopa monnieri* (Linn.) Wettst. Plant growth metabolism. Process Biochem, 47(4): 651–658.

Küpper, H., Küpper F. and Spiller M. (1998) In situ detection of heavy metal substitution chlorophylls in water plants. *Photosynth. Res*. 58: 123-133.

Latif, H.H., Ghareib M. and Tahon M. A. (2017). Photosynthesis of silver nanoparticles using leaf extracts from *Ocimum basilicum* and *Mangifira indica* and their effect on some biochemical attributes of *Triticum aestivum*. Gesunde Pflanz.69 (1):39–46.

Lee, W. M., Kwak J. I. and An Y. J. (2012). Effect of silver nanoparticles in crop plants *Phaseolus radiates* and *Sorghum bicolor*; Media effect on phytotoxicity. Chemosphere. 86 (5): 491-499.

Li, P., He C. and Lin D. (2022). Extraction and quantification of polystyrene nanoplastics from biological samples. Environ Pollut. 314: 120267.

Ma, X., Geiser-Lee J., Deng Y. and Kolmakov A. (2010). Interactions between engineered nanoparticles (ENPs) and plants: Phytoxicity uptake and accumulation, Sci. Total Environ. 408 (16): 3053-3061.

Mandal, D., Bolander M. E., Mukhopadhyay D. Sarkar G. and Mukherjee P. (2006). The use of microorganisms for the formation of metal nanoparticles and their application, Appl. Microbiol. Biotechnol. 69:485–492.

Mehmood, A. and Murtaza G. (2017). Application of SNPs to improve yield of *Pisum sativum* L. (pea). IET Nanobiotechnol.11(4):390-394.

Mirzajani, F., Askari H., Hamzelou S., Farzaneh M. and Ghassempour A. (2013). Effect of silver nanoparticles onOryza sativa L. and its rhizosphere bacteria. Ecotoxicol. Environ. Saf., 88, 48–54.

Nair, R., Varghese S. H., Nair B. G., Maekawa T., Yoshida Y. and Verma D.S. (2010). Nanoparticulate material delivery to plants. Plant Sci. 179: 154–163.

Najafi, S. and Jamei R. (2014). Effect of Silver Nanoparticles and Pb $(NO_3)_2$ on the yield and chemical composition of Mung bean (*Vigna radiate* L). J. Stress Physiol. Biochem. 10 (1):316-325.

Nhan, L. V., Ma C., Rui Y., Liu S., Li X., Xing B. and Liu L. (2015). Phytotoxic Mechanism of Nanoparticles: Destruction of Chloroplasts and Vascular Bundles and Alteration of Nutrient Absorption. Sci. Rep. 5, 11618: 1-13.

Nowack, B. and Bucheli D. T. (2007). Occurrence, behavior and effects of nanoparticles in the environment. Environ Pollut. 150(1):5-22.

Oukarroum, A., Barhoumi L., Pirastru L. and Dewez D. (2013). Silver nanoparticle toxicity effect on growth and cellular viability of the aquatic plant *Lemna gibba*. Environ. Toxicol. Chem. 32: 902–907.

Pallavi, C., Mehta M., Srivastava R., Arora S. and Sharma A. K. (2016). Impact assessment of silver nanoparticles on plant growth and soil bacterial diversity. 3 Biotech, 6,254: 1-10.

Patlolla, A. K., Berry A., May L. and Tchounwou P. B. (2012). Genotoxicity of silver nanoparticles in *Vicia faba*: A pilot study on the environmental monitoring of nanoparticles. Int. J. Environ. Res. Public Health. 9:1649- 1662.

Piper, O.S. (1947). Soil and plant Analysis. Adelaide Univ., Adelaide, Australia, pp: 258-275.

Pokhrel, L. R. and Dubey B. (2013). Evaluation of developmental responses of two crop plants exposed to silver and zinc oxide nanoparticles. Sci. Total Environ. 1:452–453: 321–332.

Pradhan, S., Bahadur S. and Pradhan S.S. (2017). Role of nanotechnology in agriculture. Contemp. Res. India. 7(4):159-161.

Râcuciu, M. and Creanga D. E (2007). TMA-OH coated magnetic nanoparticles internalized in vegetal tissue. Rom. J. Phys. 52(3/4):395-402.

Razzaq, A., Ammara R., Jhanzab H. M., Mahmood T., Hafeez A. and Hussain S. (2016). A novel nanomaterial to enhance growth and yield of wheat. J. Nano. Sci. Technol. 2(1): 55-58.

Rezvani, N., Sorooshzadeh A. and Farhadi N. (2012). Effect of nano-silver on growth of saffron in flooding stress. Int. J. Agric. Biol. Eng. 6(1):11-16.

Ruiz-Espinoza, F. H., Murillo-Amador B., Garcıa-Hernandez J. L., Fenech-Larios L., Rueda-Puente E.O., Troyo-Dieguez E., Kaya C. and Beltran-Morales A. (2010). Field evaluation of the relationship between chlorophyll content in basil leaves and a portable chlorophyll meter (SPAD-502) reading. J. Plant Nutr. 33: 423–438.

Sadak, M. S. (2019). Impact of silver nanoparticles on plant growth, some biochemical aspects, and yield of fenugreek plant (*Trigonella foenum-graecum*). BNRC. 43: 1– 6.

Salama, H. M. (2012). Effects of silver nanoparticles in some crop plants, common bean (*Phaseolus vulgaris* L.) and corn (*Zea mays* L.). Int. Res. J. Bacteriol. 3(10):190-197.

Schwab, F., Zhai G., Kern M., Turner A., Schnoor J. L. and Wiesner M. R. (2016) Barriers, pathways and processes for uptake, translocation and accumulation of nanomaterials in plants-critical review. Nanotoxicology. 10(3): 257–278.

Sharma, P., Bhatt D., Zaidi M. G. H., Saradhi P. P., Khanna P.K. and Arora S. (2012). Appl. Biochem. Biotechnol. 167(8):2225-2233.

Sharon, M., Choudhry A. and Verma R. (2010). Nanotechnology in agricultural disease and food safety. J. Phytol., 2(4):83-92.

Singh, R. D., Kumbhakar P., Pal S., Khannam S. K. and Kumbhakar P. (2021). Investigating morphology-dependent antibacterial property of ZnO nanoparticles and developing an insight into oxidative stress generation and cellular response. Biol. 6(4):1339–1348.

Snedecor, G.W. and Cochran W.G., (1980). Statistical Methods. 7th Ed. The Iowa State Univ. Press. Ames. Iowa, USA.:325-330.

Sorahinobar, M., Deldari T., Bokaeei Z. N. and Mehdinia A. (2023). Effect of zinc nanoparticles on the growth and biofortification capability of mungbean (*Vigna radiata* L) seedlings. Biol.78:951–960.

Stampoulis, D., Sinha S. K. and White J. C. (2009). Assay-dependent phytotoxicity of nanoparticles to plants. Environ. Sci Technol. 43(24):9473-9479.

Tomacheski, D., Pittol M., Simões D.N., Ribeiro V.F. and Santana R. M. (2017). Impact of silver ions and silver nanoparticles on the plant growth and soil microorganisms, Global J. Environ. Sci. Manage. 3: 341–350.

Tomaszewska-Sowa, M., Siwik-Ziomek A., Figas A. and Bocian K. (2018). Assessment of metal nanoparticle -induced morphological and physiological changes in in vitro cultures of rapeseed (*Brassica napus* L.). EJPAU. 21(4):1-7.

Tripathi, D.K., Tripathi A., Singh S., Singh Y., Vishwakarma K., Yadav G., Sharma S., Singh V. K., Mishra R. K., Upadhyay R. G., Dubey R.G., Lee Y. Chauhan D. (2017). Uptake, accumulation and toxicity of silver nanoparticle in autotrophic plants, and heterotrophic microbes: A concentric review. Front. Microbiol. 8 (7): 1-16.

Verma, D. V., Patel S. and Kushwah K. S. (2020). Green biosynthesis of silver nanoparticles and impact on growth, chlorophyll, yield and phytotoxicity of *Phaseolus vulgaris* L. Vegetos. 33:648–657.

Vishwakarma, K., Gaur C., Upadhyay N., Singh J., Liu S., Singh V. P., Prasad S. M., Chauhan D., Tripathi D. Sharma S. (2017). Differential phytotoxic impact of plant mediated silver nanoparticles (Ag^{+}NPs) and silver nitrate ($AgNO_3$) on *Brassica* sp. Front. Plant Sci. 8:1501, 1-12.

Wagi, S. and Ahmed, A. (2019). Green production of Ag^{+}NPs and their Phyto-stimulatory impact. J. Green Process. Synth. 8(1): 885-894.

Wasaya, A., Yasir T. A., Sarwar N., Farook O., Sheikh G. R. and Baloch A. W. (2020). Improving growth and yield of mungbean (*Vigna radiata* L.) through foliar application of silver and zinc nanoparticles. Pure Appl. Biol. 9(1):790-797.

Xalxo, R., Bhumika Y., Vibhuti C., Meetul K., Jipsi C. and Keshavkant S. (2021). Silver Nanoparticles and Their Morpho-Physiological Responses on Plants. Springer Nature Switzerland AG:183-216.

Xu, Z. and Rothstein, S. J. (2018). ROS-Induced anthocyanin production provides feedback protection by scavenging ROS and maintaining photosynthetic capacity in Arabidopsis. Plant Signal Behav. 13(3): e1451708

Yadu, B., Chandrakar V., Korram J., Satnami M. L., Verma M. and Keshavkant S. (2018). Silver nanoparticlemodulates gene expressions, glyoxalase system and oxidative stress markers in fluoride stressed *Cajanus cajan* L. J Hazard Mater. 5:44–52.

Yan, A. and Chen Z. (2019). Impacts of silver nanoparticles on plants: A focus on the phytotoxicity and underlying mechanism. Int. J. Mol. Sci. 20,1003: 1-21.

Zheng, L., Hong F., Lu S. and Lui C. (2005). Effect of nano-TiO (2) on strength of naturally aged seeds and growth of spinach. Biol. Trace Elem. Res. 104 (1): 83–92

استجابة نباتات الفاصوليا للرش الورقي وغمر التربة بجزيئات الفضة النانونية

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ملخص

أجري هذا البحث لتقييم استجابة الفاصوليا صنف بوليستا لمستويات من جزيئات الفضة النانونية وتشمل تركيزات صفر، 50، 100، و150 جزء في المليون كرش ورقى أو غمر للتربة. أوضحت النتائج أن أعلى قيم النمو الخضري للنبات (طول النبات، عدد الأفرع/ للنبات، والوزن الطازج للنبات) إلى جانب محتوى الورقة من الكلوروفيل، المحصول الكلي للقرون الخضراء وصفات القرن (طول القرن، قطر القرن، والوزن الطازج للقرن) كانت بمعاملة الرش الورقي50 جزء في المليون تبعها تركيز 100 جزء في المليون غمراً للتربة. بينما أدت المعاملة بجزيئات الفضة النانونية بالتركيز العالي 150 جزء في المليون رشا ورقياً أدى إلى نقص واضح في الصفات الخضرية للنبات، المحصول الكلى (طن/فدان) والمحتوي الكيميائي للقرن من البروتين والكربوهيدرات. توصي الدراسة باستعمال برش نباتات الفاصوليا بجزيئات الفضة النانونية بتركيزات منخفضة لتحسين النمو، الانتاجية والمحتوى الكيميائي لقرون الفاصوليا.

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