The Amendment with Chitin and/or Chitosan Improves the Germination and Growth of *Lycopersicon esculentum* L., *Capsicum annuum* L. and *Solanum melongena* L.

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**ABSTRACT**

**Background:** Chitin and chitosan are natural products extracted from shrimp shells. They are non-toxic, biocompatible and biodegradable which favors many applications in agricultural domain. Moreover, chitin and chitosan are known as stimulators of photosynthetic rates and enhance plants growth through minerals contains (C, O, N ....). In the present study, these co-products are evaluated for their ability to stimulate the germination and growth of *Lycopersicon esculentum* L., *Capsicum annuum* L. and *Solanum melongena* L.

**Methods:** The experiments were conducted at Ibn Tofail University-Kenitra, between July 2016 to January 2018. The experiments are carried out by using a germination test for the three seeds. On the other hand, the in vivo test is used to determine the effect of the biopolymers on plant growth (length, fresh and dry weights of aerial and root parts, number and weight of the obtained fruits).

**Result:** In vitro studies reveal a promoter action of chitosan and the mixture chitin-chitosan on increasing seed germination percentage by 16%, 34% and 22%. Thus, at both 25, 50 and 100 mg/l of chitin or chitosan, increase vigor index, shoot length and root is obtained. In vivo, the effect of chitin and chitosan is limited to stimulation of the lengths, fresh and dry weights of plants. However, a highly significant increase in the number and weight of the fruits is marked by the weekly soil amendment by the chitin-chitosan mixture at 25 mg/l and 100 mg/l.

**Key words:** *Capsicum annuum* L., Chitin, Chitosan, Germination parameters, Growth stimulation, *Lycopersicon esculentum* L., *Solanum melongena* L.

**INTRODUCTION**

Insoluble but biodegradable, chitin and chitosan are by-products of shrimp shells (Mohanta *et al.*, 2001), susceptible to the hydrolytic activity of various enzyme systems such as chitinase, chitosanase, cellulase, hemicellulase, dextranase, pectinase, lipase, pepsin, papain, pancreatin and lysozyme (Muzzarelli, 1997).

For a long time, chitin and chitosan have been considered as an elicitor on plants (Singh *et al.*, 2018). It consists in promoting the production of secondary metabolites that strengthen the immune defenses by the production of phenylalanine ammonia-lyase (PAL) and tyrosine ammonia-lyase (TAL) (Khan *et al.*, 2003). In addition, the application of these compounds affects morphology, growth, yield and biochemical parameters (Mondal *et al.*, 2012).

**MATERIALS AND METHODS**

The experiments were conducted at Ibn Tofail University, Kenitra, between July 2016 to January 2018.

**Preparation of chitin and chitosan**

The products are extracted from shrimp shells as described in the article by Rkhaila et Ounine, (2018).

**Preparation of colloidal chitin**

Colloidal chitin is prepared according to the modified method of Hsu and Lockwood (1975), Forty grams of the chitin powder (Sigma Aldrich, France) is added to 600 ml of concentrated HCl. After that we stir it for 2h and 30 min, then the chitin is precipitated by the addition of 2 L of distilled water at 5-10°C. The suspension is, thus, collected by filtration. The filtrate is rinsed with distilled water then, the pH is adjusted to 7.

**Solubilization of chitosan**

For the process, we used El Ghaout *et al.* (1991) protocol. We add 80 ml of distilled water and 2.5 ml of 10N HCl on 1g chitosan. The volume is, then supplemented with distilled water to 250 ml. The mixture is stirred for 2h and then filtered by Whatman No.1 filter paper. The volume is then adjusted to 250 ml with distilled water. The solution is then dialyzed against distilled water for 48h with 3 exchanges. The solution is then submitted to a rotatory evaporator at 40°C with 2 exchanges. The volume is then reduced to 20 ml.

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In vitro effect of chitin and chitosan on germination of tomato, eggplant and pepper seeds

The germination test is carried out according to the standard method of the International Seed Germination Test Association (ISTA, 2005). Three disks of Whatman paper N°1 are placed on each four petri dishes. Then, moistened with 4 ml of chitin, chitosan or chitin-chitosan mixture at 25, 50 or 100 mg/l concentrations. After that, 25 disinfected seeds are placed in each box (Ramana et al., 2002; Benhamou, 1996) of chitin, or chitosan or chitosan. Chitin-chitosan were mixed at 25, 50 or 100 mg/l for 12 weeks (Lafontaine and Thériault, 1992). The incubation is carried out at 26±1°C temperature and a photoperiod of 16h illumination (Lachachi, 2010). After 10 days, the germination percentage, the shoot and root length and seed vigor index are calculated.

The vigor index is calculated according to the formula of Abdul Bakri and Anderson (1973):

\[ IV = (\text{Mean root length} + \text{Mean shoot length}) \times \text{germination\%} \]

In vitro effect of chitin and chitosan on seedling growth of tomato, eggplant and pepper

Seedlings of tomato, eggplant and pepper, at the three-leaf stage (Benham and Thériault, 1992) were grown in pots with sterile Maamora soil and peat at a rate of 1/3, then transported in a greenhouse (temperature 18 to 22°C, humidity 75%, 16h photoperiod).

The effect of each treatment on the growth of tomato, eggplant and pepper plants was determined by a weekly soil amendment with a volume of 100 ml (Lafontaine and Benhamou, 1996) of chitin, or chitosan or chitosan. Chitin-chitosan were mixed at 25, 50 or 100 mg/l for 12 weeks (Nb: For the control, only sterile distilled water is used for soil amendment). Ten plants were used for each treatment.

### RESULTS AND DISCUSSION

**Effect of chitin and chitosan on germination and growth of Solanaceae seedlings**

**In vitro germination of *Lycopersicon esculentum* L. in the presence of chitin, chitosan or chitin-chitosan mixture**

After ten days of incubation at 26°C, the germination percentage, shoot length, root length and vigor index of the tomato seeds are measured (Table 1).

- When we used sterile distilled water, seed germination reached 67%, whereas it was greater than or equal to 75% in the presence of chitin. However, this percentage has exceeded 72% when we add chitosan to the culture medium. In addition, the chitin-chitosan mixture at 25 mg/l was beneficial to germinate 82% of tomato seeds. On the other hand, we noted a maximum chitosan value of 83% at 50 mg/l.
- Except chitosan 100 mg/l and chitin-chitosan 50 mg/l and 100 mg/l, all treatments contributed to improve shoot length with values greater than 3.53 cm. In contrast, control seeds have a mean of 2.79 cm, while seeds treated with 100 mg/l chitin or 25 mg/l chitin-chitosan mixture reached a similar and a maximum means of 3.74 cm.
- Seeds treated with chitin recorded mean greater than 7.68 cm, whereas it was 7.51 cm and 7.90 cm for seedlings amended by 25 mg/l of chitosan or chitin-chitosan mixture. We noticed, also, that the high concentration of these compounds (100 mg/l of chitosan, 50 mg/l and 100 mg/l of the chitin-chitosan mixture) caused a decrease in root length, which resulted in averages less than 2.20 cm.

We observed, also, similar trend for the vigor index, because only the treatments that caused the decrease in root length did in fact have the same effect on the vigor index. On the contrary, other treatments had given mean exceeding IV = 747 with a maximum of 1053.2 recorded on the medium containing chitin at 50 mg/l.

**In vitro germination of *Capsicum annuum* L. in the presence of chitin, chitosan or chitin-chitosan mixture**

Table 2 shows the averages of germination rate, shoot length, root length and seed vigor index of *Capsicum annuum* L.

Towards a germination percentage of 51%, recorded by the control seeds, chitin reaches percentages that are above 70%. So, with chitosan, this percentage ranged from 74% to 84%. In return, the mixture of the two compounds made it possible to surpass 67% of the germinated seeds to reach a percentage of 85% with the concentration 100 mg/l.

With both chitin and chitosan, shoot length and root length were strictly greater and differed significantly from control (S.L=1.74 cm, R.L=2 cm). Subsequently, similar results were observed for the vigor index, as the values obtained exceeded 331.5. On the other hand, the control recorded only 190.5.

**In vitro germination *Solanum melongena* L. in the presence of chitin, chitosan or chitin-chitosan mixture**

The effect of the three treatments on germination, shoot length, root length and vigor index of eggplant seeds is shown in Table 3.

The results indicate that chitin or chitosan significantly affected the germination percentage of eggplant seeds. In fact, with chitin or the chitin-chitosan mixture, the percentage of germination was greater than 74% and 65% respectively. Thus, the lowest concentration of those (25 mg/l) remains more effective, this is observed by a percentage of 82%. While, seeds cultivated in water (control) did not exceed 60%.

As a result, all treatments acted by increasing the parameters of shoot length, root and vigor index; the maximum value of these three parameters was recorded by the concentration 25 mg/l of chitosan- except for 100 mg/l of chitosan and chitin-chitosan mixture.

The obtained results highlight the beneficial effect of the use of chitin, chitosan and chitin-chitosan mixture as a stimulating solution for germination, shoot length, root length and index vigor. These results were confirmed by the study of Jaybhay et al. (2010), who reported that the use of chitosan...
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### Table 1: Germination parameters of *Lycopersicon esculentum* seeds.

| Treatment (mg/l) | Germination (%) | Hypocotyl lengths (cm) | Radical lengths (cm) | Vigor index |
|------------------|-----------------|------------------------|----------------------|-------------|
| Control          | 67±0.29 a       | 2.79±0.11 b            | 6.22±0.30 b          | 0640±22.33 b|
| 25               | 76±0.08 cd      | 3.62±0.08 d            | 7.68±0.28 c          | 0859±22.48 de|
| Chitine          | 80±0.13 ef      | 3.63±0.11 d            | 9.70±0.29 d          | 1053±22.76 f|
| 100              | 75±0.10 bcd     | 3.74±0.10 d            | 8.65±0.34 cd         | 0929±0.30 01 e|
| 25               | 72±0.14 abc     | 3.53±0.09 d            | 7.51±0.27 c          | 0794±23.45 cd|
| Chitosane        | 83±0.33 g       | 3.67±0.09 d            | 5.34±0.20 b          | 0747±22.00 c|
| 100              | 77±0.27 de      | 1.65±0.05 a            | 2.00±0.00 a          | 0281±0.04 21 a|
| 25               | 82±0.25 fg      | 3.74±0.10 d            | 7.90±0.30 c          | 0954±30.88 ef|
| Chitin+ chitosan | 70±0.11 a       | 2.07±0.04 ac           | 2.20±0.11 a          | 0299±0.10 86 a|
| 100              | 70±0.09 ab      | 2.00±0.00 ac           | 2.00±0.00 a          | 0280±0.00 00 a|

Means in the same column with the same letter do not differ significantly from each other at α=5%.

### Table 2: Germination parameters of *Capsicum annuum* L. seeds.

| Treatment (mg/l) | Germination (%) | Hypocotyl lengths (cm) | Radical lengths (cm) | Vigor index |
|------------------|-----------------|------------------------|----------------------|-------------|
| Control          | 51±1.13 a       | 1.74±0.07 a            | 2.00±0.12 a          | 190.5±8.90 a|
| 25               | 81±0.06 e       | 2.52±0.04 e            | 2.56±0.04 bc         | 412.0±5.46 d|
| Chitin           | 70±1.15 ce      | 2.19±0.04 c            | 2.94±0.12 e          | 359.6±7.82 bc|
| 100              | 75±0.85 ce      | 2.28±0.04 cd           | 2.98±0.10 e          | 394.6±9.96 d|
| 25               | 74±0.23 c       | 2.39±0.05 de           | 2.84±0.08 de         | 386.4±8.11 cd|
| Chitosan         | 83±0.39 f       | 2.28±0.04 cd           | 2.54±0.07 bc         | 401±1.70 d  |
| 100              | 84±0.11 f       | 2.00±0.00 b            | 2.70±0.04 bce        | 395±3.64 d  |
| 25               | 67±0.31 b       | 2.23±0.06 cd           | 2.73±0.05 bce        | 331±5.64 b  |
| Chitin+ chitosan | 73±0.75 c       | 2.11±0.03 bc           | 2.77±0.07 de         | 356±7.08 bc |
| 100              | 85±0.16 f       | 2.25±0.03 cd           | 2.39±0.05 b          | 394±4.86 d  |

Means in the same column with the same letter do not differ significantly from each other at α=5%.

### Table 3: Germination parameters of *Solanum melongena* L. seeds.

| Treatment (mg/l) | Germination (%) | Hypocotyl lengths (cm) | Radical lengths (cm) | Vigor index |
|------------------|-----------------|------------------------|----------------------|-------------|
| Control          | 60 ± 0.52 ab    | 1.95±0.08 a            | 2.21±0.13 ab         | 249.5±12.39 ab|
| 25               | 82±0.11 f       | 2.78±0.09 cd           | 2.93±0.11 c          | 467±14.07 f |
| Chitin           | 74±0.23 de      | 2.57±0.10 bc           | 2.81±0.12 bc         | 397±14.86 e |
| 100              | 80±0.22 g       | 2.91±0.10 cde          | 2.99±0.11 c          | 517±16.76 fg|
| 25               | 79±0.17 ef      | 3.22±0.11 e            | 4.12±0.21 d          | 580±21.95 g |
| Chitosan         | 60±0.13 a       | 2.95±0.10 de           | 3.58±0.16 d          | 391±14.28 e |
| 100              | 59±0.20 a       | 2.00±0.02 a            | 2.00±0.10 a          | 236±11.00 a |
| 25               | 82±0.00 f       | 3.18±0.11 e            | 3.60±0.17 d          | 558±22.00 g |
| Chitin+ chitosan | 65±0.06 bc      | 2.22±0.07 abc          | 2.28±0.09 ab         | 369±12.65 ce|
| 100              | 70±0.00 cd      | 2.00±0.03 a            | 2.50±0.08 abc        | 315±10.00 bc|

Means in the same column with the same letter do not differ significantly from each other at α=5%.

at 0.03% their permits scored a 16% difference in seed germination percentage of *Abelmoschus esculentus* (L.) *moench*. Thus, they were consistent with that obtained by Barka et al., (2004), who showed that low doses of chitosan induce an increase in the growth of *Vitis vinifera* L. compared to the control.

**Stimulation of the in vivo growth of *Lycopersicon esculentum* L. in the presence of chitin, chitosan and chitin-chitosan mixture**

The effect of weekly amendments for 12 weeks of soil treatment on agronomic parameters is shown in Table 4. The results of this test allowed us to identify the beneficial effects of chitin, chitosan and the chitin-chitosan mixture on the stimulation of tomato growth (Fig 1). Indeed, the average length of aerial part of seedlings amended by chitin exceeded 138.8 cm. In addition, when adding chitosan this average was greater than 138.8 cm. While with the chitin-chitosan mixture at 50 mg/l, it was 135 cm. On the opposite, the control plants had aerial part less than 108.4 cm.

Weekly application of chitin and chitosan (25 mg/l) generated root elongation with values exceeding 54.4 cm. In addition, the chitin-chitosan mixture at 50 mg/l recorded
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Similarly, the addition of the treatments had a positive influence on the fresh and dry weight of the tomato aerial part, with chitin; the averages exceeded 55g for the fresh weight and 42.1g for the dry weight. In addition, with the chitin-chitosan mixture (25 mg/l), maximum values of these parameters were recorded FW=74.4g and DW=59g. In contrast, the control only scored 44.8g for fresh weight and 25.4g for dry weight.

As for the fresh and dry weight of roots, we noticed that chitin acted in the same way on the two measured

| Treatment  | Length of aerial part (cm) | Length of root part (cm) | Fresh weight of aerial part (g) | Fresh weight of root part (g) | Dry weight of aerial part (g) | Dry weight of root part (g) | Number of fruits (g) | Weight of fruits (g) |
|------------|----------------------------|--------------------------|-------------------------------|------------------------------|-------------------------------|--------------------------|----------------------|---------------------|
| Control    | 0                          | 30.2 a                   | 44.8 ab                       | 062.9 a                      | 25.4 a                        | 41.1 a                   | 1.1 ab               | 032.9 a             |
|            | 25                         | 138.8 cde                | 55.9 b                        | 55.0 abc                      | 055.7 a                       | 42.1 b                   | 40.2 a               | 059.5 ab             |
| Chitin     | 50                         | 157.1 de                 | 58.0 b                        | 57.8 abc                      | 078.5 a                       | 44.5 b                   | 61.7 b               | 076.1 ab             |
|            | 100                        | 171.1 e                  | 54.4 b                        | 63.2 bc                       | 094.4 b                       | 51.9 bc                  | 78.8 b               | 041.5 ab             |
|            | 25                         | 122.6 abc                | 56.8 b                        | 40.8 a                        | 060.6 a                       | 28.6 a                   | 47.5 a               | 019.7 a             |
| Chitosan   | 50                         | 103.8 ab                 | 40.6 a                        | 51.8 ab                       | 083.6 b                       | 41.7 b                   | 63.5 b               | 044.7 ab             |
|            | 100                        | 120.5 abc                | 47.4 a                        | 49.2 ab                       | 047.4 a                       | 42.9 b                   | 36.8 a               | 042.0 ab             |
| Chitin     | 25                         | 111.2 abc                | 42.6 a                        | 74.4 c                        | 095.4 b                       | 59.0 bc                  | 79.6 b               | 097.6 bc             |
| + Chitosan | 50                         | 135.0 bcd                | 72.4 c                        | 42.4 a                        | 062.8 a                       | 29.6 a                   | 50.4 ab              | 031.1 a             |
| Chitosan   | 100                        | 098.2 a                  | 37.8 a                        | 64.0 bc                       | 101.6 b                       | 49.8 bc                  | 60.4 b               | 156.4 c             |

Means in the same column with the same letter do not differ significantly from each other at α=5%.

Fig 1: Comparison of control and treated *Lycopersicon esculentum* L. sizes.
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parameters, which gives us results as follows, averages of 94.4 g for fresh weight and averages exceeding 61.7 g for dry weight. Yet, with chitosan at 50 mg/l, these averages were 83.6 g and 63.5 g successively for fresh and dry weight. Idem, chitin-chitosan mixture at 25 and 100 mg/l recorded an average of 95.4 g and 101.6 g for fresh weight, so averages of 79.6 g and 60.4 g respectively were marked by the concentrations of the same treatment.

Relative to the average number of fruits, only the chitin-chitosan mixture at 50 and 100 mg/l (2.6 and 5 fruits) indicated statistically significant values compared to the control (1.1 fruit). These same treatments noted the fresh weight score of 96.4 g and 156 g (Fig 2).

Stimulation of *in vivo* growth of *Capsicum annuum* L. in the presence of chitin, chitosan and chitin-chitosan mixture

After 12 weeks of cultivation of pepper seedlings, agronomic parameters were measured (Table 5).

The results of the test indicate a strong stimulation of agronomic parameters. The height of the aerial part exceeded 53.9 cm and 55.9 cm with the soil amendment by chitin. Moreover, chitosan has a highly significant effect with the concentration 100 mg/l.

A similar trend is observed for the size of the root system, since the amendment with chitin and low-concentration of chitosan (25 mg/l) increased root size by up to 40 cm and 28.7 cm simultaneously. On the other hand, the other concentrations of the same product as well as all the concentrations of the chitin-chitosan mixture did not show any significant differences compared to the control (24 cm) (Fig 3).

![Fig 2: Fruits size produced by control and treated *Lycopersicon esculentum* L. with chitin, chitosan or chitin-chitosan mixture at 25, 50 or 100 mg/l.](image)

**Table 5: Agronomic parameters of *Capsicum annuum* L. treated with chitin, chitosan and chitin-chitosan mixture powders.**

| Treatment | Length of aerial part (cm) | Length of root part (cm) | Fresh weight of aerial part (g) | Fresh weight of root part (g) | Dry weight of aerial part (g) | Dry weight of root part (g) | Number of fruits | Weight of fruits (g) |
|-----------|---------------------------|--------------------------|-------------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------|-------------------|
| Control   | 0                         | 49.9 bc                  | 24.0 de                      | 08.0 a                      | 05.0 a                      | 03.0 a                      | 02.0 a                      | 1.3 a             | 46.6 cd           |
| 25        | 55.9 cd                   | 40.0 f                   | 34.0 e                       | 50.0 e                      | 25.0 e                      | 31.9 d                      | 1.5 a             | 39.8 bcd          |
| Chitin    | 50                        | 53.9 cd                  | 25.3 de                      | 16.7 bc                     | 43.3 d                      | 09.0 bc                     | 19.1 bc                      | 1.2 a             | 37.8 bc           |
| 100       | 47.4 bc                   | 22.2 cd                  | 14.6 bc                      | 32.2 cd                     | 10.0 bc                     | 15.0 bc                     | 1.2 a             | 32.8 bc           |
| 25        | 49.2 bc                   | 28.7 e                   | 17.2 c                       | 39.1 d                      | 12.0 bc                     | 16.2 bc                     | 1.6 a             | 44.7 cd           |
| Chitosan  | 50                        | 45.9 abc                 | 16.6 abc                     | 12.0 ab                     | 13.4 ab                     | 07.0 ab                     | 05.5 a                      | 1.5 a             | 36.8 bc           |
| 100       | 63.3 d                    | 21.1 bcd                 | 18.0 c                       | 08.0 ab                     | 10.0 bc                     | 02.5 a                      | 1.4 a             | 42.6 cd           |
| Chitin +  | 25                        | 35.0 a                   | 11.9 a                       | 08.0 a                      | 05.0 a                      | 05.0 a                      | 03.0 a                      | 1.3 a             | 28.8 a            |
| Chitosan  | 50                        | 46.3 abc                 | 15.6 ab                      | 17.0 bc                     | 20.0 bc                     | 11.0 bc                     | 13.9 bc                      | 1.4 a             | 51.0 e            |
| 100       | 40.1 ab                   | 26.2 de                  | 13.0 abc                     | 09.0 ab                     | 08.0 ab                     | 04.1 a                      | 1.3 a             | 51.1 e            |

Means in the same column with the same letter do not differ significantly from each other at α=5%. 

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With regard to the fresh weight of the areal part, we note that the values of this parameter exceeded 14.6 g for most treatments, except the one with chitosan at 50 mg/l and the other based on the chitin-chitosan at 25 and 100 mg/l. The mean recorded by the control was 8g. After drying, we noted that our products have kept the same properties on the dry weight of the stems, with a maximum value marked by the amendment of the soil with chitin at 25 mg/l (25g).

In addition, the root system showed highly significant means relative to the control at the addition of treatments. These means were above 20g for fresh weight and above 13.9g for dry weight. Besides, chitosan at 50 and 100 mg/l as well as the chitin-chitosan mixture at 25 and 100 mg/l did not show significant differences with respect to the control for the two parameters.

As for the number of fruits, we did not receive statistically different means compared to the control P <0.839. In contrast, these fruits had variable weights, the mean of which differed significantly from the control (Fig 4). Yet, the chitin-chitosan mixture at 50 and 100 mg/l marked a maximum weight of 51g and 51.1g successively.

Stimulation of the in vivo growth of *Solanum melongena* L. in the presence of chitin, chitosan and chitin-chitosan mixture

The results recorded after 12 weeks of eggplant culture are shown in Table 6.

We obtained a maximum average of 80.8 cm with the 50 mg/l concentration, followed by the 25 mg/l concentration of the same compound (75.3 cm) (Fig 5). The concentration of 100 mg/l of this treatment (chitin-chitosan mixture), also, noted a value of 71.4 cm. Chitosan formed our second class with stems of average lengths of 65.2 cm, 70.9 cm and 68.3 cm depending on the gradual concentration. On the other hand, the control showed only average stem lengths of 42.6 cm which did not differ significantly at the concentrations (25, 50 and 100 mg/l) of chitin (P <0.07).

The average root length increased when the 25 mg/l and 50 mg/l concentration of chitosan (50.8 cm, 62.5 cm) and the 100 mg/l concentration of the chitin-chitosan mixture (55.8 cm) were added. The remaining concentrations of chitin (50 mg/l), chitosan (100 mg/l) and chitin-chitosan (25 and 50 mg/l) were, on the other hand, less important but statistically significant.

![Fig 3: Comparison of control and treated *Capsicum annuum* L. sizes.](image-url)
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**Fig 4:** Fruits size produced by control and treated *Capsicum annuum* L. with chitin, chitosan or chitin-chitosan mixture at 25, 50 or 100 mg/l.

**Fig 5:** Comparison of control and treated *Solanum melongena* L. sizes.
As for the fresh and dry weight of the stem, the chitosan at 50 mg/l recorded the maximum average fresh weight (43.1g) and at 100 mg/l, we obtained the maximum score of the dry weight (20.8g). While in the control plants, the average fresh weight would not exceed 10.1g and an average of 4.5g dry weight, which means a loss of 55.45% of the weight when drying at 60°C for 12 hours.

The average number of fruit produced per plant varied from 1 to 2.2. It was higher than (2.2) in plants treated with chitin-chitosan mixture at 25 mg/l and lower than control plants (1) but it was different as compared to other treatments (P <0.08). The maximum fruit weight (81.1g) was shown by plants treated with chitin-chitosan mixture at 25 mg/l. It was only 30.6g for the control (Fig 6).

Table 6: Agronomic parameters of Solanum melongena L. treated with chitin, chitosan and chitin-chitosan mixture powders.

| Treatment  | Length of aerial part (cm) | Length of root part (cm) | Fresh weight of aerial part (g) | Dry weight of aerial part (g) | Dry weight of root part (g) | Number of fruits | Weight of fruits (g) |
|------------|---------------------------|--------------------------|-------------------------------|-------------------------------|---------------------------|------------------|----------------------|
| Control    | 42.6 a                    | 23.6 a                   | 20.0 b                        | 11.0 ab                       | 09.0 a                    | 1.0 a            | 30.6 a               |
| 25         | 52.8 ab                   | 30.7 ab                  | 13.9 ab                       | 08.5 a                        | 06.5 a                    | 1.5 a            | 29.5 a               |
| Chitin     | 62.5 g c                  | 50.8 e                   | 38.6 cd                       | 19.2 d                        | 19.1 d                    | 1.5 a            | 39.1 b               |
| 50         | 65.2 b ab                 | 50.8 e                   | 15.8 ab                       | 10.3 ab                       | 09.2 b                    | 1.2 a            | 38.1 b               |
| 100        | 68.3 b bc                 | 41.0 d                   | 26.5 bc                       | 15.4 bc                       | 20.8 e                    | 1.5 a            | 52.0 cd              |
| Chitosan   | 70.9 c                    | 62.5 g                   | 43.1 d                        | 22.1 de                       | 12.3 bcd                  | 1.6 a            | 60.2 e               |
| 50         | 75.3 cd                   | 43.2 d                   | 30.1 c                        | 13.7 b                        | 10.5 bc                   | 2.2 b            | 81.1 g               |
| 100        | 71.4 c                    | 55.8 f                   | 23.3 b                        | 12.0 b                        | 11.7 bc                   | 1.8 a            | 70.8 ef              |

Means in the same column with the same letter do not differ significantly from each other at α=5%.

Fig 6: Fruits size produced by control and treated Solanum melongena L. with chitin, chitosan or chitin-chitosan mixture at 25, 50 or 100 mg/l.
In light of this study, the weekly chitin amendment provided maximum values for root length, fresh and dry weight of stem and root of pepper plants. In addition, the maximum average length of the stem was recorded by chitosan at 100 mg/l. In the study by Liopa-Tsakalidi et al. (2010), the peat-sand-chitin mixture significantly stimulated the fresh and dry weight of Melissa officinalis by 58% and 72%, respectively. However, the presence of chitin in the two substrates (peat-chitin and peat-sand-chitin) did not affect the height of the lemon balm plants.

CONCLUSION
To conclude, chitin and chitosan seem to be very promising products because of their proven properties in agriculture. Since these induces favorable responses to stimulate plant growth, increase fruit production, improve the mechanical properties of plants.

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