Shrimp shells, Chitin and chitosan powders effect on growth of *Lycopersicon esculentum* and their ability to induce resistance against *Fusarium oxysporum* f.sp. radicis-lycopersici attack

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**ABSTRACT**

The potential of co-products of shrimp shells on the germination parameters, growth, and for inducing defense reactions in tomato (*Lycopersicon esculentum*) plants inoculated with *Fusarium oxysporum* f.sp. *radicis-lycopersici* (FORL) was investigated in vitro and in vivo. It was found that chitosan at 50mg/l increased the germination percentage by 2.66%; the shrimp shells powder at 50mg/l was best in increasing the length of radical and length and weight of hypocotyl in vitro. In Vivo, chitosan at 50mg/l increased length, fresh/dry weight of aerial and radicle parts compared to control. An inhibition of FORL growth in vitro was obtained by addition of chitosan at 100mg/l. In addition, chitin at 25 mg/l decreased the foliar alteration index by 73.34% compared to control.

**Key words:** Chitin, Chitosan, *Fusarium oxysporum* f.sp, *Lycopersicon esculentum*, *Parapenaeus longirostris*, Radici-lycopersici, Shrimp shells.

**INTRODUCTION**

Destined in its entity for human consumption, shrimp generates co-products (heads, shells and tails) as wastes. These wastes contain several substances, which are worth of recovery (lipids, chitin, carotenoid astaxanthin, mineral elements ...) (Heu et al., 2003) and other bioactive compounds (Kim et al., 2008) that are beneficial for both human and animal health.

The chitin is obtained by different methods including the chemical ones (Varun et al., 2017). Shrimp co-products can play an important role in elicitation of plants, inducing a non-host resistance, and prime the plants for systemic acquired resistance (Singh et al., 2018).

In the present study, red shrimp shells (*Parapenaeus longirostris*) were used to extract chitin and chitosan. The objectives of the experiments are to determine the effects of three treatments (shrimp shells, chitin and chitosan powders’) on the germination of tomato seeds in vitro; and on plant growth parameters of *Lycopersicon esculentum* in vivo and, also, on the inhibition of FORL which causes very large yield reductions in tomato.

**MATERIALS AND METHODS**

**Preparation of the raw material:** Shrimp shells of *Parapenaeus longirostris* species are collected at the central market of Mehdia town of Kenitra, and transported to the laboratory in a cooler (4°C). They are washed thoroughly to remove all impurities. The obtained shells were dried at 70°C for 12h, then ground and sieved at -20°C.

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Physico-chemical analysis of shells

Moisture content: The shrimp shells were dried at 70°C for 12 hours and the moisture content was determined using the following formula:

\[
\text{Moisture content \%} = \frac{\text{Initial weight (g)} - \text{Dry weight}}{\text{Dry weight}} \times 100
\]

Measurement of ash content: A sample of 2g of the shrimp shells powder was incinerated at 600°C for 6 hours (Kim, 2004), and the ash content was determined by the following formula:

\[
\text{Ash content \%} = \frac{\text{weight of ash}}{\text{Original sample weight}} \times 100
\]

Determination of the degree of deacetylation by potentiometric titration: According to the protocol of Rutherford and Austin (1978), a sample of 0.1g of chitosan and 40ml of NaOH (50%) were stirred for 1hour and 30 min in water bath at 100°C, after that 25ml of concentrated phosphoric acid was carefully added. The resulting solution is distilled on vigreux colonne. When the distillation flask began to dry, 15ml of hot distilled water was added to the flask. This step was repeated until 250ml of distillate is recovered. A sample of 25ml of distillate was titrated with 0.1N NaOH using phenolphthalein as an indicator. The percentage of acetyl was determined by the following formula:

\[
\text{Acetyl \%} = \frac{V \times 0.04305}{W}
\]

V: NaOH volume
W: weight of sample

Germination and growth of Lycopersicon esculentum

In vitro assay

A. Disinfection of Lycopersicon esculentum seeds: Seeds of the tomato (Rio Grande variety) were disinfected by successive immersion in 1% aqueous NaOCl for 10 minutes (Rao et al., 2006) and then 3 times in sterile distilled water.

B. Filter paper medium: Concentrations of 25, 50, and 100mg/l of shrimp shells, chitin and chitosan powders’ were macerated in distilled water for 24 hours at room temperature to extract the soluble principles. The solutions’ pH was adjusted to 6.0 with 1% NaOH solution.

Seeds (25) placed on the Petri dishes (90mm) containing three discs of filter paper moistened with 4 ml of macerate (Ramanaand et al., 2002). For the control, the sterile distilled water was used. The incubation was carried out at 26±1°C, and a photoperiod of 16h of illumination. After 10 days, the germination parameters was determined.

In vivo assay: Seedlings at the three-leaf stage (Benhamou and Thériault, 1992) were cultivated on pots containing sterilized Maamora soil and then transported in a greenhouse.

The effect of each treatment was determined by a weekly soil amendment for 8 weeks with a volume of 100ml of each treatment (Lafontaine and Benhamou, 1996). For the control, only sterile distilled water was used. Five seedlings were used for each treatment, and the experiment was repeated twice (Benhamou and Thériault, 1992).

Stimulation of resistance of Lycopersicon esculentum seedlings

Action on Fusarium oxysporum f.sp. radicis-lycopersici in vitro: Discs of 5 mm diameter were cut from a pure culture of Fusarium oxysporum f.sp. radicis-lycopersici (isolated and identified in the Laboratory of Botany, Biotechnology and Plant Protection, Faculty of Science, Ibn Tofail University, Kenitra) cultured on PDA medium for 7 days. After that, 0.1ml of each treatment was spread on the surface of the PDA medium (Cheah et al., 1997). Finally, discs (5 discs per treatment) were put face down on the surface of the PDA medium plus treatment (repeated five times per treatment) (Fig 1). The antifungal effect was determined by measuring the inhibition percentage of diametric growth using the following formula (Hajji et al., 2016):

\[
\text{P.I.C.D} = \left( \frac{\text{Mt} - \text{Me}}{\text{Mt}} \right) \times 100
\]

P.I.C.D = percentage of inhibition of diametric growth. Mt=mean diameter of the control colony. Me=mean diameter of colony exposed to shrimp shells, chitin or chitosan powders’.

In vivo assay: Five discs of 1cm³ of a 7-days-old pathogenic fungal colony were immersed in 750ml of Potato Dextrose Broth (PDB) for 5 days at 26°C; after that, the final density was adjusted to 3x10⁶(CFU) ml⁻¹ (Lafontaine and Benhamou, 1996).

Fig 1: Schematic representation of the in vitro test on FORL.
Roots of seedlings at the three-leaf stage (Rio Grande variety) are thoroughly washed with sterile water and treated by soaking for 10 min in different concentrations of the three powders’ (25, 50 or 100 mg/l) with Tween 80 (0.01% v/v) (Benhamou and Thériault, 1992).

After that, each seedling was transplanted into a pot containing sterilized Maamora soil. Next day, the roots were inoculated by soaking for 30 seconds in the inoculum suspension. Five seedlings were used for each treatment, and the experiment was repeated twice (Benhamou and Thériault, 1992).

Re-isolation of FORL: The presence of FORL is searched in the roots of the tomato plants. The root system is disinfected by rapid soaking in 90° alcohol, rinsed several times with sterile distilled water, dried and cut into 5 mm length fragments. The fragments are deposited in PDA medium. The incubation is carried out for 7 days at 26°C, in the dark.

Degree of infection
A. Alteration of leaves: The expression of foliar symptoms is estimated by a foliar index using the following rating scale (Douira et al., 1994):

0 = healthy appearance leaves;
1 = cotyledonal leaf: wilting or yellowing;
2 = drop of the cotyledonal leaf;
3 = wilting or yellowing of the true leaf;
4 = necrosis of the true leaf;
5 = fall of the true leaf;

The sum of the notes relative to the number of leaves is the foliar alteration index. An average index is then calculated for each plant (Douira and Lahlou (1989)).

FAI = \frac{\sum (i \times Xi)}{6 \times NtF}

Where:
FAI: Foliar alteration index;
i: Appearance notes for sheets 0 to 5;
xi: Number of sheets with the note i;
NtF: Total number of sheets.

Table 1: Germination parameters means of tomato seeds.

| Treatments (mg/l) | Germination (%) | Hypocotyl lengths(cm) | Radicular lengths(cm) | Hypocotyl fresh weight (g) | Radicular fresh weight (g) | Hypocotyl dry weight (g) | Radicular dry weight (g) |
|------------------|----------------|-----------------------|-----------------------|---------------------------|---------------------------|--------------------------|-------------------------|
| Control 0        | 86.67 cde      | 5.03 abc              | 07.41 a               | 0.374 a                   | 0.086 a                   | 0.025 a                  | 0.009 a                 |
| Shrimp shells powder 25 | 86.67 bcde    | 5.33 abc              | 09.46 bc              | 0.612 ef                  | 0.249 b                   | 0.030 cd                 | 0.010 ef                |
| Chitin 25        | 82.67 abc      | 6.65 c                | 10.52 c               | 0.632 f                   | 0.251 b                   | 0.030 cd                 | 0.012 g                 |
| Chitosan 25      | 80.00 a        | 5.29 abc              | 08.75 abc             | 0.506 b                   | 0.244 b                   | 0.026 ab                 | 0.008 b                 |
| Chitin 50        | 80.00 a        | 5.29 abc              | 08.75 abc             | 0.506 b                   | 0.244 b                   | 0.026 ab                 | 0.008 b                 |
| Chitosan 50      | 80.33 e        | 5.44 bc               | 10.43 c               | 0.541 c                   | 0.097 a                   | 0.029 bcd                | 0.010 f                 |
| Chitosan 100     | 88.00 de       | 5.44 bc               | 10.43 c               | 0.568 cd                  | 0.358 d                   | 0.040 e                  | 0.012 g                 |

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

Statistical analysis: The difference between the means of each experiment is analyzed by the TUKEY test at α=0.05 by a statistical software.

RESULTS AND DISCUSSION
Moisture and ash content: The obtained results from the measured parameters (moisture content “55.0764%” and ash content “51.2%”) for the shrimp shells explain the low productivity during the extraction of chitin and chitosan. The demineralization and the deproteinization of 100 g of the shrimp shells powder gives 23.93% of chitin, which is comparable to those (24% of chitine) obtained by Benhabiles et al., (2012).

Degree of deacetylation of chitosan: Using the formula of Rutherford and Austin (1978), we obtain 1.076% of acetyl; our results were considered high compared to those obtained by Putra and Husni (2013) (7.26% acetyl), even if we used a potentiometric titration, which could be the most reliable and robust of the non-NMR methods (Renata et al., 2012).

Table 1: Germination parameters means of tomato seeds.

Effect of treatments on the germination of Lycopersicon esculentum
Effect of treatments on the germination of Lycopersicon esculentum: The effect of the three treatments on germination parameters is set out in Table 1.

We found that the seed germination rate of the tomato was affected by the addition of chitosan at 50 mg/l, which increased by 2.66% and 1.33% for the other chitosan concentrations (25 mg/l and 100 mg/l).

As for the hypocotyl and the radicle lengths, the seedlings from the medium containing the shrimp shells powder at 50 mg/l shows the highest values of these parameters. Similarly, the treatments had a favorable effect on the fresh weight of the two parts (hypocotyl and radicle).

Effect of treatments on the growth of Lycopersicon esculentum: The data for the weekly Maamora soil amendments are shown in Table 2.

Compared to control, a stimulation of length, fresh/dry aerial weight, and fresh/dry root weight are observed
among plants treated with chitosan at 50mg/l. Similarly, chitin at 50mg/l recorded the maximum value (51.2cm) over the length of the root compared to the control (21.2cm).

It could be deduced that, the improvement of the root system’s growth allowed a greater exploration of the soil and, consequently, an improved nutrition, which also results in a better development of the aerial part (size and biomass) (Fig 2).

Our results demonstrate the beneficial effect of the weekly soil amendment by chitosan 50mg/l, 100mg/l and chitin 50mg/l on tomato growth compared to the study of Lafontaine and Benhamou (1996) which demonstrates only the protective effect of chitosan at 37mg/l.

**Stimulation of resistance**

*In vivo inoculation of tomato seedlings with Fusarium oxysporum f.sp. radicis-lycopersici*: After observation of the typical symptoms of Fusarium on the control plants (Fig 3), the experiment is stopped (8 weeks after inoculation). Table 3 reports the average sizes of epicotyl, hypocotyl and means of foliar alteration indices of tomato plants inoculated with FORL.

It was found that the treated plants with chitin (25, 50 and 100mg/l) and chitosan (50 and 100mg/l) give maximum and highly significant means compared to the control.

Based on the foliar alteration index, it could be easily concluded that the addition of treatments to the soil induce a highly significant reduction compared to the control of the symptoms; and the lowest FAI was registered by chitin at 25mg/l (FAI=0.165), contrary to the control with the highest FAI (0.619).

The effect of chitosan on FORL could be explained by the penetration of chitosan into conidia of the pathogen and the ultrastructural changes that might result in disorganization of the cytoplasm and loss of intracellular content in spores than in the mycelium (Pulma-Guerrero et al., 2008).

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**Table 2:** Agronomic parameters of plants treated with shrimp shells, chitin and chitosan powders.

| Treatments (mg/l) | 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) |
|-------------------|---------------------------|--------------------------|---------------------------------|-------------------------------|-----------------------------|----------------------------|
| Control 0         | 16.3a                     | 21.2 a                   | 4.116 a                         | 0.468 a                       | 1.082 a                     | 1.572 a                    |
| Shrimp shells 25  | 19.0 ab                   | 21.8 a                   | 4.170 a                         | 0.730 ab                      | 2.006 ab                     | 3.172 b                    |
| Shrimp shells 50  | 29.0 abc                  | 32.0 abc                 | 6.154 ab                        | 0.848 b                       | 2.440 ab                     | 4.946 bc                    |
| Shrimp shells 100 | 22.4 abc                  | 28.2 ab                  | 5.334 ab                        | 0.476 a                       | 1.826 ab                     | 2.098 a                    |
| Chitin 25         | 27.8 abc                  | 38.0 abc                 | 6.562 ab                        | 0.146 a                       | 2.182 ab                     | 1.612 a                    |
| Chitin 50         | 33.2 c                    | 51.2 c                   | 8.938 b                         | 03.108 a                      | 3.732 b                      | 1.286 a                    |
| Chitin 100        | 31.2 bc                   | 33.2 abc                 | 7.196 ab                        | 03.656 a                      | 2.454 ab                     | 1.460 a                    |
| Chitosan 25       | 27.2 abc                  | 36.8 abc                 | 7.518 ab                        | 05.288 ab                     | 3.234 ab                     | 2.728 a                    |
| Chitosan 50       | 35.4 c                    | 42.2 bc                  | 9.090 b                         | 10.948 c                      | 3.758 b                      | 5.808 c                    |
| Chitosan 100      | 30.4 bc                   | 36.0 abc                 | 8.664 b                         | 10.712 c                      | 3.730 b                      | 5.770 c                    |

Means in the same column with the same letter do not differ significantly from each other at α=5%.
In vitro test on Fusarium oxysporum f.sp. radicis-lycopersici: Data in Table 4 reports the results of the three treatments on the growth of FORL cultivated on PDA medium.

At 25 and 100mg/l of chitin, the inhibition of pathogen colonies reach 43.68% and 56.55%, respectively. However, at the 100mg/l of chitosan, the inhibition of pathogen is maximal (73.04%).

Re-isolation of Fusarium oxysporum f.sp. radicis-lycopersici: After one week of incubation in the dark at 26°C, the colonies of violet color characteristic of the pathogen appear around the root fragments deposited on the surface of the PDA medium (Fig 4).

CONCLUSION

This study implies that application of shrimp shells, chitin and chitosan powders’ to seeds of Lycopersicon esculentum in vitro and soil application for once a week tend to stimulate germination parameters, growth and significantly increased resistance to fusarium attacks.
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