# Thiamethoxam seed treatment controls Pea Leaf Weevil (*Sitona lineatus* (L.)) on faba bean in Morocco

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## Abstract

Pea Leaf Weevil (PLW) or Sitona Weevil (*Sitona lineatus* (L.)) is one of the major insect pests on faba bean in Morocco. The PLW uses peas and faba beans as reproductive hosts and can cause important economic damage to these crops. Economic damage is caused mainly by the larvae. The adult weevils feed on emerging faba bean seedlings, chewing leaf margins and growing points, which produce a characteristic scalloped or notched edge. Once the larvae hatch, they begin feeding on the Rhizobium or nitrogen-fixing nodules of the host roots, resulting in partial or complete inhibition of nitrogen-fixation by the plant. This damage results in poor plant growth and low seed yields, and may make the host more susceptible to drought stress and to other diseases through secondary infection. The adults feed on the leaf margins and growing points of many other legume seedlings including alfalfa, dry beans, clover, lentils, lupins and vetch. In order to ensure a good protection of faba bean against pests, a wise and efficient use of agrochemicals is to be boosted. To do so, thiamethoxam seed treatment was evaluated under natural pest infestation in Morocco. Experiment was carried out simultaneously at Douyet and Marchouch INRA experimental stations according to a randomized complete block design with four replications, during 2021-2022 cropping season. The results indicated that thiamethoxam as seed treatment is highly effective in controlling *Sitona lineatus* under both Douyet (SAIS) and Marchouch (ZAIR) conditions; and there was no significant interaction between site and treatment for the severity of the PLW. On average, the treatment reduced the infestation by 91% compared to untreated control. That is, thiamethoxam seed treatment is a simple, accurate, efficient, and low-cost control technology of *Sitona lineatus* on faba bean in Morocco and then should be scaled out and adopted. However, PLW control tactics are more effective and sustainable when used in an integrated pest management (IPM) program.

**Keywords:** Morocco, Faba bean, Sitona lineatus, Seed treatment, Thiamethoxam

# Le traitement des semences au thiaméthoxame contrôle le Sitone (*Sitona lineatus* (L.)) sur Fèverole au Maroc

**Résumé**

Le charançon du pois (PLW) ou Sitone (*Sitona lineatus (L.)*) est l'un des principaux insectes ravageurs de la fève et de la fèverole au Maroc. Le Sitone utilise les pois et les féveroles comme hôtes pour sa reproduction et peut causer des dommages économiques à ces cultures. Les dommages économiques sont principalement causés par les larves. Les charançons adultes se nourrissent sur les plantules de fèves en mâchant les bords des feuilles et les points de croissance, ce qui produit des bords de feuilles dentées, caractéristique des morsures des adultes du Sitone. Les larves causent les dégâts les plus importants. Une fois que les larves éclosent, elles commencent à se nourrir du Rhizobium ou des nodules fixateurs d'azote des racines hôtes, entraînant une inhibition partielle ou complète de la fixation de l'azote par la plante. Ces dommages entraînent une mauvaise croissance des plantes et un faible rendement en grains, et peuvent rendre l'hôte plus sensible au stress hydrique et aux maladies via les infections secondaires. Les adultes se nourrissent des bords des feuilles et des points de croissance de nombreux autres légumineuses, notamment la luzerne, les haricots secs, le trèfle, les lentilles, les lupins et la vesce.
Afin d'assurer une bonne protection de la fève contre les ravageurs, une utilisation judicieuse et efficace des produits agrochimiques doit être encouragée. Pour ce faire, le traitement des semences de fèverole au thiaméthoxame a été évalué sous infestation naturelle par les ravageurs au Maroc, sachant que le contrôle le plus efficace contre le sitone est obtenu avec des traitements insecticides des semences. L'expérimentation a été menée simultanément aux stations expérimentales de Douyet et Marchouch selon un dispositif en blocs aléatoires complets avec quatre répétitions, au cours de la campagne agricole 2021-2022. Les résultats ont indiqué que le thiaméthoxame en tant que traitement des semences est très efficace pour contrôler *Sitona lineatus* dans les conditions de Douyet (SAIS) et de Marchouch (ZAIR) pendant la saison 2021-2022 ; et il n'y avait pas d'interaction significative entre le site et le traitement pour la sévérité du Sitone. En moyenne, le traitement a réduit l'infestation de 91 % par rapport au témoin non traité. Autrement dit, le traitement des semences au thiaméthoxame est une technologie de contrôle simple, durable, précise, efficace, peu coûteuse et respectueuse de l'environnement de Sitona lineatus sur la Fèverole au Maroc et devrait ensuite être vulgarisée et adoptée. Cependant, les tactiques de lutte contre le Sitone sont plus efficaces lorsqu'elles sont utilisées dans un programme de lutte intégrée contre les ravageurs (IPM).

**Mots-clés** : Maroc, Fèverole, Sitona lineatus, Traitement des semences, Thiaméthoxame

# تتحكم معالجة البذور بمبيد تيامطوكسام (Thiamethoxam) في سوسة البازلاء (سيتون) ((L.) *Sitona lineatus*)على الفول في المغرب

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**ملخص**

سوسة البازلاء (سيتون) (PLW) أو Sitone (Sitona lineatus (L.)) هي واحدة من الآفات الحشرية الرئيسية في الفول في المغرب. تستخدم سيتون البازلاء والفول كمضيفين لتكاثرها ويمكن أن تسبب أضرارًا اقتصادية لهذه المحاصيل. لكن الضرر الاقتصادي تسببه اليرقات. يتغذى السيتون البالغ عن طريق المضغ على حواف الأوراق ونقاط النمو، وينتج حواف أوراق مسننة، وهو ما يميز لدغات السيتون البالغة. اليرقات تسبب أكبر قدر من الضرر. بمجرد أن تفقس اليرقات، تبدأ في التغذي على الجذور أو العقيدات المثبتة للنيتروجين في جذور العائل، مما يؤدي إلى منع جزئي أو كامل لتثبيت النيتروجين من قبل النبات. يؤدي هذا الضرر إلى ضعف نمو النبات وانخفاض إنتاجيتة، ويمكن أن يجعل المضيف أكثر عرضة لنذره الماء والأمراض من خلال العدوى الثانوية. يتغذى البالغون على حواف الأوراق ونقاط نمو العديد من البقوليات الأخرى، بما في ذلك البرسيم والفاصوليا الجافة والبرسيم والعدس والترمس والبيقية. من أجل ضمان حماية جيدة للفول من الآفات، يجب تشجيع الاستخدام الحكيم والفعال للمواد الكيميائية. للقيام بذلك، تم تقييم معالجة بذور الفول بالثيامثوكسام في ظل الإصابة الطبيعية بالآفات في المغرب، مع العلم أن أكثر المكافحة فعالية ضد السيتون يتم الحصول عليها من خلال معالجة البذور بالمبيدات الحشرية. أجريت التجربة في المحطتين التجريبيتين دويات ومرشوش وفق جهاز في كتل عشوائية كاملة بأربعة تكرارات خلال الموسم الفلاحي 2021-2022. أشارت النتائج إلى أن الثيامثوكسام كمعالجة للبذور فعال للغاية في السيطرة على Sitona lineatus تحت ظروف دويات ومرشوش خلال موسم 2021-2022. ولم يكن هناك تفاعل بين الموقع والعلاج. في المتوسط ، قلل العلاج من الإصابة بنسبة 91 ٪ مقارنةً بالشاهد الغير المعالج. وبعبارة أخرى، فإن معالجة البذور باستخدام الثيامثوكسام هي تقنية تحكم بسيطة، دائمة، دقيقة، فعالة، غير مكلفة وصديقة للبيئة في مقاومة Sitona lineatus على الفول في المغرب ، ومن ثم يجب تعميمها واعتمادها. لكن أساليب مكافحة السيتون تكون أكثر فاعلية عند استخدامها في برنامج الإدارة المتكاملة للآفات.

**الكلمات المفتاحية:** المغرب، الفول، سيتونا لينياتوس، معالجة البذور، ثيامثوكسام

## Introduction

Food legumes notably faba bean, chick pea and lentil are major staple crops after cereals and make up the dominant part of population's diets in Morocco. Moreover, faba bean is by far the most important pulse grown in Morocco. It contributes to food security and also plays key roles in soil fertility improvement through a large biological Nitrogen fixation potential and its positive impact in improving soil structure and health (Daoui et al. 2015; Badraoui et al., 2016). However, productivity of food legumes in Morocco has remained low because of many constraints notably the biotic one.

Insect pests are amongst the main components of the biotic stress constraint. With the widespread adoption of no-tillage technology, outbreaks of insect pests is expected as it was the case of thrips that have caused serious damage to summer corn fields under no till in China (Ding et al., 2018), corroborating what has been reported by Mrabet et al. (2008, 2022). The latter authors reported that there is a tendency to weed speciation and disease/insect infestation under no tillage systems if not appropriately managed.

Pea Leaf Weevil (PLW) or Sitona Weevil (*Sitona lineatus* (L.)) is one of the major insect pests on faba bean in Morocco (Lhaloui et al. 2014; Chandrashekhar et al., 2014). The PLW uses peas and faba beans as reproductive hosts and can cause economic damage to these crops. The adult weevils feed on emerging faba bean seedlings, chewing leaf margins and growing points, which produces a characteristic scalloped or notched edge. The larvae develop underground by feeding on the root nodules which cause significant economic damage. In other terms, once the larvae hatch, they begin feeding on the Rhizobium or nitrogen-fixing nodules of the host roots, resulting in partial or complete inhibition of nitrogen-fixation by the plant. This damage results in poor plant growth and low seed yields, and may make the host more susceptible to drought stress and to diseases through secondary infection. The adults feed on the leaf margins and growing points of many other legume seedlings including alfalfa, dry beans, clover, lentils, lupins and vetch (Velázquez de Castro et al., 2007). Cárcamo et al. (2015) reported that adults of *Sitona lineatus* feed on foliage of several Fabaceae species but larvae prefer to feed on nodules of *Pisum sativum* L. and *Vicia faba* L**.** inducing the most serious damage. Piedra-Garcia and Struck (2021) presented a state of the art review on Lupin Root Weevils in terms of distribution but also on challenges for pest management and control.

Insecticidal seed treatments (neonicotinoids) allow farmers to control insect pests on a variety of field crops worldwide. Systemic neonicotinoid insecticides have a number of useful chemical qualities including a relatively high water solubility and reduced toxicity to humans and mammals (Tang et al., 2017). They can be taken up by roots during germination to protect the growing plants 'from the inside out' against insect pests (Tomizawa and Casida, 2005), and to promote vigor and protection against abiotic stress (Casida, 2011). To date, carbosulfan (Tang et al., 2006), imidacloprid (Li et al., 1996), thiacloprid (Deng et al., 2011) and thiamethoxam (Tang et al., 2017) are the insecticides most commonly used as seed treatments.

Thiamethoxam is the first commercial second-generation neonicotinoid insecticide from the thianicotinyl sub-class (Maienfisch et al., 2001). It is able to control many commercially important insect pests effectively on a variety of crops, such as cotton, wheat, and corn; and it works through contact, stomach and systemic activity (Wilde et al., 2001). Yue et al. (2003) reported high control efficacies against the European corn borer, *Ostrinia nubilalis* (Hübner) and the Indian meal moth, *Plodia interpunctella* (Hübner). Such control efficacies could be achieved using thiamethoxam (Cruiser) and imidacloprid (Gaucho) seed treatments. Netam et al. (2013) reported that seed treatments of thiamethoxam 70 WS (water dispersible powder for slurry seed treatment) (Cruiser) and imidacloprid 600 FS (flowable concentrate for seed treatment) (Gaucho) were effective against sucking pests for up to four weeks after seed germination in soybean plants, *Glycine* max (L.).

Several studies have been conducted on the control efficacy in rice of thiamethoxam seed treatment against insect pests such as the rice water weevil, *Lissorhoptrus oryzophilus* (Kuschel) and the rice thrips, *Chloethrips oryzae* (Lanka et al., 2013). Good control on *C*. *oryzae* could be achieved by 30% thiamethoxam FS plus 25 g/L fludioxonil (Tang et al., 2017).

Control efficacy of thiamethoxam seed treatment for *Chloethrips oryzae* and its effects on growth and yield of rice was investigated by Tang et al. (2017) in 2014–2016. Excellent control of *C*. *oryzae* was achieved using thiamethoxam 350 FS (flowable concentrate for seed treatment) seed treatment at a rate of 70 g ai/100 kg of seeds, at 17–28 days after sowing (Tang et al., 2017*)*. Field observations indicated that thiamethoxam seed treatment at this rate had no negative effects on the timing or percentage of seedling emergence, establishment, and key seedling characteristics including plant height, root length, and fresh above-ground and underground weight (Tang et al., 2017*)*. However, rice yields of thiamethoxam seed treatment were increased significantly compared to untreated control. Use of thiamethoxam seed treatment was not phytotoxic to rice and represents an important alternative for *C*. *oryzae* management in the crop (Tang et al., 2017*).*

Effective control of pest populations is often essential for cost-effective crop production. Ding et al. (2018) found that among the seven tested neonicotinoid seed treatments, thiamethoxam, clothianidin and imidacloprid showed the highest effectiveness against corn thrips. Moreover, Huang et al. (2015) found that seed treatment of oilseed rape (*Brassica napus)* with the neonicotinoid insecticides imidacloprid or thiamethoxam significantly and with the same magnitude reduced the average number of aphids occurring on the plants and the number of plants infested with aphids.

Cárcamo et al. (2015) conducted a greenhouse study to quantify nodulation, soil and plant N content, and nodule damage by weevil larvae in relation to soil N amendment with urea, thiamethoxam insecticide seed coating and crop stage. They concluded that PLW reduced the number of older tumescent (multilobed) nodules and thiamethoxam addition increased them regardless of other factors such as N amendment and crop stage, and that PLW decreased plant N content at early flower and thiamethoxam increased it. The authors also reported that pea crops in soils with high levels of soil nitrogen are unlikely to be affected by PLW and should not require use of insecticides.

Asha et al. (2021) tested the efficacy of insecticidal seed treatment and foliar insecticide (thiamethoxam and lambda-cyhalothrin, respectively), and nitrogen amendment for PLW control using a multi-year field plot study at two sites in Alberta, Canada. They found that PLW feeding damage significantly reduced faba bean yields, and that Thiamethoxam reduced adult and larval damage, and protected faba bean yield, while neither lambda-cyhalothrin nor a nitrogen amendment was effective in protecting the crop from yield loss.

Cárcamo et al. (2015) concluded that Thiamethoxam seed treatments could potentially be used as a tool for the integrated pest management of the pea leaf weevil, *Sitona lineatus* (L.), particularly in combination with other methods such as biocontrol and trap crops.

The damage by PLW is not highly visible and noticeable and then underestimated by farmers. As with many root-damaging pests, PLW management and control are still challenging both researchers and growers. The objective of the present study was to evaluate the effectiveness of thiamethoxam seed treatments against *Sitona lineatus* on Faba bean under Moroccan conditions.

## Materials and Methods

Two experiments were performed simultaneously at Marchouch (latitude 6.71 W; longitude 33.61 N and altitude 397 m above see level) and Douyet (5.08 W; 33.05 N and 405 m above the see level) INRA experimental stations during 2021-2022 cropping season in order to investigate the effect of chemical seed dressing on insect pests of Faba bean under Moroccan conditions. The cultivar used was ICARUS, a small seeded variety of Faba bean (*Vicia faba var. minor*), seeded at a rate of 100 kg/ha. A total of five seed treatments were investigated including an untreated control, two fungicide seed treatments and two fungicide-insecticide seed treatment mixtures (Table1).

**Table 1.** List of agrochemicals used as seed treatments

| Label | Treatment (Trade name) | Active ingredients |
|---|---|---|
| T0 | Untreated control | No ingredient |
| T1 | Vibrance Maxx | Metalaxyl-M + Fludioxonil+ sedaxane |
| T2 | Vibrance Maxx + RHZ | Metalaxyl-M +Fludioxonil+ sedaxane + Trichodermaharzianum (Rhizoderma) |
| T3 | Apron Star | Difénoconazole (20 g/l) + Métalaxyl-M (200 g/l) + **Thiamethoxam** (200 g/l) |
| T4 | Apron Star + RHZ | Difénoconazole (20 g/l) + Métalaxyl-M (200 g/l) + **Thiamethoxam** (200 g/l) + Trichodermaharzianum (Rhizoderma) |

Plots were arranged in a randomized complete block design with four replications. Individual plots were 12 m wide by 20 m long. Planting dates was 7th and 10th December 2021 at Marchouch and Douyet respectively. Seeding rate was 100 kg/ha and a row spacing of 60 cm. The crop was fertilized and managed for weeds based on standard recommendations.

Visual assessment of the severity of Pea Leaf Weevil (PLW) was performed by estimating the severity of U-shaped notches on leaves (Figures 1 & 2) using a scale from zero (no visible notches) to 20% of area of leaves damaged, corresponding to more than 80% of the edges of leaves notched (Figure 3).

**Figure 1.** U-shaped notches on faba bean leaves at Marchouch on January 24th, 2022, induced by the adult of *Sitona lineatus*


**Figure 2.** Effectiveness of Thiamethoxam faba bean seed treatment (T3 : Apron Star) on *Sitona lineatus*. The untreated control (T0) exhibits the U-shaped notches induced by the insect. (Douyet, February 8th, 2022)

**Figure 3.** Damages on faba bean leaves induced by the adult of *Sitona lineatus*

The Effectiveness (%) refers to how well the insecticide performs in the field when compared to untreated control. It was computed, for a given seed treatment against PLW, as follow:

$$ET_i = (1-ST_i/ST_0)*100$$

Where $ET_i$ stands for Effectiveness of treatment $T_i$; $ST_i$ stands for severity of PLW for treatment $T_i$; and $ST_0$ stands for severity of PLW for treatment $T_0$ (untreated control).

Standard analysis of variance was performed using the SAS software package to analyze the data obtained and means were compared by Duncan's multiple range test at 5% probability level.

## Results and discussion

The analysis of variance of data of PLW (*Sitona lineatus*) infestation of Faba bean (cv. ICARUS) at Marchouch and Douyet during 2021-22 cropping season revealed a highly significant difference between sites and between treatments but their interaction was not significant meaning that the effectiveness of treatments has the same trend in both sites (Table 2). It might be drawn from Table 2 that 91.12 % of the variation is explained by the effect of treatment.

**Table 2.** Analysis of variance of data on *Sitona lineatus* damage on leaves of Faba bean (cv ICARUS) at Marchouch and Douyet during 2021-22 cropping season

| Source of variation | Degree of freedom | Sum of squares | Mean squares |
|---|---|---|---|
| Site | 1 | 36.1 | 36.1*** |
| Treatment | 4 | 1185.6 | 296.4 *** |
| Site*Treatment | 4 | 4.4 | 1.1 ns |
| Replication(Site) | 3 | 14.8 | 4.9 ns |
| Error | 27 | 59.5 | |
| Total | 39 | 1300.4 | |

*** *Highly significant difference at P<0.001 probability level*

The Duncan's multiple range test at 5% probability level showed two clusters significantly different from each other and no significance within each. The 1st cluster includes the untreated control and the two fungicide-seed treatments (T0, T1 &T2) and the 2nd one includes the two fungicide-insecticide seed treatment mixtures (Apron star (T3) & Apron star + RHZ (T4)) (Table 3).

**Table 3.** Mean values of the severity of damages induced by *Sitona lineatus* on Faba bean leaves (cv ICARUS) at Marchouch and Douyet during 2021-22 cropping season for each seed dressing treatment

| Treatment label | Active ingredients | Magnitude of Sitona damage at : | | |
|---|---|---|---|---|
| | | Douyet | Marchouch | Average |
| T0 | None (Untreated control) | 11.75 a | 13.00 a | 12.37 a |
| T1 | Metalaxyl-M + Fludioxonil + sedaxane | 12.00 a | 14.25 a | 13.12 a |
| T2 | Metalaxyl-M + Fludioxonil + sedaxane + Trichodermaharzianum (Rhizoderma) | 11.50 a | 13.75 a | 12.62 a |
| T3 | Difénoconazole + Métalaxyl-M + Thiamethoxam (200 g/l) | 0.62 b | 1.62 b | 1.12 b |
| T4 | Difénoconazole + Métalaxyl-M + Thiamethoxam (200 g/l) + Trichodermaharzianum (Rhizoderma) | 0.75 b | 3.50 b | 2.12 b |

*Means within columns with the same letter are not significantly different at 5% probability level according to Duncan's test*.

These experiments showed that Apron Star (that contains 200 g/l of Thiamethoxam) as seed treatment is highly effective for managing Pea Leaf Weevil in Faba bean under Moroccan conditions (Figure 4). On average, the treatment reduced the infestation by 91% compared to untreated control.

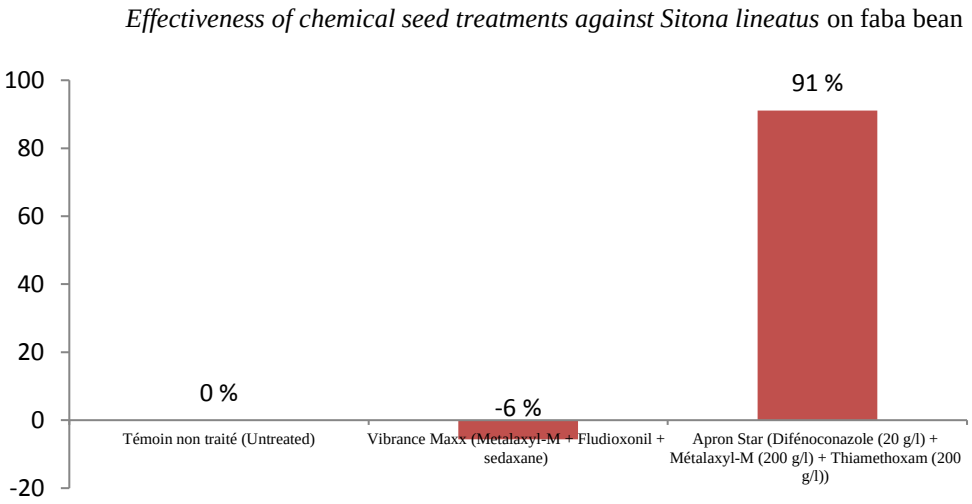


**Figure 4.** Effectiveness of Thiamethoxam seed treatment for managing *Sitona lineatus* in Faba bean under Moroccan conditions during 2021-22 cropping season

This finding corroborates what has been reported by many authors regarding the effectiveness of Thiamethoxam in controlling many insect pests on many crops. Wilde et al. (2001) tested the efficacy of three insecticides as seed treatments for control of insect pests on wheat and found that Imidacloprid (Gaucho®) and thiamethoxam (Adage®) were effective in controlling early season (fall) infestations of the greenbug, *Schizaphis graminum* (Rondani), and the Russian wheat aphid, *Diuraphis noxia* (Mordvilko), whilst Fipronil (Regent®) was not effective against these two aphid species. However, they found that these three compounds effectively controlled fall infestations of Hessian fly, *Mayetiola destructor* (Say).

Kathy et al. (2013) reported that Clothianidin, thiamethoxam, or imidacloprid provide fair to good control of Hessian fly. Schmid et al. (2018) stated that seed treatments protect against feeding insects for 1-2 months after planting; and Whaley (2019) from his side stated that seed treatment consisting of Gaucho 600F (imidacloprid) or Cruiser 5FS (thiamethoxam) is recommended against Hessian fly. Moreover, Cárcamo et al. (2015) concluded that PLW on *Pisum sativum* reduced the number of older tumescent (multilobed) nodules and decreased plant N content at early flower, whilst thiamethoxam used as seed treatment increased the nodules and plant N content. Asha et al. (2021) found that PLW feeding damage significantly reduced faba bean yields, and that Thiamethoxam reduced adult and larval damage, and protected faba bean yield, while neither lambda-cyhalothrin, used as foliar insecticide, nor a nitrogen amendment was effective in protecting yield.

Thiamethoxam seed treatments could potentially be used as a tool for the integrated pest management of the pea leaf weevil, *Sitona lineatus* (L.), particularly in combination with other methods such as biocontrol and trap crops (Cárcamo et al.,

2015). However, prolonging storage time of the treated seeds could significantly reduce cumulative germination rate; it is therefore suggested that, treated seeds with imidacloprid or thiamethoxam before planting should be stored for no longer than 30 d (Huang et al., 2015).

## Conclusion

These experiments showed that Thiamethoxam as seed treatment is highly effective for managing Pea Leaf Weevil in Faba bean under Moroccan conditions. On average, the treatment reduced the infestation by 91% compared to untreated control. That is, this seed treatment is a simple, accurate, efficient, and low-cost control technology of *Sitona lineatus* on faba bean in Morocco and then should be scaled out and adopted. However, PLW control tactics are more effective, sustainable and ecofriendly when used in an integrated pest management (IPM) program.

Using seed treatments in place of foliar sprays on crop plants avoids many difficulties including the proper timing of application, inadequate coverage, and reduced efficacy. This method is consistent with the current concept and characteristics of green crop protection, and should be, therefore, spontaneously used by farmers.

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## Conflict of interest

The authors declare that they have no conflict of interest.

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