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Pesticide use in saharan agriculture: evaluation of insecticide treatments against *Tuta absoluta* (meyrick, 1917) in greenhouse tomato production in the Ziban region, southern Algeria

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Abstract

The objective of this study is to evaluate the efficacy of insecticides employed by tomato cultivators against *Tuta absoluta* under greenhouse conditions, during the 2021-2022 crop year in the region of Biskra (south-eastern Algeria). Three experimental sites (Ain Naga, M'ziraa and Doucen) were selected for the study, each of which was equipped with a greenhouse. Samples of tomato leaves were collected on a fortnightly basis, following each treatment, at three levels of the plant (basal, middle and apical), with the objective of evaluating infestation rates. The highest infestation rates were observed between spring and summer, reaching 64.35%, 61.34% and 55.55% respectively at Ain Naga, M'ziraa and Doucen. Basal leaves exhibited the highest infestations in all three sites, with averages of 47.29, 34.62 and 37.36 in Ain Naga, M'ziraa and Doucen, respectively. Abamectin, the most frequently used active ingredient, demonstrated variable efficacy depending on its commercial formulation. The efficacy of combinations with other active ingredients, such as Emamectin benzoate and Chlorantraniliprole, was found to be moderate to good. Conversely, the efficacy of Acetamiprid-based products was found to be contingent upon their formulation. When administered as a standalone treatment, active ingredients such as Emamectin benzoate and Thiocyclam hydroxalate exhibited only marginal effectiveness

Key words: greenhouse, pesticides, saharan agriculture, *Tuta absoluta*, Ziban

Introduction

The tomato (Lycopersicon esculentum Mill.) is indigenous to South America. In 2017, the total area devoted to tomato cultivation worldwide was 4.84 million hectares, with an estimated yield of approximately 182 million tons of fresh fruit **(FAO, 2019)**. In Algeria, tomato production in the Saharan region has undergone a remarkable expansion, establishing the region as the country's primary center for early tomato cultivation **(Daoudi and Lejars, 2016)**. Over the past two decades, Algeria has witnessed a significant development in its agricultural sector, driven by the thriving market garden crops cultivated within the confines of greenhouses. This growth can be attributed to the government's strategic policy initiatives, which have fostered the growth of this sector **(Nourani and Bencheikh, 2017).** Consequently, the wilaya of Biskra has become the foremost national producer of early vegetables **(Allache *et al.*, 2015)**.

Tomato production is limited by insect pests, in particular the tomato leaf miner *Tuta absoluta* Meyrick, 1917 (Lepidoptera:Gelechiidae). This invasive insect was first reported in Algeria in 2008 in tomato greenhouses in Mostaganem **(Guenaoui, 2008)** and at the end of the same year in Biskra **(Belhadi *et al*., 2009)**. Its presence can cause losses of between 70% and 100% **(Paratissoli and Parra, 2000; Oliveira *et al*., 2007).**

In the context of Saharan greenhouse agriculture, crops are subjected to a series of harsh environmental conditions, characterised by chronic water scarcity and extreme temperatures. Limited water availability has been demonstrated to exert a deleterious effect on plant health, rendering them more susceptible to infestation by pests. Furthermore, elevated ambient temperatures and considerable diurnal fluctuations have been demonstrated to promote the accelerated development and reproduction of insect pests, including *Tuta absoluta* **(Desneux *et al*., 2010; Biondi et *al*., 2018).** As demonstrated by **Mao *et al.* (2019)**, these climatic factors exert a significant influence on the dynamics of pest populations, thereby compromising the efficacy of pesticides. Such efficacy can be subject to variations under different thermal conditions. As highlighted by **Aktar et al. (2009)**, high temperatures accelerate the degradation of pesticide active ingredients, reducing their persistence and efficacy on plant surfaces.

Pest management strategies in these arid environments require meticulous adaptation to guarantee treatment efficacy and mitigate the risks associated with pesticide overuse. With the diversification of recommended control strategies, farmers in the Ziban are choosing insecticides to control *T. absoluta* **(França *et al*., 2000).** Moreover, the impact of this intensive agriculture, with its high consumption of chemical inputs, is certainly not without harmful consequences for human health and the environment of the region **(Belhadi *et al*., 2016).**

This study sheds light on the increasing use of pesticides. The study was carried out on greenhouse tomatoes by evaluating the efficacy of insecticide treatments used against *T. absoluta* by greenhouse growers in the Ziban region.

Materials and methods

Study region

The study was conducted over a nine-month period from October to June during the season of 2021/2022 in the region of Biskra, 470 km south-east of the country's capital. The agro-ecological region of Ziban belongs to the Saharan bioclimatic zone that is characterised by mild dry winters and dry hot summers. Rainfall rarely exceeds 250 mm per year and the dry season lasts almost the whole year. Three sites of tomato growing areas were selected: Ain Naga, M'ziraa (Ziban East) and Doucen (Ziban West) **(Figure 01).**

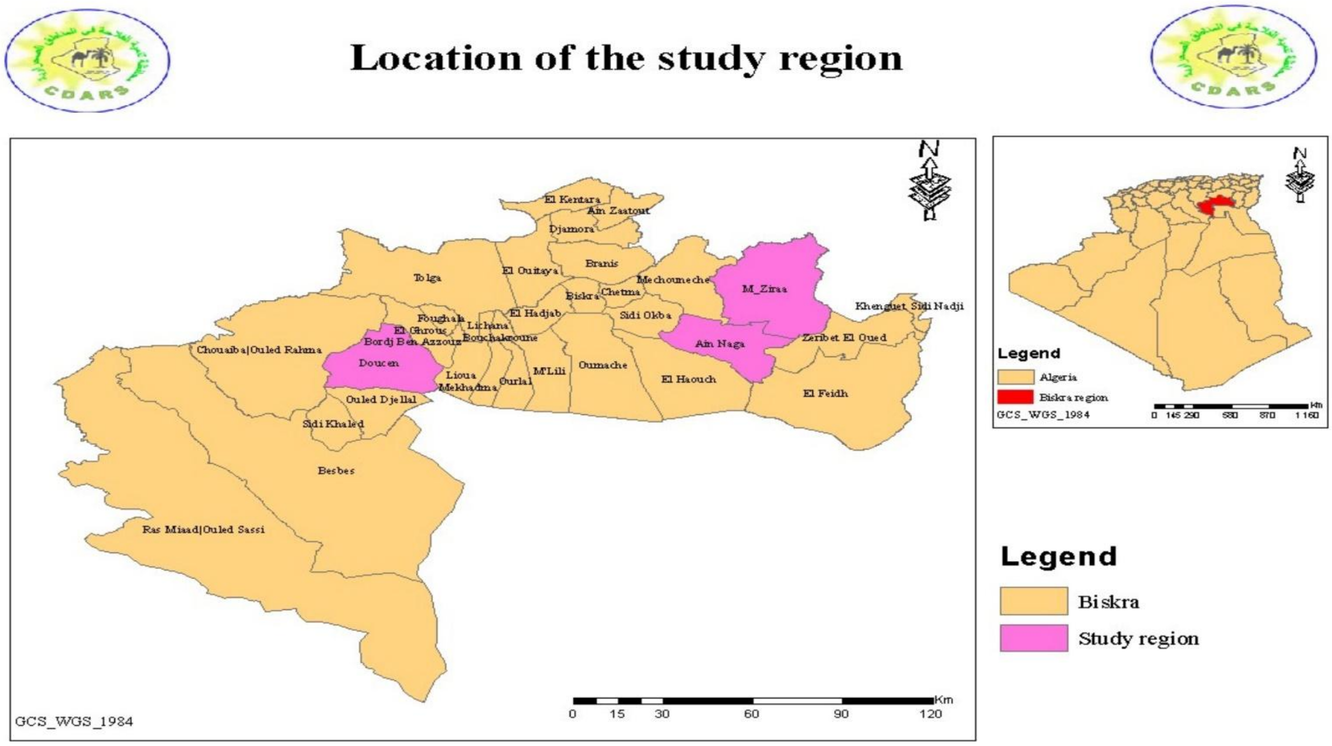

Figure 1: *location of the study region* **(CDARS , 2023)**

Sampling

Sampling was based on two principles: accessibility to the farm and the willingness of the farmers to carry out the observations. The long distance between the sites and the difficulty of access meant that sampling could not be carried out simultaneously at all three sites. A 400 m² tunnel greenhouse was selected at each site, with a total of 800 plants per greenhouse, divided into 8 rows, 80 cm apart and 50 cm between plants. Two samples were taken every 15 days. Three leaflets were taken from each plant from a sample of nine plants per row giving a total of 72 plants per greenhouse and 216 leaflets per greenhouse. leaflets sampling was carried out outside the treatment periods. The leaflets were brought to the laboratory and subjected to careful observations under a stereo microscope, counting both healthy and mined leaflets. **(Binns and Nyrop, 1992)**

Assessment of the infestation rate

The infestation rate was determined through visual examination of the tunnels created by larvae on the leaflet blade. This rate was calculated using the formula proposed by **Abbott (1925**) as follows:

Ti= (Number of infested leaves/Σof sampled leaves) ×100

Food preference of leafminer larvae

The food preference of the insect and its distribution on the host plant were assessed by calculating the rate of infestation of leaflets in the three layers of the plant: the top or apical layer, the middle or mid-layer and the bottom or basal layer **(Southwood and Henderson, 2000).**

Evaluation of the efficacy of the insecticides used during the treatment program

Insecticide efficacy against *Tuta absoluta* was assessed through field monitoring, without direct intervention in treatment application. Insecticide treatments were carried out by farmers according to their regular practices. For each treatment, leaf samples were randomly collected from multiple plants before application (day 0) and after application, following the pre-harvest interval (DAR) specific to each product. For each sampling date, 216 leaves were examined to determine infestation rates and the number of dead larvae. Treatment effectiveness was evaluated by comparing infestation rates and larval mortality before and after each application, the treatment efficacy rate was calculated according to the formula adopted by **(Abbott, 1925)**., as follows:

Pre-treatment infestation % - Post-treatment infestation %/ pre-treatment infestation % × 100

Treatments showing negative efficacy were considered as 0%

Statistical analysis

The data were analyzed using XLSTAT version 2014.5.3 software. A two-factor analysis of variance (ANOVA) was conducted to evaluate the effects of time factor and level factor.

1 Results and discussion

Tuta absoluta infestation in tomato crops

The prevalence of *Tuta Absoluta* infestations on tomato leaves at the three study sites demonstrated a progressive increase over the course of the observation period reaching a maximum of 64.35% ± 6.81 at Ain Naga, 61.34% ± 4.66 at M'ziraa, and 55.55% ± 9.60 at Doucen in April, May and June, respectively **(Figure 2, A, B & C)**. This increase was corroborated by an analysis of variance, which revealed a statistically significant difference between months ($p < 0.01$). As reported by **Attrassi (2014)**, the development cycle of *T Absoluta* results in the destruction of 28.7% of the green surface area of a leaflet in the field. These findings are corroborated by the number of adult males captured in pheromone traps, which ranged from 543 to 1055 male per trap per week at the end of the season. In contrast, the lowest infestations were recorded between December and March at the three sites: at Ain Naga in December and March, at M'ziraa in January and March, and at Doucen in February and March. The relatively low levels of attacks are likely attributable to the lower temperatures observed during this period, which ranged between 19 and 22°C. Indeed, the development of the leafminer is linked to climatic conditions, particularly temperatures. As previously indicated by **Mahdi *et al*. (2010)**, higher temperatures facilitate its proliferation, which is particularly evident during the spring and summer months in Mediterranean countries **(Desneux *et al*., 2010)**. Furthermore, **Bellatreche *et al.* (2021)** approved that the region of Biskra in southern Algeria is more severely affected by infestations than the other areas studied (eastern, western and central Algeria).

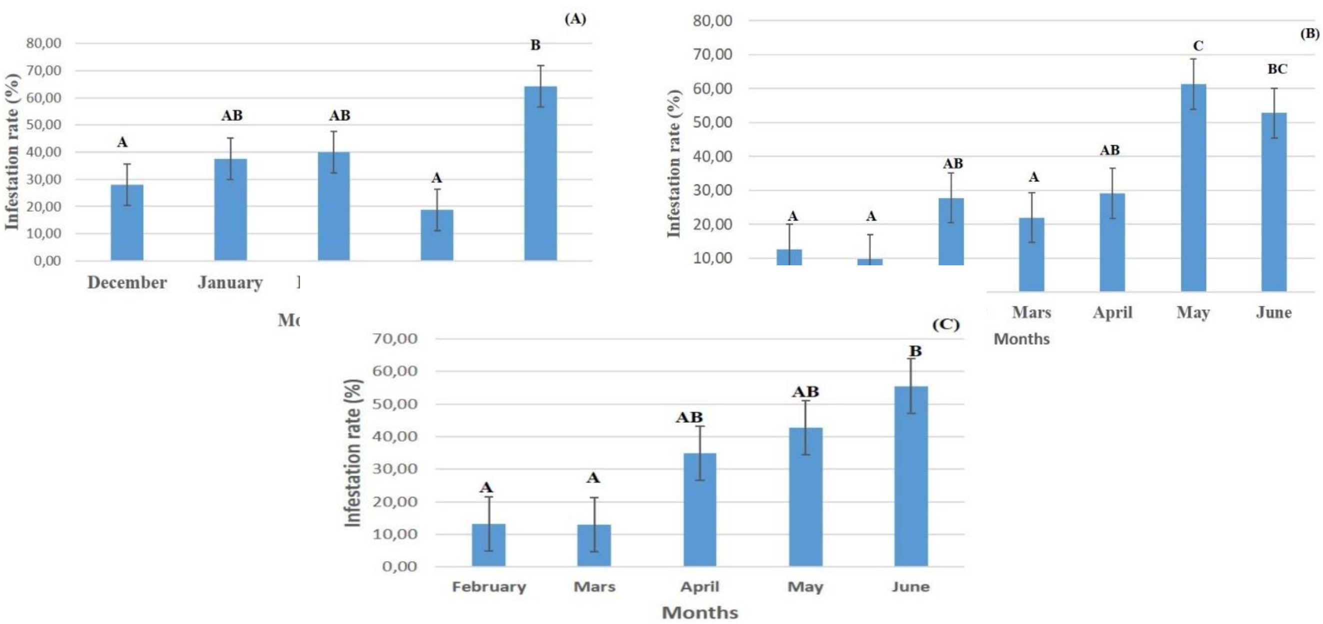

Figure 02 : *Tuta absoluta infestation of tomato in the three study sites (**A**: Ain naga, **B**: M'ziraa, **C**: Doucen)*

Food preference of *Tuta Absoluta* larvae according to leaf strata

The larvae of *Tuta absoluta* exhibited a pronounced preference for the leaves of the basal stage of the tomato plant, with average infestation rates of 47.29 ± 5.00 at Ain Naga, 34.62 ± 3.26 at M'ziraa, and 37.36 ± 6.22 at Doucen **(Figure 3, A, B & C)**, observed throughout the crop cycle. These findings align with those of **Aroun *et al*. (2010)**, who similarly observed heightened infestation at the basal level. However, Torres et al. (2001) and **Leite *et al.* (2004)** have reported that females prefer to lay eggs on the underside of apical leaves, which are softer than those of the middle or basal stages, characterised by a low calcium content. Larval development has been influenced by The nutritional quality of the leaves **(Bawin *et al*., 2016).** The contradiction between the results may be attributed to the fact that the leaves of the apical stage, which contain the eggs laid by the females, are subsequently found at the basal level as the plant progresses through its phenological stages. The emergence of larvae results in the infestation of these leaves, which progresses in accordance with the growth stages of the plant .Consequently, the basal stage of the leaves is typically the first to become infested, in contrast to those in the middle and apical stages. The results suggest that the migration of larvae from the apex to the base as the plant grows could explain this increased infestation at the base **(Cherif *et al.*, 2013).** Moreover, at the end of the season, the increase in damage to the upper leaves is attributed to the synchronized spread of the pest with plant development **(Nayana *et al*., 2017; Lietti *et al.*, 2005).**

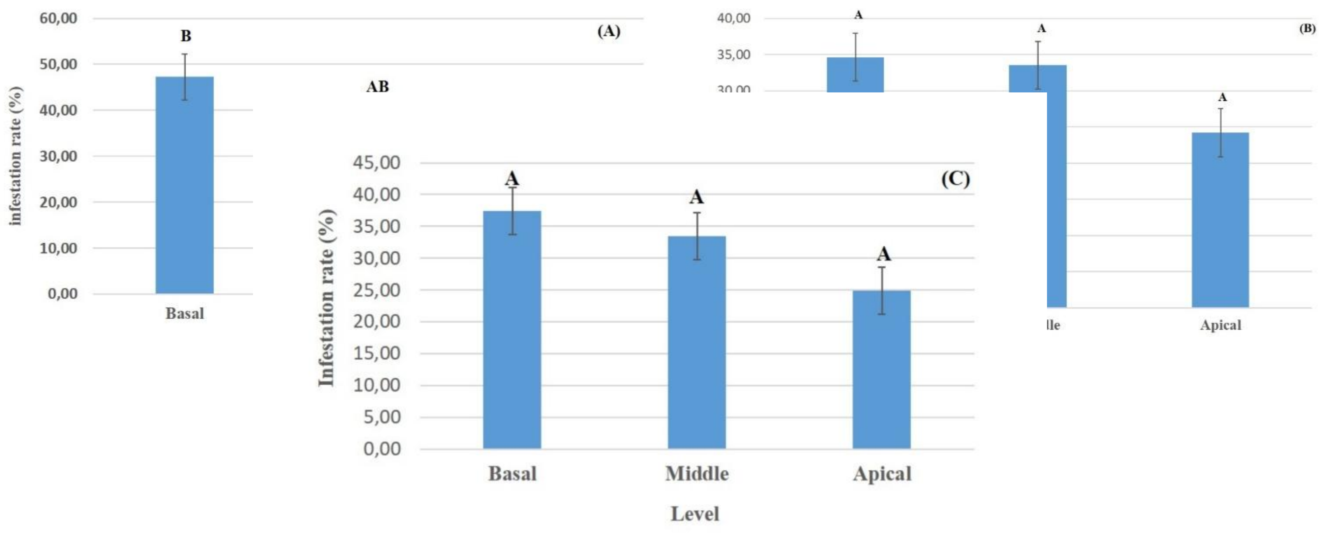

Figure 03 : *Food preference of leafminer larvae according to leaf strata (**A**: Ain Naga, **B**: M'ziraa, **C**: Doucen)*

Effectiveness of insecticides used by greenhouse growers against *T absoluta*.

Chemical control remains one of the most widely adopted strategies for the management of *Tuta absoluta* **(Lebdi-Grissa *et al*., 2010**; **Silverio et al., 2009).** However, this approach presents considerable challenges, particularly due to the endophagic behaviour of larvae that develop inside leaves, stems and fruit **(Konus, 2014)**. The efficacy of some insecticides on pest larvae can be attributed to the action of the chemical, the formulation or the diet of the pest **(Siegwart, 2017)**. The findings of this study indicate that Abamectin is the most frequently utilized active substance by greenhouse growers at the three investigated sites, either as a standalone treatment or in combination with other active ingredients. Abamectin exerts its effect on the pest through ingestion and contact. Some chemicals display a relatively short persistence, including Abamectin, which frequently undergoes rapid photodegradation in the environment (**Novelli et al., 2012**; Tisler and Erzen, 2006). This provides an explanation for the moderate efficacy observed at the M'ziraa site (59.97%) (**Figure 4, B)**, as well as the potential resistance developed by local *T. absoluta* populations to this insecticide **(Lietti et al., 2005)**. Indeed, numerous studies have documented the resistance of *T. absoluta* to active substances such as Abamectin and Deltamethrin in various regions, including Brazil, Europe and North Africa **(Silva et al., 2015**; **Roditakis et al., 2015**; **Guedes et al., 2019**; **Langa et al., 2022).** It is conceivable that Mediterranean populations of *T. absoluta* have already developed genetic resistance **(Braham and Hajji, 2012)**. The efficacy of Emamectin Benzoate, a substance belonging to the Avermectin class, was found to be insignificant in the context of this study **(Figure 4, C)**. This finding is consistent with the observations of **Shiberu and Getu (2017)**, who reported that Emamectin Benzoate demonstrated enhanced efficacy when used in combination with other active ingredients, as opposed to a single application.

Conversely, Acetamiprid demonstrated notable efficacy (60.62%) **(Figure 4, A)** in the management of *T. absoluta.* This insecticide, which is systemic in nature, acts by contact and ingestion and has a broad spectrum of activity covering several orders of insects, including Lepidoptera **(Zekeya et al., 2017)**. The insecticide exerts its effects on the digestive system, as well as exhibiting strong osmotic and systemic activity **(Takahashi et al., 1998).**

High levels of resistance to Diamides (including Chlorantraniliprole) have been documented in leafminers from Brazil, Italy, and Turkey (**Silva et al., 2016**; **Roditakis et al., 2015**; **Yalcin et al., 2015).**

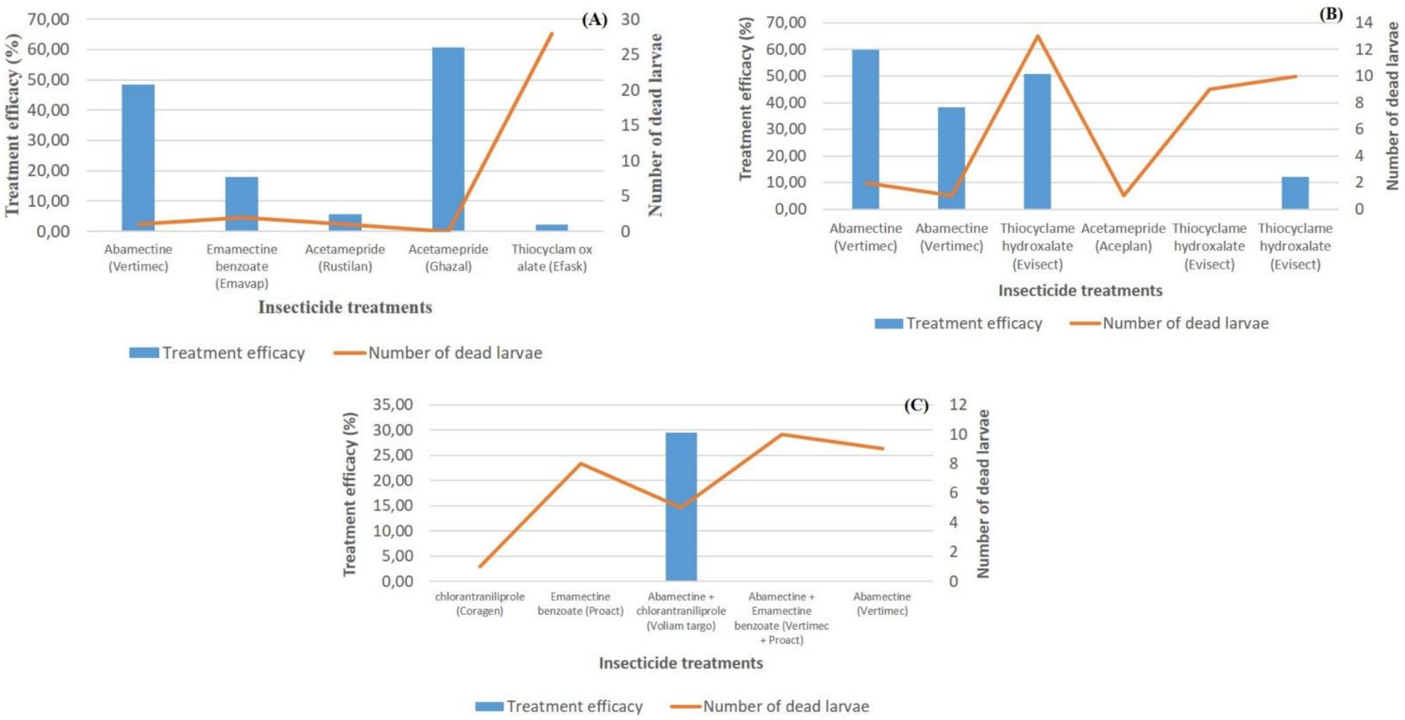

Figure 04 : *Efficacy of insecticides used by greenhouse growers against T absoluta at the three sites (**A** : Ain naga, **B** : M'ziraa, **C** : Doucen)*

Despite the presence of similar active ingredients among the insecticides evaluated, substantial variations in efficacy were observed among the commercial products. This variability may be attributed to differences in formulation quality, types of adjuvants used, product stability, and storage conditions. It is well established that the effectiveness of an insecticide depends not only on the active ingredient itself, but also on the formulation and additives that can influence the absorption, adhesion, and persistence of the product on plant surfaces **(Matthews, 2016).** These findings underscore the necessity of evaluating commercial products individually rather than basing their efficacy solely on the active ingredient.

The differences observed between infestation rate reduction and recorded larval mortality across treatments may be explained by the mode of action of the insecticides used.

Conclusion

The present study underscores the heterogeneity of active ingredients employed in conventional agriculture within the region under scrutiny, in conjunction with the variability of their efficacy against *Tuta absoluta*. Despite the demonstration of partial efficacy in a number of formulations, the majority of the insecticides evaluated were found to demonstrate a lack of effectiveness. The repeated use of ineffective products, in conjunction with the variability in performance between formulations, may have encouraged the development of cross-resistance in the pest. This situation serves to underscore the considerable threat posed by *Tuta absoluta* to tomato cultivation in southern Algeria, while concurrently encouraging the intensive and at times excessive utilisation of pesticides. This has far-reaching consequences for the sustainability of agricultural systems and gives rise to significant public health and environmental concerns linked to the accumulation of chemical residues.

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