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Economic impact of pests on tomato production in southern and central Benin: The cases of *Helicoverpa armigera, Tuta absoluta, Tetranychus evansi,* and root-knot nematodes

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Abstract

Tomato (*Lycopersicon esculentum* Mill), the most cultivated and consumed fruit vegetable in Benin, is subjected to parasitic attacks reducing its productivity. This study assesses the economic impacts of *Helicoverpa armigera*, *Tuta absoluta*, *Tetranychus evansi* and root-knot nematodes. One hundred and forty-four (144) focus group sessions, supported by individual interviews with 60 farmers were conducted from August 24 to 29, 2020, and from September 7 to 12, 2020 in eighteen (18) Districts in southern and central Benin. The results indicated that growers recognize different pests affecting tomato farming, especially by symptoms on it fruit, leaves, stem and root system. *Helicoverpa armigera* has the highest gross output reduction rate for both severe (78.3%) and moderate (38%) attacks. This reduction corresponds to losses of 104.62 kg and 50.75 kg on a harvest of 133.62 kg per plank of 1.2m x 13m (i.e. 15.6 m^2), equivalent to average economic impacts of 37,052.92 F CFA and 17,973.96 F CFA respectively for severe and moderate attacks. *Helicoverpa armigera* is the main pest of tomato against which the development of control technologies appears more relevant.

Keywords: Tomato, pests; Economic impacts; Ecological management; Perception; Benin

1 Introduction

In sub-Saharan Africa, market gardening in cities with a high population concentration and in peri-urban centres is considerable for meeting vegetable consumption needs [1]. This activity is the main source of income for many of the producers who invest in it. By growing food products at home or through professional agricultural organizations, poor households are able to lower the financial burden of food supply, build up a large food stock and bring crop calendars closer to vegetable production [2]. The share of income generated from market gardening activities is exploited for the purposes of household survival and the education of offspring [3]. In addition to the financial aspect, this sub-sector of

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activity owes its importance to the professional integration acquired and the food and social functions that result from it.

In Benin, the history of market gardening activities goes back to the colonial era with the French missionary fathers in 1945 who worked on the Acron site for food needs [4]. Nowadays, this sector is experiencing a surge due to population growth, galloping unemployment and ambient food insecurity, which appear as contemporary challenges. According to [5], in southern Benin, leafy vegetables are second only to tomatoes and are widely consumed by 62.5% of the beninese population. Despite its growth, the market gardening sector is prone to the invasion of pests which cause considerable damage in terms of yield reduction. Overall, insects pests have significant effect on crop productivity and quality which generate annual losses estimated between 20% and 30% of total yield [6]. For example, one of the major constraints to tomato production although it remains the most consumed and demanded vegetable throughout the year in Benin [7], is the incidence of the fruit borer *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) [8]. It is a polyphagocyte that causes immense damage to the tomato fruit, reducing its yield [9]. This pest can be associated with another equally virulent called *Tuta absoluta* which is itself responsible for the low productivity of tomatoes since this plant represents its basic food [10]. As matter of fact, this pest causes crop losses of up to 100%, making it one of the most destructive tomato enemies in the world [11]. It is a micro-lepidoptera native to South America whose larvae burrow into tomato leaves and fruits [12].

Nematodes of the genus *Meloidogyne*, which are among the main soil pests, hosts of vegetable crops in the field or under cover, induce characteristic symptoms (galls) on the attacked roots [13]. Root-knot nematodes (*Meloidogyne* spp.) are present on tomatoes and are a limiting factor in vegetable production, particularly in tropical regions [14]. For instance, [15] studies found that *Tetranychus evansi* caused more foliar damage to drought-stressed tomato plants. The attacks of the above-mentioned pests significantly affect the yield of the tomato, thus leading to a scarcity of this product on the market [16].

In the aim at coping with this pest pressure, market gardeners use a number of plant protection products such as pacha, k-optimal, acarius and nematicides to fight these pests [17]. Often, alternative methods that refer to the destruction of infested plants, crop rotation, weed control and biopesticides are employed [12]. As a result, smallholder farmers in Africa routinely use pesticides to optimize the yield of vegetable crops [3; 18]. However, vegetable producers, mainly because of their low level of education, do not know or are unaware of the real toxicity of the pesticides used and how they are used. In general, they rarely have access to training on the use of pesticides and their complex management [19]. This is not without harmful consequences for the health of the farmers themselves, consumers and more broadly the environment. Ultimately, by consuming market garden products, populations expose themselves to contamination and risks related to the accumulation of heavy metals in water, soil and vegetables [1]. Avoiding such negative impacts that stem from the pesticides has resulted in the development of integrated pest management (IPM) programs which consist in the analysis of the presence of pest population in the field to better choose the right time for applying the pesticides [17].

This is to offer a sustainable solution (ecological, economic and social) to the problem of pest invasion and its corollaries that project n°3 of the National Agricultural Research Program (PNRA) 2020-2024 intends to develop integrated pest control in tomato cultivation in Benin. However, it is not yet known whether the level of damage caused by the various pests allows the development of modern control technologies acceptable to producers. The objective of this paper is to assess the economic impact of pests on tomato production in central and southern Benin in order to evaluating the cost-effectiveness of the technologies considered before their development. For this to happen, two hypotheses emerge: (i) vegetable growers perceive *Helicoverpa armigera* as the most devastating pest of tomato cultivation in the field; (ii) *Helicoverpa armigera reduces* by at least half the crude product generated by tomato production in the event of a severe attack.

2 Material and methods

2.1 Study Area

The study took place in southern and central Benin. Ten Communes in southern Benin were visited during the first phase of data collection which occured from 24 to 29 August 2020. These are the Communes of Toffo, Tori, Kpomasse, Ouidah, Grand-Popo, Athieme, Klouekanme, Lalo, Abomey-Calavi and Seme-Podji. Eight other Communes in the South and the Centre of Benin were visited during the second phase of data collection which happened from 7 to 12 September 2020. These are the Communes of Adjohoun, Kétou, Adja-Ouere, Ouinhi, Abomey, Bohicon, Zogbodomey and Cotonou.

2.2 Preparing for data collection

As a prelude to the field phase, the Agricultural Research Centre (CRA) of Agonkanmey hosted an information and training workshop for the benefit of the various actors involved in the implementation of project n°3 of the National Agricultural Research Program (PNRA) in order to enable them to immerse themselves in its content. The research team is made up of several specialists (plant pathology, entomology, plant science and socioeconomics), supported by doctoral and master's students who are also positioned on the project, to carry out the various components. Indeed, the PNRA is a four-year program (2020-2024) composed of eighteen projects, of which four projects are launched and funded in the year 2020 from the budget of the National Institute of Agricultural Research of Benin (INRAB). The main scientific objective of PNRA 3 is to develop a sustainable pest management program for vegetable crops through the development of integrated pest management methods. For this to happen, the multidisciplinary researchers team selected a number of villages in the research and development sites already defined by INRAB to serve as study fields for agricultural research in Benin. Survey sheets on root-knot nematodes, *Tuta absoluta*, *Helicoverpa armigera* and *Tetranychus evansi* were developed and presented in plenary session for the appropriation of their content by all researchers and technicians. Afterwards, questionnaires and interview guides were elaborated.

2.3 Data and information collection and analysis

Due to the use of qualitative approach of research in this study, data collection and analysis were done simultneously. Data and information collection was carried out in two stages. First, a series of *focus group* sessions (144 in total) were held using an interview guide and related to the socio-demographic characteristics of producers, their perception about tomato pests (*Helicoverpa armigera, Tuta absoluta,* root-knot nematodes *and Tetranychus evansi*) as well as the endogenous means and practices of control used. Six to ten farmers of varying farm sizes and levels of prosperity were mobilized for each of these sessions. This approach has taken into account the participation of women in these spaces of exchange, even though they remain a minority in the production chain. For the purposes of determining the selling and purchase prices of tomatoes, the producers' source of information was compared with that of the women traders involved in the discussions in order to have reliable data. As a reminder, the unit of measurement of tomatoes considered on the market for this study is the 24 kg basket. These sessions made it possible to assess the recognition of diseases and pests in the fields by market gardeners and their effects in terms of the extent of damage on tomato cultivation.

Then, individual interviews were conducted in addition to the focus group sessions in order to deepen some information on the parasites, the photos of which were provided to the respondents. These interviews made it possible to calculate the economic impact of pests on the nightshade studied (tomato), with a distinction between the period of high tomato price (lean season, say ...to ....) and the period of decline in tomato prices (period of abundance, say ....to.....). A total of sixty interviews were conducted in the eighteen Communes with producers selected on the basis of purposive sampling.

The transcription of the speeches recorded during the group interviews and the analysis of their contents were carried out as soon as the survey progressed. However, some data from individual interviews were processed using SPSS version 21 and Microsoft Excel for descriptive statistics on socio-demographic characteristics and other agronomic and economic variables.

Limitations of the study

This prospecting study on tomato pests took place in a particular context, characterized by the health crisis caused by the COVID-19 pandemic, which required the observance of barrier gestures decreed by the World Health Organization (WHO) and reinforced by the Beninese Government. Even though there appeared to be a slight relaxation in the respect of these barrier gestures on the ground, the fact remains that it was necessary to limit contacts while ensuring the collection of a critical amount of data and information. This led the socio-economic research team to prioritize the focus group sessions to the detriment of a massive survey. Finally, very few producers, avoiding groups for fear of being contaminated and not having been warned, made themselves available for the said focus group sessions where a dozen of participants were expected. The focus group sessions were held with only six to ten tomato growers. In conclusion, the mobilization of all the stakeholders was not effective in all the localities visited and it goes without saying that there are so many missing data that could have allowed to refine the analyses.

3 Results

3.1 Socio-demographic characteristics of producers

Table 1 shows that in southern and central Benin, market gardeners are mostly men, i.e. 86% compared to 14% of women.

Table 1 Sociodemographic characteristics of market gardeners (qualitative variables)

Qualitative variables	Modalities	Absolute Frequency	Relative Frequency (%)
Sex	Female	6	14
	Male	37	86
Educational attainment	None	10	23,3
	Primary	3	7,0
	Secondary	22	51,2
	Tertiary	8	18,6
Marital status	married	40	93
	single	3	7
Organizational aspect	Village grouping	1	2,3
	Cooperative/association	38	88,4
	Other organisations	3	7
	None	1	2,3

It should be noted that 76.5% of respondents are educated, most of them have secondary education (51.2%). This means that market gardening requires a minimum of background (training) and specific skills which can be acquired through experience. Marriage (civil, religious/traditional) is expressed as an essential characteristic of these market gardeners through a high rate of 93%. This reveals that in Benin, market gardening is a sub-sector of activity intended preferentially for people who have acquired marital status. Most of the respondents (85%) belong to an association or cooperative, which facilitates their access to the production sites, trainings from other partners working in the sector and allows them to get in touch with market gardening advisors (CM) to benefit from their expertise. According to them, it was the technical supervision of these CMs that enabled them to recognize the pests as well as the means of control to be implemented.

It is also important to note that market gardening households are made up of an average of 4 people (± 2) over 7 years old, including the farmer himself. The average age of producers is 36 years (±10). The youngest producer is 18 years old while the oldest is 60 years old (Table 2).

Table 2 Sociodemographic characteristics of market gardeners (quantitative variables)

Quantitative variables	Minimum	Average	Maximum
Age	18	36 (±10)	60
Household size	1	4 (±2)	8
Experience in market gardening	1	11(±11)	48

Market gardening experience averages around 11 years (±11). The most experienced grower has been doing market gardening for 48 years and the least experienced has been doing it a year ago.

3.2 Growers' Perception of Tomato Pests

In addition to the diseases that are observed on crops, four pests are mainly disrupting tomato production in the fields of southern and central Benin. These are the insects *Helicoverpa armigera* and *Tuta absoluta*, the mites *Tetranychus evansi* and the root-knot nematodes.

According to growers, *Helicoverpa armigera* is the most dangerous pest. This alone destroys more than 76% of their tomato production. As a result, they believe that it is harmful to them and that technology must be developed and disseminated to combat it effectively. Moreover, unaware of its origin, some respondents (29%) assumed that it would be "the product of environmental imbalance", while others (61%), more reassuring in their response, stated that "it comes from the self-produced seeds of the host plant, from the fields of Gboma, cucumber and eggplant that surround the perimeter of the tomato". The remaining 10% say they don't know the source of the problem at all. This relative knowledge of the origin of this pest is linked to the morphological transformations it undergoes from the larval stage to adulthood.

Tuta absoluta are notorious for their severe attacks and literally harmful according to producers who believe they are a major hindrance to their agricultural production activities. As a result, they all say that it is necessary to fight against them in order to make their activities profitable. The pests *Tuta absoluta* and *Helicoverpa armigera* appear simultaneously in tomato fields and produce damage of different magnitudes.

All the market gardeners surveyed stated that the mites *Tetranychus evansi* are also harmful because of their attacks, as they prevent the development of crops and thus reduce yields. It shows that dust mites are also a source of losses and expenses for market gardeners. It is therefore crucial to control them in order to limit their damage and obtain good yields from the solanaceous plant under study.

The root-knot nematodes that appear in the soil would also be a source of huge losses and expenses for the producer, especially for chili peppers and Gboma. It is therefore necessary to limit the losses they cause in order to save producers' investments by minimizing the risk of spreading the pest and improving yields to meet market demand.

Moreover, the needs of tomato growers are focused on new types of effective treatment products. The proposal of an alternative solution will therefore be welcome. Also, the lack of efficient irrigation systems, subsidies and the lack of control of effective control measures to deactivate the virulence of the pests of this nightshade are of primary concern for market gardeners in southern and central Benin.

3.3 Effects of *Helicoverpa armigera* attacks on tomato production

Pests have a considerable economic impact on the profitability of market gardeners' activities, to the point of causing some to reconvert to other sectors of activity. Table 3 presents the economic impact of *Helicoverpa armigera* attacks assessed at the scale of a 1.2mx13m (15.6m^2) plank.

Table 3 Economic Impact of *Helicoverpa armigera* on tomato production by plank (15.6 m^2)

	Average yield/plank (kg)	Turnover (F CFA)		Loss (kg)	Economic Impact (F CFA)		
		Period of Abundance	Lean Period		Period of Abundance	Lean Period	Avg.
No Attack	133.62 (±48.66)	11,135	83,512.5	0	0	0	0
Moderate Attack	82.87 (±35.85)	6,905.83	51,793.75	50.75	4,229.17	31,718.75	17,973.96
Severe Attack	29 (±20.59)	2,416.67	18,125	104.62	8,718.33	65,387.5	37,052.92

For an expected harvest of 133.62 kg per plank, *Helicoverpa armigera* causes losses of 50.75 kg when it comes to moderate attack. In the event of a severe attack, this loss amounts to 104.62 kg. In terms of the economic impact of moderate and severe attacks, this loss amounts to an average of 4,229.17 F CFA and 8,718.33 F CFA per plank respectively during the period of abundance when the 24 kg basket is delivered at the average price of 2000 F CFA. During the lean season when the price of the basket rises to an average of 15,000 F CFA, the loss is estimated at

31,718.75 F CFA and 65,387.5 F CFA on average per plank for a moderate and a severe attack respectively. In the end, the severe attack due to Helicoverpa results in an average loss of 37,052.92 F CFA per plank, compared to an average of 17,973.96 F CFA in the event of a moderate attack.

3.4 Effects of *Tuta absoluta* attacks on tomato production

Like *Helicoverpa armigera*, *Tuta absoluta* also causes yield losses that affect producers' incomes. Table 4 shows the economic impact of this pest on tomato crops.

Table 4 Economic Impact of *Tuta absoluta* on tomato production by plank (15.6 m^2)

	Average yield/plank (kg)	Turnover (F CFA)		Loss (kg)	Economic Impact (F CFA)		
		Period of Abundance	Lean Period		Period of Abundance	Lean Period	Avg.
No Attack	133.62 (±48.66)	11,135	83,512.5	0	0	0	0
Moderate Attack	117.62 (±43.80)	9,801.67	73,512.5	16	1,333.33	10.000	5,666.67
Severe Attack	79.5 (±31.39)	6,625	49,687.5	54.12	4,510	33.825	19,167.5

Similarly, for a harvest of 133.62 kg per plank, *Tuta absoluta* causes losses of 16 kg when it comes to moderate attack. In the case of a severe attack, this loss is equivalent to 54.12 kg. From the point of view of the economic impact of moderate and severe attacks, this loss amounts to an average of 1,333.33 F CFA and 4,510 F CFA per plank respectively during the period of abundance. During the lean season, the loss is estimated at 10,000 F CFA and 33,825 F CFA on average per plank for a moderate and a severe attack respectively. The severe attack due to Tuta therefore generates an average loss of 19,167.5 F CFA per plank, compared to an average of 5,666.67 F CFA in the event of a moderate attack.

3.5 Effects of *Tetranychus evansi* attacks on tomato production

The damage caused by Tetranychus mites is also not negligible, as shown in Table 5.

Table 5 Economic Impact of *Tetranychus evansi* on tomato production by plank (15.6 m^2)

	Average yield/plank (kg)	Turnover (F CFA)		Loss (kg)	Economic Impact (F CFA)		
		Period of Abundance	Lean Period		Period of Abundance	Lean Period	Avg.
No Attack	133.62 (±48.66)	11,135.00	83,512.50	0.00	0.00	0.00	0.00
Moderate Attack	110.45 (±39.87)	9,204.17	69,031.25	23.17	1,930.83	14,481.25	8,206.04
Severe Attack	67.42 (±10.15)	5,618.33	42,137.50	66.20	5,516.67	41,375.00	23,445.83

Tetranychus evansi causes losses of 23.17 kg per plank in a moderate attack and 66.20 kg in a severe attack. In terms of economic impact, in times of abundance, this loss amounts to 1,930.83 F CFA/plank and 5,516.67 F CFA/plank respectively for moderate and severe attacks. The loss incurred during the high price period is 14,481.25 F CFA/plank and 41,375 F CFA/plank respectively for moderate and severe attacks. The severe attack due to Tetranychus therefore generates an average loss of 23,445.83 F CFA per plank, compared to an average of 8,206.04 F CFA in the event of a moderate attack.

3.6 Effects of root-knot nematode attacks on tomato production

The economic impact of root-knot nematodes on tomato production is presented in Table 6.

Table 6 Economic impact of root-knot nematode attacks on tomato production per plank (15.6 m^2)

	Average yield/plank (kg)	Turnover (F CFA)		Loss (kg)	Economic Impact (F CFA)		
		Period of Abundance	Lean Period		Period of Abundance	Lean Period	Avg
No Attack	133.62 (±48.66)	11,135.00	83,512.50	0.00	0.00	0.00	0.00
Moderate Attack	98.44 (±30.49)	8,203.33	61,525.00	35.18	2,931.67	21,987.50	12,459.58
Severe Attack	78.35 (±12.95)	6,529.17	48,968.75	55.27	4,605.83	34,543.75	19,574.79

Nematodes cause losses of 35.18 kg per plank during a moderate attack. This loss amounts to 55.27 kg of tomato in the event of a severe attack. In terms of economic impact, in times of abundance, this loss amounts to 2,931.67 F CFA and 4,605.83 F CFA respectively for moderate and severe attacks. During the lean season, the loss caused is 21,987.50 F CFA and 34,543.75 F CFA per plank respectively for moderate and severe attacks. The severe attack due to nematodes therefore generates an average loss of 19,574.79 F CFA per plank, compared to an average of 12,459.58 F CFA in the case of a moderate attack.

3.6.1 Hierarchy of Pest Impacts on Tomato Production

Figure 1 presents a summary of the comparative average economic impact of the four pests on tomatoes in the field in terms of the proportion of turnover lost in the event of moderate and severe attacks.

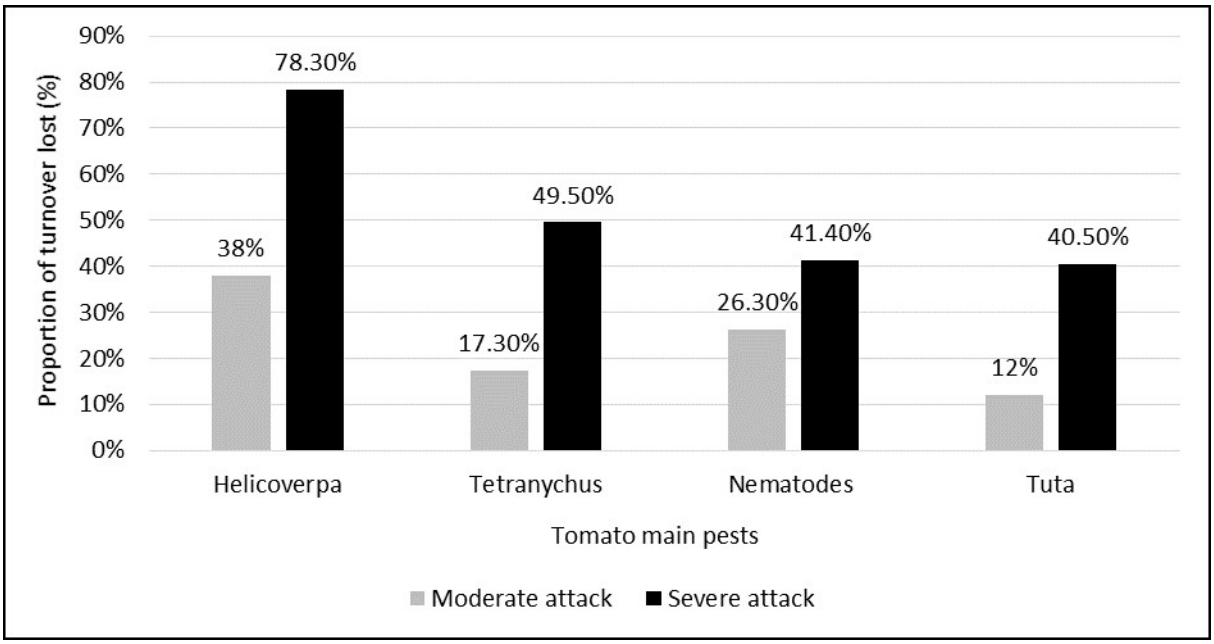

Figure 1 Economic impact of the four tomato pests as a proportion of lost turnover

It appears that the pest that has the highest economic impact on tomato cultivation in the field is *Helicoverpa armigera*, whether it is a moderate or severe attack. The rate of reduction in turnover in the event of a severe attack is close to 80%; this makes this pest the most dangerous for tomato cultivation. It is followed in descending order of importance by root-knot nematodes, *Tetranychus evansi* and *Tuta absoluta* in the case of a moderate attack. On the other hand, *Tetranychus evansi* has the greatest economic impact after *Helicoverpa armigera* in severe attack, followed by root-knot nematodes and *Tuta absoluta*. The moderate attack of root-knot nematodes is therefore the most economically harmful to tomatoes *after Helicoverpa armigera, while Tetranychus evansi* comes in second place in terms of economic impact after *Helicoverpa armigera* in the event of a severe attack, with about 50% reduction in turnover.

4 Discussion

4.1 Attack mode and dominant economic impact of *Helicoverva armigera* on tomato

Tomato pests operate differently depending on which part of the plant is being attacked. *Helicoverpa armigera* position themselves on the fruit and make it their best habitat, while *Tuta absoluta* and *Tetranychus evansi* are stuck to the stem and leaves, respectively. In the case of root-knot nematodes, they mark their presence on the roots of the plant and weaken its growth. From the point of view of damage, *Helicoverpa armigera* is the first to present an economically heavy toll for market gardeners, whether it is a severe or a moderate attack. These reduce the gross product of tomato production from 38% to 78.3%. These results are consistent with those of [20] who found that the moth (*Helicoverpa*) is one of the most important pests of tomato in Niger, the most severe damage is caused by the attack of fruits and flowers and a single larva can destroy several fruits during its lifetime. They can be explained by the fact that *H. armigera* induces fruit losses of about 29% in tomatoes [21]. Also, the highest economic impact, estimated at 33,825 F CFA on average per plank caused by *T. absoluta*, is observed during the lean season for a severe attack. This is due to the virulence of this pest that infests 60% of tomato leaves [22]. Other natural enemies of tomatoes such as *Tetranychus evansi* and root-knot nematodes have lower impacts. This reflects the emergence of "new pests" in addition to those already known as "the main ones" of the tomato that further increase the economic impact.

4.2 An activity dominated by men with a medium level of education but organized

The study also reveals the predominance of men in the market gardening sector (86%), which explains the withdrawal of men from annual and perennial crops in favor of this activity as a means of adapting to the adverse effects of climate change and feeding their cash-flow. In addition, with unemployment on the rise, unemployed young graduates are swelling the ranks of market gardeners and women are making marketing their priority. These results corroborate those of [23] on the one hand and [24] on the other, who concluded that market gardening on the Lomé coastline is mainly practiced by men, who make the beds and set up the nurseries. Moreover, [21] showed that the production of vegetable crops in Port-Bouët (Abidjan) was mainly carried out by men (98.68%), while women representing 1.32% were mainly responsible for marketing these products to market vendors or buyers in the field. Conversely, these same results are the antithesis of those of [25] who support a kind of feminization of market gardening due to women's attraction to short-cycle income-generating activities in order to meet family needs. More than three-quarters of vegetable producers are educated (7% at the primary level and 18.6% at the university level) with 51.2% having reached the secondary level (below undergraduate studies certificate). The education factor explains why a minimum background is necessary for market gardening. But in general, the secondary level observed among respondents remains insufficient, which leads to risks of inappropriate use of phytosanitary products [16]. In addition, 85% of market gardeners belong to an association or cooperative for the defence of the community of interests of the members, the facilitation of access to land (production sites) and the use of the technical support offered by the Support Project for the Development of Market Gardening in Benin (PADMAR). These results are similar to those of [26], who demonstrated that producers' organizations work together to plan the market gardening season, strive to find external partners for various supports (equipment, credits, fertilizers, seeds), serve as training structures for producers and facilitate the adoption of new crops, seeds and production technologies. In addition, this research revealed that 93% of respondents involved in market gardening are married (either civil, traditional or religious), which confirms the results of the study conducted by [27] on market gardening systems in the city of Garoua (Cameroon).

4.3 Relative Effectiveness of Tomato Pest Treatment Products

As far as control products are concerned, bio-pesticides such as aqueous neem extracts, neem oil, neem leaf solution, "cidakin" or ash, as well as the mixture obtained from palmida soap and black soap, seem to be more effective than chemical pesticides (pacha, k-optimal, emacote, tecknokel) in the treatment of attacks linked to *Helicoverpa armigera* and *Tuta absoluta*. This could be explained by the fact that *H. armigera* is currently insensitive to several families of insecticides [26]. These results are consistent with those of [27] who found that bioinsecticides such as spinetoram, spinosad and emamectin show good efficacy in controlling these two tomato pests. However, it should be noted that these control methods are time-consuming for large-scale production treatments.

5 Conclusion

Pests associated with significant tomato damage exist in all the environments visited. The most dangerous pest is *Helicoverpa armigera* according to product perception and economic calculations. It has the highest economic impact in both severe and moderate attacks. This implies that it is the main pest against which the development of modern control technologies is more relevant for the sustainable production of tomatoes in Benin. These pests are recognized by market

gardeners by their manifestations and the local names attributed to them. Faced with attacks, producers mainly use synthetic products available on the market and sometimes endogenous means. These products are not very effective because of the resistance that the pests develop over time. Systematic treatment with synthetic pesticides emerges as the preferred means of response used against pests in most of the municipalities visited (e.g. Grand Popo, Bohicon, etc.). However, this method is becoming less and less effective unless the said pesticides are constantly modified. In some communes where soil fertility is still high, despite the fact that the attacks have been reported, producers abstain from tomato treatment altogether, but still obtain a good overall harvest. This is the case in Idigny (Commune of Kétou), Cotonou and Monzoungoudo (Commune of Ouinhi). Producers from other municipalities, on the other hand, treat the crop with irregular frequency. This is the case in Dédomey (Commune of Kpomassè), Tori-Bossito and Togba (Commune of Abomey-Calavi).

In addition, market gardeners are facing market difficulties for their products due to the closure of the borders with Nigeria, which would be the "first consumer" of Benin's tomatoes. Also, there is competition on the ground with tomatoes from Togo and Burkina Faso, which export their harvests to the Beninese market. In addition, tomato production is subject to the unavailability, low quality and high cost of seeds as well as the unavailability of storage warehouses. Added to this is the fact that market gardeners do not master the techniques for preserving and processing these products, even though they believe that their products could be used for other purposes in the event of poor sales. In addition, considerable losses of tomatoes occur during transport, which leads to the deterioration of the quality of the product. The volatility of tomato sales prices due to competition from other countries in the sub-region (Burkina Faso, Togo) and the low functionality of market gardeners' cooperatives were widely highlighted as difficulties encountered by stakeholders. All this favours the sell-off of market gardeners' products and most often leads them to poor sales. These different aspects will need to be addressed by future research in order to strengthen the cost-effectiveness analysis of tomato pest control technologies to be developed in Benin with a view to their adoption by producers.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors confirm and declare that there are no known conflict(s) of interest.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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