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ABSTRACT

This study was carried out 7 years after a first one conducted in 2013 as part of the policy of the Benin government to promote the vegetable production sector. Data collection was mostly based on a countrywide survey conducted in 25 municipalities throughout Benin, from August to December 2020. Farmers were selected based on their experience in cultivating solanaceous crops, and were interviewed to assess their perception about the severity of the spider mite *Tetranychus evansi*, the control method they used against this pest, and their knowledge about potential predators associated with the mites. Additionally, predatory mites associated with *T. evansi* in farmer fields were identified. All farmers recognized *T. evansi* to which they attributed local names depending on their ethnic group. They were also able to identify its damages on solanaceous crops. They indicated that outbreaks of *T. evansi* occurs at the end of the rainy season while their damages are more severe during the dry season. Production losses due to the mites were estimated by farmers to 27%, 24% and 22% respectively for tomato, African eggplant, pepper in the moderate damage case and 80%, 79%, 55% respectively for tomato, African eggplant and pepper in the severe damage conditions. To fight the mites, farmers generally apply heavy doses of chemical pesticides at high frequency. Pyrethroid and organophosphate compounds are the most frequently used pesticides. The only phytophagous mite recorded was *T. evansi*. A total of four species of predatory mites, all belonging to the phytoseiid family, were found associated with the pest on Solanaceous plants: *Amblyseius swirskii, A. tamatavensis, Neoseiulus barkeri* and *N. longispinosus*. This is the first report of the presence of *N. longispinosus* in Benin. Considering the high losses attributed to the pest, effective and sustainable management practices are necessary.

1. Introduction

In sub-Saharan Africa, vegetable crops are an essential component of sustainable development, with a significant contribution to food and nutritional security, but also an important source of income for resource-poor growers, especially in urban and peri-urban areas [1]. In Bénin, about 20 indigenous and exotic species are grown on vegetable farms, among which tomato (*Solanum lycopersicum* L.), pepper (*Capsicum annum* L.) and African eggplant (*Solanum macrocarpon* L.) appear as the most economically important [2]. However, a major constraint to growing horticultural crops is the reduction in yield and quality caused by insect pests by direct feeding or as plant disease vectors [2,3]. In the last 15 years, the tomato red spider mite *Tetranychys evansi* Baker & Pritchard (Acari: Tetranychidae) has expanded its geographical distribution range and has emerged as a serious invasive agricultural pest in Africa, Asia and Europe [4–6]. In Benin, outbreaks of *T. evansi* were

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observed for the first time on tomato and eggplant in the vegetable growing area of Sèmè-Podji in 2008 (Martin, personal communication). Since then, its outbreaks have been observed frequently during the dry season in all growing areas of southern Benin with severe damage on tomato, African eggplant and *Amaranthus* spp [5]. The invasion of *T. evansi* in Benin displaced the native red mite species such as *Tetranychus urticae* Koch, *T. ludeni* (Zacher) and the broad mite *Polyphagotarsonemus latus* Banks, particularly on indigenous leafy vegetables [5,7]. The increasing outbreaks of *T. evansi* prompted farmers to increasing applications of chemical pesticides, particularly cotton insecticides, though their effectiveness against this pest was not established [5].

A first survey to assess the pest status of *T. evansi* was carried out in 2013 among 150 farmers in the three major growing areas of southern Benin, and revealed *T. evansi* as the main mite pest encountered on African eggplant, tomato and purple amaranth causing production losses estimated respectively at 65%, 56% and 25% [5]. The survey revealed that chemical control was the prevalent control measure against this pest. No predatory mites were found associated with the pest during that first survey, further indicating the negative effect of the heavy spraying regimes on beneficial fauna. After 7 years of this first survey, we deem necessary to expand the assessment of the pest status of *T. evansi* to its impact on solanaceous crops and assess possible changes in the related farmers phytosanitary practices accross Benin as well as implication on the diversity, distribution and abundance of its associated predatory mites.

2. Materials and methods

2.1. Study sites

This study was carried out in 25 municipalities of Benin (South, Center and North regions) (Fig. 1). Benin has two major agroecologies: equatorial climate in the South and tropical climate in the Center and North. The South harbors a bimodal rain pattern with main rainy season between March and June and the small one from September to October, and an annual rainfall between 1000 and 1300 mm. The temperatures ranges between 23 and 39 °C. The Center and North are characterized by a monomodal rainy pattern, with rains occurring June to September with annual rainfall generally below 1000 mm [8]. The monthly relative humidity across the country ranges from a minimum of 44% to a maximum of 99%.

2.2. Data collection

In 2020, three sampling visits were conducted from August to

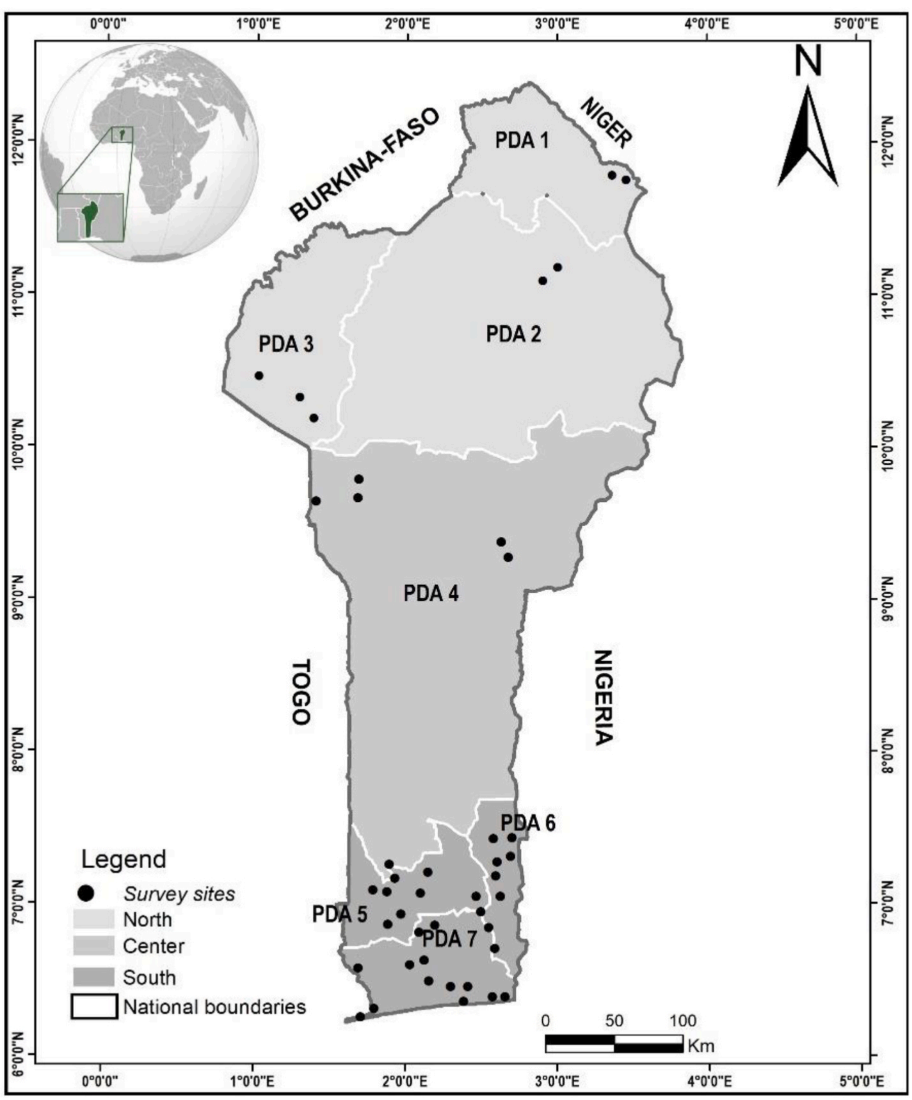

Fig. 1. Samples collection site in southern, central and northern Benin.

December. During the first visit from 24th to 29th August, we visited 9 municipalities; the second survey from 07th to 12th September was carried out in 9 municipalities while we visited 7 municipalities during the last survey from 14th to 21st December. A total of 25 municipalities were visited, where questionnaires were administered to 1250 households (839 and 411 responded by male and women respectively) as showed in Fig. 1. Farmers were selected according to their experience in tomato, African eggplant and pepper production, and their farms were georeferenced with a GPS. To maximize chances of finding predatory mites, only plots that were already harvested were sampled [5,7]. A total of 10 plants were sampled per crop species (tomato, African eggplant and pepper) per plot. On each plant, five top leaves, five middle leaves and five bottom leaves were picked. A total of 6150 leaves were collected on tomato, 1800 on African eggplant and 600 on pepper. A total of 43 farms were sampled. From each farm and for each crop species, all sampled leaves were put together in a paper bag and transported to the laboratory at IITA (Abomey-Calavi, Benin) in plastic bags kept in styrofoam boxes at 10 °C, to prevent mites from escaping. Mites were checked under a dissecting microscope, counted, collected from the leaves and put in 70% alcohol, then mounted in Hoyer's medium and identified under phase contrast microscope. Whenever possible, predatory mites as well as spider mites were identified up to species level. All phytoseiid mites were identified by Professor Serge Kreiter (Institut Agro, Montpellier SupAgro University, France).

After sampling, we used the same questionnaire of 2013 survey [5] to get information from *T. evansi* about its impact on tomato, African eggplant and pepper. Thus, 50 farmers per municipalities randomly selected were interviewed for 30 min. The choice of farmers was mainly based on the production of tomato, African eggplant and pepper. After obtaining information on the socio-demographic characteristics, each farmer was asked about *T. evansi* local name, their perception on its damage and production losses on tomato, African eggplant and pepper production in moderate and severe damage scenarios. They were also interviewed about the strategy used to control the pest. Other questions about the severity and evolution of damage were also asked.

2.3. Data analysis

The geostatistical software ArcMap version 10.1 was use to illustrate the distribution of pests and predatory mites. The frequency and abundance of pests and their associated predators were calculated using data from mite counts. Analysis of variance followed by Bonferroni test was used to discriminate the crops according to the losses in production estimated by the farmers. Analysis of variance was done using the software R version 3.4.2 (R Core Team 2016) to compare means at 5% level.

3. Results

3.1. Socio-economic characteristics of farmers

Horticultural production was the main activity for the majority of farmers (99%) in south, center and north Benin. In South Benin, on average, farmers were 34 year-old: the youngest was 18 years and the oldest was 70 years. In the Center and North Benin, farmers were on average 31 year-old with 22 years being the youngest in both regions and 43 and 41 years being the oldest in Centre and North respectively. (Table 1). In all these regions, horticultural production was more a male activity (70%, 70% and 67% in South, Center and North respectively) than a female one (30%, 30% and 41% in South, Center and North respectively) (Table 1).

In these three areas, the majority of young farmers interviewed had at least a secondary school level of education (46%, 74% and 78% in South, Center and North respectively). Very few farmers had reached the university level (2%, 6% and 8% in South, Center and North respectively). The others farmers who had not received any formal education were 18%, 11% and 4% in South, Center and North respectively (Table 2).

3.2. Mites' diversity

All phytophagous mites collected on African eggplant *S. macrocarpon* were *T. evansi* (100%). On tomato, 90% of the collected phytophagous mites were *T. evansi* and 10% *T. urticae*. No mites were found on pepper (Table 3). The pest was confirmed over 43 sites assessed (31, 5 and 7 in

Table 2
Education level of farmer's growing tomato, African eggplant and pepper in southern, center and northern Benin.

Variables	Description	Frequency	Percentage	Cumul
South Benin				
Level of education	No education	128	18	18
	Primary	233	34	52
	Secondary	322	46	98
	University	17	2	100
Center Benin				
Level of education	No education	21	11	11
	Primary	18	9	20
	Secondary	148	74	94
	University	13	6	100
North Benin				
Level of education	No education	14	4	4
	Primary	36	10	14
	Secondary	271	78	92
	University	29	8	100

Table 1
Age and gender of farmer's growing tomato, African eggplant and pepper in southern, center and northern Benin.

Variables	Description	Observation	Mean	Std DEV	Min	Max	Percentage
South Benin							
Gender	Male	492	34	8	19	62	70
	Female	208	33	7	18	70	30
Age		700	34	8	18	70	
Center Benin							
Sex ratio	Male	139	31	4	22	41	70
	Female	61	32	5	22	43	30
Age		200	31	4	22	43	
North Benin							
Sex ratio	Male	208	32	5	22	41	59
	Female	142	30	5	25	40	41
Age		350	31	5	22	41	
Global							
Age	Male	839	33	7	19	62	67
	Female	411	32	6	18	70	33
		1250	33	7	18	70	

Table 3
Proportion of pests and predatory mites on tomato, pepper and African eggplant during the surveys.

Family/Species	Mite infestation/plant species (%)		
	Tomato	African eggplant	Pepper
Tetranychidae			
Tetranychus evansi Baker and Pritchard	90	100	0
Tetranychus urticae Koch	10	0	0
Phytoseiidae			
Neoseiulus barkeri Hughes	76	0	0
Neoseiulus longispinosus (Evans)	21	0	0
Amblyseius swirskii Athias-Henriot	0	100	0
Amblyseius tamatavensis Blommers	3	0	0

the South, Center and North respectively). A total of 59 specimens of predatory mites from the Phytoseiidae family were collected, belonging to the genera *Amblyseius* and *Neoseilus* (Phytoseiidae, Amblyseiinae). They were identified as *Amblyseius swirskii* Athias-Henriot (22%), *Amblyseius tamatavensis* Blommers (6%), *Neoseiulus barkeri* Hughes (69%) and *Neoseiulus longispinosus* Evans (3%) (Fig. 2 and Fig. 3). While *N. barkeri*, *N. longispinosus* and *A. tamatavensis* were encountered on tomato, only *A. swirskii* was collected on African eggplant (Table 3). Overall predatory mites were recorded in 10, 1 and 0 sites in South, Center and North respectively (Table 4).

3.3. Farmers' knowledge on T. evansi and its damages

The local name given to *T. evansi* depended exclusively on locality and ethnic group. Thus, in South and Center Benin, all surveyed farmers belonging to the ethnic group Fon call it "yè" or "oyè", that of Mina call it "amina", that of Adja call it "yeii" and the ethnic group Mahi call it "wanvu". However, ethnic groups in the northern region did not have any specific local names for this pest. Most farmers (95%) in the three regions were able to describe *T. evansi* damage symptoms as beginning with a progressive shrinking, yellowing, folding and stunting of the leaves as well as the presence of dense webbing coating the leaves, flowers and fruits. However, the webbing precluded early detection of the mite pest before it was able to cause serious crop losses. The majority of farmers (89%) reported very severe *T. evansi* damages in the absence of chemical control, with highest outbreaks during the dry season as observed by 92% of farmers. However, 79% of farmers reported that the observed damage did not progress anymore in case of chemical application (Table 5). Whatever the degree of damage intensity (moderate or severe) due to *T. evansi*, yield losses were estimated by farmers to be higher in South of the country (Table 6). The analysis of variance showed a significant difference (df = 2; $P < 0.0001$) between the three regions irrespective of the crop. Thus, yield losses were estimated at 27%, 24%, and 22% in crops with moderate damage, and 80%, 79%, 55% in crops with severe damage for tomato, African eggplant and pepper, respectively (Table 6).

3.4. Tetranychus evansi control by farmers

Due to the importance of *T. evansi* damages farmers reported having no other choices than using chemical control. A total of 26 different chemical formulations were mentioned during the survey, most of them were registered for cotton protection (Table 7). The most frequently used pesticides belonged to the pyrethroids family (62%) alone or associated with an organophosphate (42%). Our survey showed that a significant number of farmers (65%) used lambda-cyhalothrin + profenofos at different doses. Some of them used high doses to get a better control of the mites. Other farmers combined several formulations such as lambda-cyhalothrin + profenofos and deltamethrin without any respect of the recommended doses. Very few farmers used abamectin (15%) and neem oil (3%) which are recommended to control this pest on vegetable.

4. Discussion

This study showed that *T. evansi* was the only mite observed on African eggplant (100%) and the most frequently collected Tetranychid mite species (90%) followed by *T. urticae* (10%) on tomato crops. Moreover, *T. urticae* was only collected on one site in the southern Benin. Previous studies reported *T. ludeni* Zacher and *P. latus* Banks as major horticultural pests in Benin [9,10]. However, none of the above two mite species could be observed in our samples, confirming earlier results by Ref. [5] who found only *T. evansi* on tomato, African eggplant and purple amaranth during a survey carried out in January 2013, during the dry season. The lack of native mite species in these two last studies could be explained by the invasive nature of *T. evansi* which probably outcompeted and displaced the native phytophagous mites, thereby supporting the recent report by Ref. [11]. In 2013 [5], did not observe any predatory phytoseiid mites in the southern areas of Benin probably because farmer fields were heavily treated with chemical insecticides/acaricides. In the present study, few specimens of indigenous phytoseiid mites (*A. swirskii, A. tamatavensis, N. barkeri* and *N. longispinosus*)

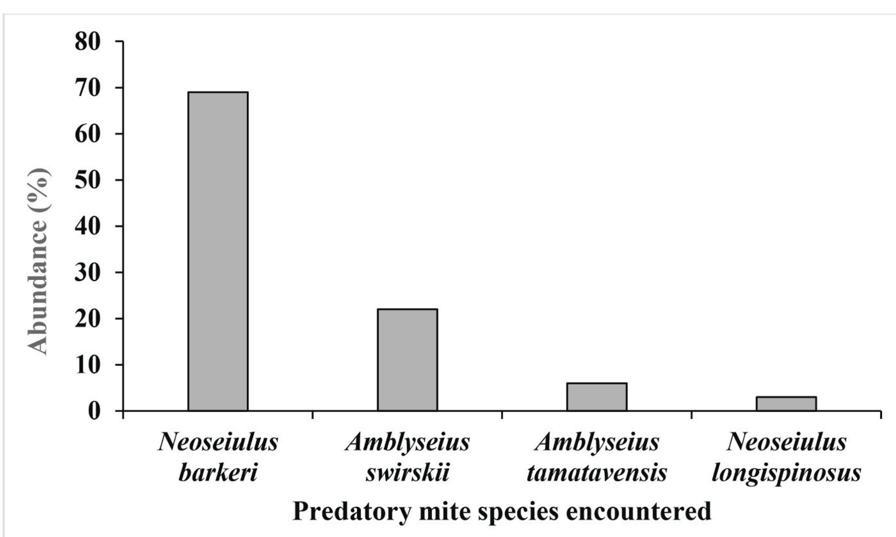

Fig. 2. Abundance of predatory mites collected from Benin.

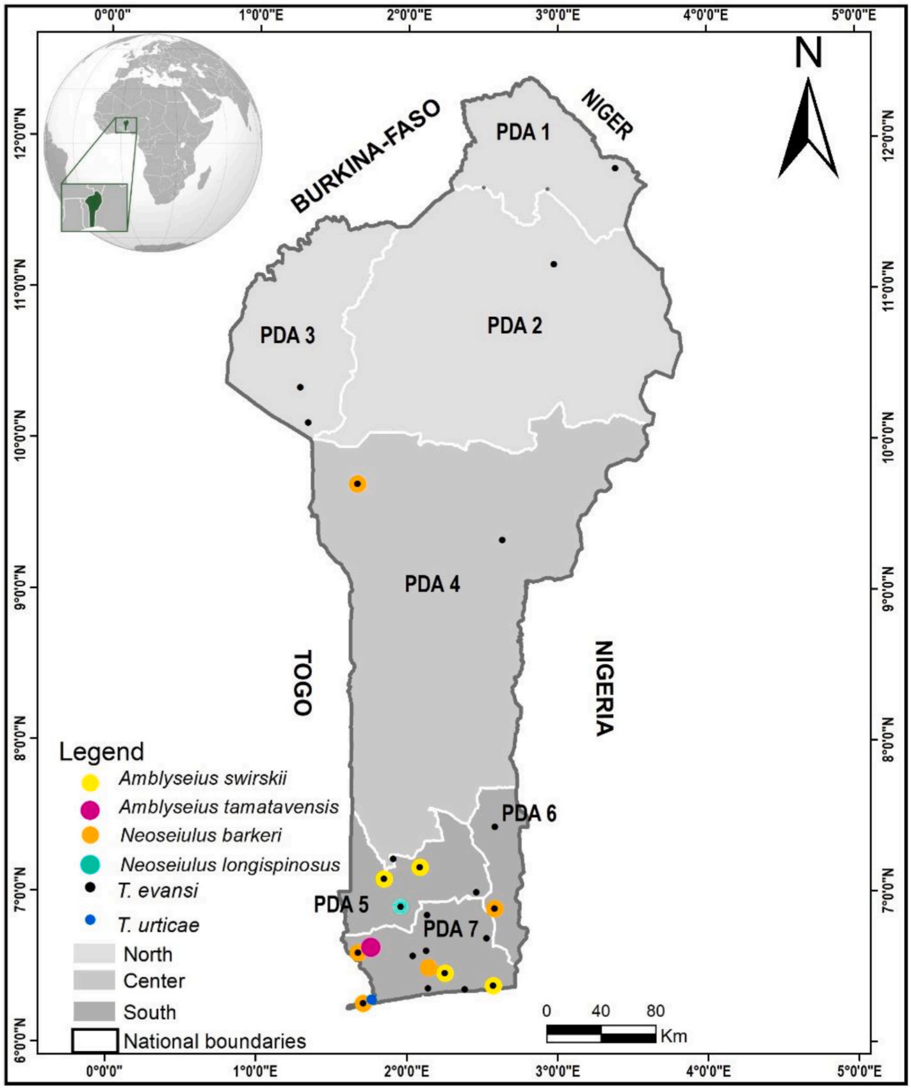

Fig. 3. Distribution map of pests and predatory mites in Benin.

were observed. However, phytoseiid diversity was relatively low as compared to previous investigations by Ref. [10] carried out at the research station of IITA-Benin and on a vegetable farm at Togba, in the southern part of Benin during the rainy season. They reported *Typhlodromalus saltus* (Denmark & Matthysse), *N. barkeri, Iphiseius degenerans* (Berlese), *Euseius* sp., *Afrotydeius* sp. associated with *T. ludeni*, *T. urticae* and *P. latus* on African eggplant and purple amaranth at the IITA station. The targeted sampling of old or abandoned (harvested) fields where no more pesticide applications are expected could explain the higher phytoseiid mite diversity observed during the current survey. These results confirm those of [7] who found more predatory mite species in the untreated vegetable plots at IITA–Benin compared to the treated plots at Togba. In our study, *N. barkeri* was the most abundant and frequent predatory species followed by *A. swirskii*, and *N. longispinosus*. Many authors have reported the capacity of these predators to control diverse mite and insect pests including *P. latus*, *T. urticae, Oligonychus coffeae* Nietner, *Scirtothrips dorsalis* (Capuche) and *Bemisia tabaci* (Gennadius) [12–17]. However, none of them have been reported feeding on *T. evansi*. Our study reported for the first time in Benin and the Sub-Saharan Africa the presence of the predatory mite *Neoseiulus longispinosus*, which had been originally described from Indonesia and reported in India and other Asian countries quite a long time ago, although more recently it has been reported from other tropical and subtropical countries: Taiwan (mainly in the South), Philippines, Indonesia, Australia and New Zealand, with only the report in Africa prior to the present work being in Egypte in 2018 [18–20]. *Neoseiulus longispinosus,* a 'Type II' predator [21] is known to be efficient against a large number of mite pests, especially teranychids including *T. kanzawai* Kishida on cotton and rose, *T. macfarlanei* Baker and Pritchard on okra and yard long bean, and *T. urticae* on strawberry and rose [17,22–25].

Farmers have reported that *T. evansi* has been a pest causing serious damage to their crops, with increasing severity and extent of damages since 2008. The outbreaks seem more important in southern Benin than central and northern Benin especially in the dry season as compared to the rainy season. This could explain the losses observed on the crops suffering moderate damage and severe damage conditions. All farmers were able to recognize *T. evansi* damages and could easily describe them. According to them, when the damages become severe, mites destroy the leaf parenchyma cells causing leaf drop and subsequently a reduction in productivity [26]. The perceived losses are similar to those reported by Ref. [5] in Benin and [27] in Zimbabwe who evaluated the production losses on African eggplant and tomato respectively to almost 90%. Our results showed that outbreaks of *T. evansi* in vegetable production areas represented a real threat for vegetable production and a big challenge for growers. Effective and adapted solutions have to be found and shared with vegetable growers who have no other option rather than chemical

Table 4
Number of predatory mites on target crops, tomato, African eggplant during the surveys.

Survey sites	Target crops	Mites pest	Nb. predators	Phytoseids mites
Agonmè	Tomato	*T. evansi*	3	*Neoseiulus barkeri*
Ahogbémè 1	Tomato	*T. evansi*	1	*Neoseiulus barkeri*
Ahogbémè 2	Tomato	*T. evansi* *T. urticae*	1	*Neoseiulus barkeri*
Hounnonkon	Tomato Pepper	*T. evansi*	0	–
Telokoe	Tomato	*T. evansi*	0	–
Telokoe Awaya	Pepper	*T. evansi*	0	–
Ahouicodji	Tomato African eggplant	*T. evansi*	0	–
Ouèdo	African eggplant	*T. evansi*	1	*Amblyseius swirskii*
Ewécondji	Tomato	*T. evansi*	0	–
Sèko	Tomato	*T. evansi*	6	*Neoseiulus barkeri*
Toulassihoue	Tomato	*T. evansi*	16	*Neoseiulus barkeri* *Amblyseius tamatavensis* *Neoseiulus longispinosus*
Sènahoué	Tomato	*T. evansi*	0	–
Kochihoue Lanta	Tomato	*T. evansi*	1	*Amblyseius swirskii*
Devigue Hlassame	Tomato	*T. evansi*	1	*Neoseiulus longispinosus*
Lalo Centre	Tomato	*T. evansi*	0	–
Djeffa	Tomato	*T. evansi*	5	*Amblyseius swirskii*
Kpodji	Tomato	*T. evansi*	3	*Amblyseius swirskii*
Kouhouekpota	Tomato	*T. evansi*	0	–
Houéli Gaba	Tomato	*T. evansi*	0	–
Ipkinlè	Tomato	*T. evansi*	7	*Neoseiulus barkeri*
Ayélawadjè	Tomato	*T. evansi*	0	–
Ikodèto	Tomato	*T. evansi*	0	–
Bossa	African eggplant	*T. evansi*	0	–
Kpetekpa	Tomato	*T. evansi*	0	–
Saclo	African eggplant	*T. evansi*	3	*Amblyseius swirskii*
Gnidjazoun	African eggplant	*T. evansi*	0	–
Canakpota	Tomato	*T. evansi*	0	–
Houeyiho	Tomato	*T. evansi*	0	–
Tri Postal	Tomato	*T. evansi*	0	–
Banikani	African eggplant	*T. evansi*	0	–
Banikani Abattoir	Tomato, African eggplant	*T. evansi*	0	–
Dimadi	Tomato	*T. evansi*	0	–
Kpodo	Tomato	*T. evansi*	0	–
Garou	Tomato	*T. evansi*	0	–
Monkassa	Tomato	*T. evansi*	0	–
Koutchaliko Oungo	Tomato	*T. evansi*	0	–
Moussansamou	Tomato	*T. evansi*	0	–
Kètourgey	Tomato	*T. evansi*	0	–
Zongo-Cobly	Tomato	*T. evansi*	0	–
Sassirou	Tomato	*T. evansi*	0	–
Kili	Tomato	*T. evansi*	7	*Neoseiulus barkeri*
Kantè	Tomato	*T. evansi*	0	–
Kantè-Bia	Tomato	*T. evansi*	0	–

control. The reduction of damage symptoms and pest outbreaks observed shortly after pesticide applications probably encourages farmers to continue relying on this approach rather than on other pest control methods, especially in the case of short-cycle crops [28]. Our survey showed that famers make inappropriate use of pesticides to control *T. evansi*. The insecticide profenofos is known to have acaricidal properties, mainly against *P. latus* [29], but it has not proven to be effective against *T. evansi* [5]. The level of pesticide use recorded during the present survey was more intense than recorded seven years prior to the present study [5] None of the pesticides frequently used by farmers are reported anywhere effective in *T. evansi* control [30]. demonstrated this in a recent study when assessing performance of pesticides commonly used in vegetable production systems against *T. evansi*. This low performance of the pesticides is the main reasons why they are forced to apply mixtures of pesticides with no proper guidance about their uses. As a consequence, pests become prone to developing pesticide resistance, often leading to environmental pollution and poisoning risks to farmers and consumers [31,32]. In the list of pesticides in Table 6, Acarius and Neem oil for which the active ingredient are respectively abamectin and azadirachtin are the only insecticide/acaricide recommended on vegetables as effective against mites [33,34] (https://www.sagepesticides.qc.ca〉DisplayMatiere). However, few growers used them as compared to the cotton chemicals. As for Neem oil, farmers complained about the cost despite its efficacy.

Table 5
Responses of farmers about the severity of damage due to *Tetranychus evansi*, the degree of damage according to season in three areas South, Center and North Benin.

Variables	**Damage description**	**South (N = 700) %**	**Center (N = 200) %**	**North (N = 350) %**	**Total**
Gravity	Very serious	94	83	90	89
	Serious	3	9	7	6
	Moderate	2	5	2	3
	Not serious	1	3	1	2
Evolution	Increase	15	22	13	17
	Constant	80	75	82	79
	Decrease	5	3	5	4
Season	Rainy season	3	7	4	5
	Dry season	95	88	92	92
	Rainy and dry season	2	5	4	3

The results of this study re-assessing the pest status of *T. evansi* in Benin showed that the awareness campaign carried out among farmers regarding the use of Acarius and Neem oil has failed (Azandémè-Hounmalon, pers. comm.). The number and spread of natural enemies are also very limited in addition to the fact that *T. evansi* is known to deter all predatory mites except for a south American population of *Phytoseiulus longipes* Evans [35]. Therefore, alternative control methods using agroecological practices must be developed to better control *T. evansi* outbreaks. Particularly, a biological control approach could be useful to reduce the risk of *T. evansi* outbreak on Solanaceous crops as already done by *icipe* in Kenya [36] by releasing the exotic phytoseid *P. longipes*. The comparative predation efficacy of these predators (exotic and local) and their intraguild predation effect could be tested [37–39] to guide experimental releases in vegetable production areas. However, for the biological control agents to be efficient, farmers must be aware and convinced to reduce chemical pesticides on or around their vegetable crops, since phytoseiids predators are very sensitive to them [5,7].

5. Conclusions

The re-assessment of the status of *T. evansi* in Benin has showed that seven years after the first survey in 2013, both damage severity of the pest and farmers' use of chemical pesticide have remained high despite awareness efforts on the use of less toxic alternatives such as abamectin and Neem oil. While no predatory mites were recorded in the initial survey, four species of predatory mites were found in the vegetable production system during the present survey. However they were in extremely low numbers and with very limited spread. Laboratory studies are warranted to assess their potential performance against the pest. Considering that studies on various predatory mites against *T. evansi* revealed only *P. longipes* to be effective against the pest, we recommend

Table 6
Percentage of production loss estimated by farmers on tomato, African eggplant, and pepper in South, Center and North Benin.

Variables	Observations	Mean percentage of loss (SD)					
		Moderate damage			Severe damage		
		Tomato	African eggplant	Pepper	Tomato	African eggplant	Pepper
South	700	28 ± 3a	25 ± 5a	24 ± 10a	90 ± 11a	88 ± 14a	57 ± 4a
Center	200	26 ± 5b	24 ± 5b	20 ± 7b	74 ± 19b	75 ± 18b	54 ± 5b
North	350	26 ± 5b	23 ± 4b	19 ± 4b	62 ± 14c	64 ± 13c	53 ± 6b
Benin	1250	27 ± 4	24 ± 5	22 ± 7	80 ± 18	79 ± 18	55 ± 5
Df		2	2	2	2	2	2
F		32	17	47	570	328	80
P		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

SD = Standard deviation.

Table 7
List of insecticides routinely sprayed by growers to control *T. evansi* on the indigenous leafy vegetables in Benin.

Pesticides trade name	Frequency (%)	Active ingredients	Concentration of active ingredient	Target crops of manufactures	Chemical familly[(1)]	Class[(2)]
ACARIUS 018 EC	22 (15)	abamectin	18 g/L	Vegetable insecticide acaricide	AVER	IV
ALPHACAL P 218 EC	97 (64)	alpha-cypermethrin	18 g/L	Cotton insecticide/acaricide	PY	II
		profenofos	300 g/L		OP	II
CAPT 88 EC	35 (23)	acetamiprid	16 g/L	Cotton insecticide/acaricide	NE	II
		cypermethrin	72 g/L		PY	II
CAPT FORTE 184	55 (36)	lambda-cyhalothrin	120 g/kg	Cotton insecticide/acaricide	PY	II
		acetamiprid	64 g/kg		NE	II
COTALM P 218 EC	145 (96)	lambda-cyhalothrin	18 g/L	Cotton insecticide	PY	II
		profenofos	200 g/L		OP	II
COTOFAN 350 EC	25 (17)	endosulfan	350 g/L	Cotton insecticide acaricide	CY	II[3]
CYDIM C 50	48 (32)	cypermethrin	50 g/L	Coton insecticide/acaricide	PY	II
		profenofos	200 g/L		OP	II
CYFLUTHRALM 318 EC	8 (5)	cyfluthrine	18 g/L	Cotton insecticide	PY	II
CYPADEM	14 (9)	cypermethrin	36 g//L	Insecticide	PY	II
		dimethoate	400 g/L	Insecticide	OP	II
CYPERCAL P 330 EC	78 (52)	cypermethrin	30 g/L	Insecticide/acaricide	PY	II
		profenofos	300 g/L		OP	II
CYPER D	22 (15)	cypermethrin	10 g/L	Insecticide	PY	II
DECIS 25 EC	24 (16)	deltamethrin	25 g/L	Vegetable insecticide	PY	II
DIMEX 400 EC	22 (15)	dimethoate	400 g/L	Insecticide	OP	II
DURSBAN 4[E]	15 (10)	chlopyrifos-ethyl	480 g/L	Insecticide	OP	II
EMACOT 019 EC	14 (9)	emamectine benzoate	19 g/L	Insecticide	Aver	II
K-OPTIMAL	65 (43)	lambda-cyhalothrin	15 g/L	Cotton insecticide/acaricide	PY	II
		acetamiprid	10 g/L		NE	II
LAMBDACAL P 315 EC	92 (61)	lambda-cyhalothrin	15 g/L	Cotton insecticide/acaricide	PY	II
		profenofos	300 g/L		OP	II
LAMBDACE 25	81 (54)	lambda-cyhalothrin	15 g/L	Cowpea insecticide	PY	II
		acetamiprid	10 g/L		NE	II
Neem Oil	5 (3)	azadirachtin	–	Biopesticide		
ORTHEN 50 SP	2 (1)	acephate	500 g/kg	Cotton insecticide	OP	III
PACHA 25 EC	72 (48)	acetamiprid	10 g/L	Vegetable insecticide	NE	II
		lambda-cyhalothrin	15 g/L		PY	II
PYRIFORCE 480 EC	15 (10)	chlorpyrifos-ethyl	480 g/L	Insecticide	OP	II
SUNPYRIFOS 48% EC	18 (12)	chlopyrifos-ethyl	480 g/L	Insecticide	OP	II
TALSTAR 40	32 (21)	bifenthrin	40 g/L	Coton insecticide/acaricide	PY	II
THIONEX 350 EC	10 (7)	endosulfan	350 g/L	Cotton insecticide	CY	
TIHAN 175 O-TEQ	5 (3)	flubendiamide	100 g/L	Cotton insecticide		
		spirotetramate	75 g/L			
VIZIR C 92 EC	68 (45)	cypermethrin	72 g/L	Coton insecticide/acaricide	PY	II
		abamectin	20 g/L			

(1) PY: pyrethroid; OP: organophosphorus; NE: neonicotinoid; CY: cyclodien; AVER: avermectin.
(2) Class II: moderately hazardous; Class III: slightly hazardous; Class IV: null toxicity.
(3) Because of its threats to human health and the environment, a global ban on the manufacture and use of endosulfan was stipulated under the Stockholm Convention in April 2011.

introduction and release of beneficial organism in vegetable production area could reduce *T. evansi* outbreak in solanaceous crops. We recommend vast agricultural campaigns targeting vegetable producers and that aim at building their capacity on safe and efficient pest management practices across the country.

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Declaration of competing interest

The authors declare that they have no conflict of interest.

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Data availability

The authors do not have permission to share data.

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