ACAROLOGY

Effectiveness of combining bioacaricides with sprinkler irrigation to control the red spider mite, *Tetranychus evansi* Baker and Pritchard (Acari: Tetranychidae), in irrigated tomato crops in Burkina Faso, West Africa

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Abstract

Tomato production plays an important role in Burkina Faso by contributing to food security and increasing farmers' income. However, this crop is susceptible to several pests among which *Tetranychus evansi* Baker and Pritchard is of economic importance. The present study carried out in the commune of Yako, an important tomato production area in northern Burkina Faso, aims to evaluate the outcome of combining a bioacaricide (Biopiq) from plant origin with sprinkler irrigation in the view of an integrated control of *T. evansi* in tomato irrigated crops. The experimental design consisted of six treatments in four replications including sprinkler irrigation, gravity irrigation, Acarius (abamectin-based commercial acaricide used as positive control) and Biopiq (plant-based acaricide) sprayings and the combination of each acaricide with both irrigation techniques. Observations made from tomato transplanting to harvest included *T. evansi* density/leaf, plant infestation levels, leaf damage index, plant production parameters such as numbers of leaves, flowers and fruits and yield assessment. Results showed that the combination of Acarius and Biopiq with sprinkler irrigation significantly reduced density and damage caused by *T. evansi*. These treatments also produced similar and significantly higher yields (14,875±1,982 kg/ha; 14,687±924kg/ha respectively) compared to other treatments. These results lead to promising prospects for the control of *T. evansi* in irrigated tomato crops in West Africa. The strategies for an optimal use of these findings on a large scale through an integrated management approach remain to be defined.

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Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most consumed vegetables in the world, just behind potato (Camara *et al.*, 2013). In Burkina Faso, with an estimated production of 200,518.93 tons in 2018, tomato is the second most produced vegetables after onions (MAH, 2018). Tomato is also one of the most exported vegetables towards some countries of the West African sub-region such as Benin, Côte d'Ivoire, Ghana, Equatorial Guinea and Togo (CILSS, 2017). In addition, tomato production contributes to food security and increased income for producers (MAAH, 2011). Despite these assets in the country's economy, this crop faces many constraints, the most important of which are biotic (Ouattara *et al*., 2017). In Burkina Faso, pests represent the main constraint to tomato production (Son, 2018). Among these pests, *Tetranychus evansi* Baker and Pritchard is currently a serious threat to tomato production in Burkina Faso and even in West Africa (Azandémè, 2015; Drabo *et al.,* 2020). This mite is characterized by high reproductive capacity, which leads to high population levels in a short time, causing significant economic damage and yield losses close to 90% (Azandémè *et al.,* 2014). As a result, producers in some vegetables production sites in Burkina Faso are renouncing to tomato cultivation (Drabo *et al.,* 2020). On the other hand, to limit losses, other farmers are intensifying the use of synthetic pesticides with negative economic and environmental consequences (Lehmann *et al*., 2016) without providing a satisfactory and sustainable solution (IFDC, 2007).

It is therefore necessary to seek effective alternative methods to control *T. evansi* while preserving the environment, producers and consumers. In this context, some alternatives can be considered and evaluated with a view to setting up an effective integrated pest management strategy. Among these, genetic improvement, with the development of tolerant or resistant varieties, appears to be a promising approach (Djossou *et al.,* 2020; Camara *et al.,* 2013; Resende *et al*., 2002; Gonçalves *et al*., 2006; Resende *et al*., 2008; Murungi *et al*., 2009, 2010) but the sources of resistance seem limited and difficult to apply in the context of Burkina Faso. Another potentially interesting alternative that should be evaluated is the use of natural acaricides/insecticides. These biopesticides have the advantage of being biodegradable, non-persistent in the environment, affordable and therefore more suitable and more accessible to small producers (Zakari, 2013). In addition, it is known that rains play an essential role in reducing mite populations by leaching plants in rainy season crops (Azandémè, 2015). Moreover, the resulting high relative humidity inhibits the activity of spider mites (Ferrero, 2009). Sprinkler irrigation could therefore create an unfavorable environment for the pest while eliminating large numbers of individuals by leaching. This practice could thus constitute a viable component of the integrated pest management strategy of the red spider mite.

Therefore, the present study aims to evaluate some components of integrated control of *T. evansi*. Specifically, we evaluated the effectiveness of a plant-based biopesticide (Biopiq) alone or in combination with a sprinkler irrigation technique to control tomato spider mite infestations and limit yield losses in irrigated tomato plots. The results are compared to those obtained from Acarius, an abamectin-based commercial acaricide already used by some tomato producers in West Africa (Adango *et al*., 2020).

Materials and methods

Study area

The study was carried out in a vegetable production site in the commune of Yako, a well-known production area, in the northern region of Burkina Faso. The city of Yako (12°57′44″ N, 2°15′ 6″ W) is located 110 km from Ouagadougou on the national road No. 2, leading to Mopti in Mali. The climate is of Sudano-Sahelian type marked by two distinct seasons: a long dry season, from November to June, during which vegetables are produced under irrigation and a short rainy season, from July to October (Guinko, 1984). In addition, the presence of high densities of red spider mites was recorded there during preliminary observations before the implementation of our trials.

Plant material

The *Petomech* tomato variety obtained from the commercial distributor NANKOSEM was used in the trials. This variety was chosen based on its high productivity during the dry season in Burkina Faso, the firmness of its fruits, its yield and especially its good appreciation by producers and consumers (Drabo *et al*., 2020).

Acaricides and irrigation techniques tested

Two acaricides provided by the Prophyma company located in Bobo-Dioulasso (Burkina Faso) were used and compared regarding their performances in *T. evansi* control. These acaricides included Biopiq (soluble concentrate to be used at a dose of 1l/ha), a natural acaricide (from plant origin) extracted from *Sophora flavescens* Kushen and containing 0.6% matrin. Once sprayed, the pests are contaminated by contact and by ingestion; then the acaricide acts on the nervous system. The second pesticide, used as positive control, was Acarius 018 EC, a combined insecticide and acaricide acting by contact and by ingestion. Acarius 018EC was formulated as an emulsifiable concentrate containing 18 g/l abamectin and used at the recommended dose of 0.5 l/ha in tomato crops. As a translaminar product, it penetrates into the treated leaves which are therefore protected for 3 to 6 weeks (Son, 2018).

Regarding irrigation techniques, two methods were under investigation. The first method, widely used by producers in the study area, is a gravity-fed irrigation technique using a motor pump fitted with pipes bringing water to the feet of the plants into plots. Sprinkler irrigation has also been tested using a manual watering can. This technique consists of distributing water over the entire cultivated area in the form of water drops to simulate rainwater. In both cases, irrigation began immediately after transplanting and continued twice a week until the fruit ripened.

Obtaining nursery plants, transplanting and maintaining crops

A tomato nursery was set up on November 28, 2019 in order to produce plants for the implementation of the trial. The seedlings in the nursery were carried out on soil beds arranged in the shade, enriched with compost with regular watering once a day. Young plants were transplanted on January 1, 2020, *i.e.* 34 days after sowing. The plants were about 20cm tall and had 4-5 leaves. In all the plots of the trial, NPK fertilizer (14-23-14) was added at a dose of 80 g per plant during the vegetative stage (Azandémè, 2015) 10 days after transplanting. Watering was done twice a week until the fruit ripened. Hand weeding was also carried out whenever needed.

Treatments under investigation

To assess the effectiveness of a biopesticide combined with sprinkler irrigation to control *T. evansi*, the following six treatments were implemented:

i. SI: Control sprinkler irrigation, twice a week;
ii. GI: Control gravity irrigation, twice a week;
iii. Acarius + SI: combination of the pesticide Acarius with sprinkler irrigation twice a week, Acarius being applied once a week;
iv. Acarius + GI: combination of the pesticide Acarius with gravity irrigation twice a week, Acarius being applied once a week;
v. Biopiq + SI: Combination of the biopesticide Biopiq with sprinkler irrigation twice a week, Biopiq being applied once a week;
vi. Biopiq + GI: Combination of the biopesticide Biopiq with gravity irrigation twice a week, Biopiq being applied once a week.

Experimental set-up

The experimental set-up was a randomized Fisher Block consisting of six treatments in four replications (Figure 1). The elementary plot had an area of 6 m^2 (2×3 m) and included 48 plants. It consisted of 6 lines of 3 m long with 0.4 m between the lines and 0.4 m between the pockets. Elementary plots were spaced 1 m apart in blocks that were also spaced 2 m apart.

Data collection

Observations for data collection began one week after transplanting and continued every three days which makes two observations per week. Then, 10 plants along the two diagonal transects (5 plants per diagonal) were chosen from each elementary plot at each date and subjected to observations until the end of the study. Observations were made early in the morning between 8 a.m. and 10 a.m. The following parameters were determined on each observation date

– *T. evansi* density/leaf was assessed in each treatment: on each observation plant, five leaves were chosen at random from bottom to top and all the leaflets were observed. On each leave, the number of mites (both juveniles and adults) was counted using a manual magnifying glass of 10x according to the method described by Benziane *et al*. (2003). The number of individuals per leaf was obtained by taking the sum of the individuals of all the leaflets of the same whole leaf;

- the level of leaf infestation: on the five leaves chosen from each plant, the number of leaves infested by *T. evansi* was determined. A leaf was considered infested when at least two individuals of mites were found there;
- the production of leaves, flowers and fruits: on each plant, the leaves, flowers and fruits were counted;
- Leaf damage index (LDI): on the 5 leaves observed per plant, mite damage was evaluated according to the classification of Hussey and Scopes (1985) which includes 5 damage classes (Figure 2).
- yield assessment: all the fruits were harvested from the four central rows except those from the two pockets located at the ends of these rows. Then, for yield determination, the useful surface considered was 2.2×1.2m (2.64 m^2) and the yield was estimated per hectare from the weight of harvested tomatoes (kg) on the 4 central rows.

Data statistical analysis

Shapiro and Bartlett tests were performed to test for normality and homogeneity of the data for all variables, respectively. As these analyses indicated that our data were nonnormal distributed, they were first subjected to the Kruskal Wallis nonparametric test. Then, the separation of significantly different means was performed using the Student-Newman-Keuls multiple comparison test. When applicable, comparative boxplots were also used to compare treatments. Statistical processing of data and Boxplots were carried out using R software (version 4.0.2). The significance threshold was 5% for all statistical analyses.

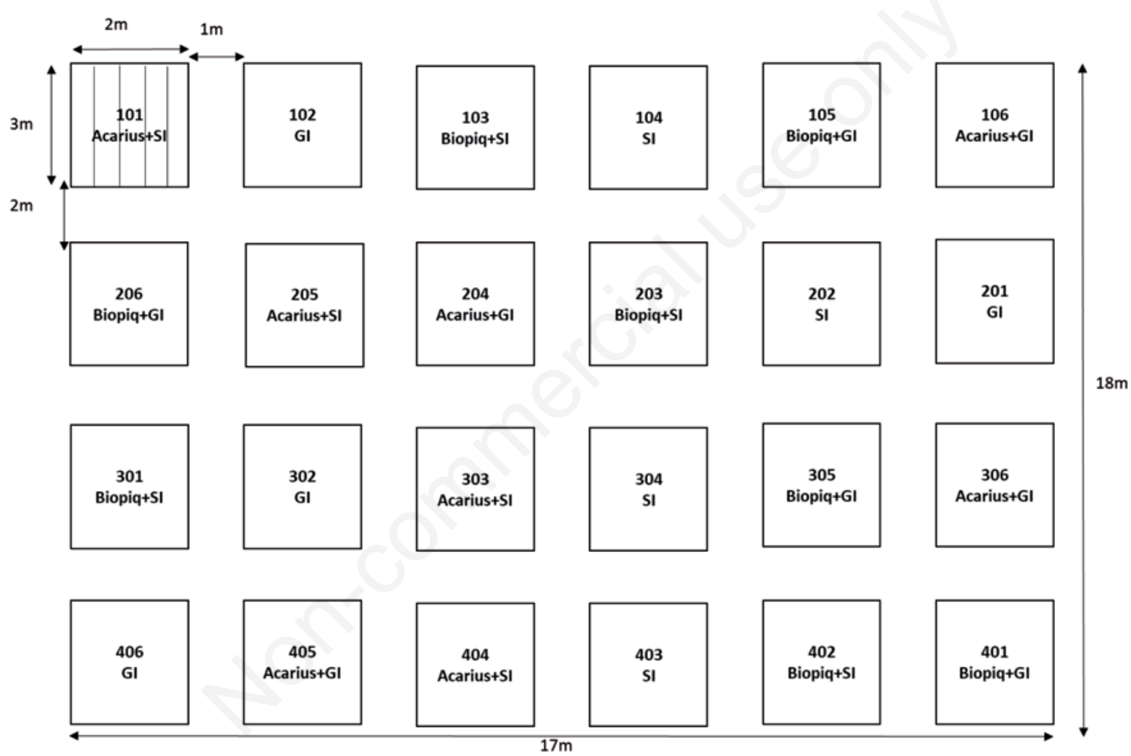

Figure 1. Diagram of the experimental set-up.

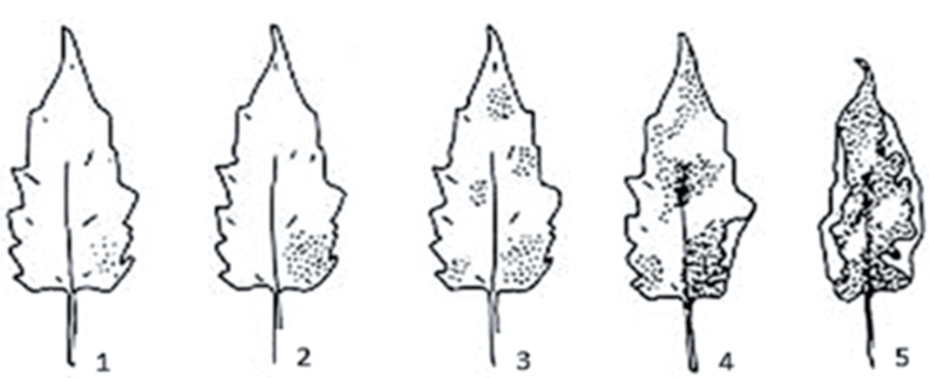

Figure 2. Classification of mite damage on tomato leaves according to Hussey and Scopes (1985). Class 0: no damage; class 1: appearance of the first bites; class 2: appearance of new areas of punctures; class 3: leaf strongly attacked, appearance of the first necrosis; class 4: discolored leaf, presence of canvas; class 5: leaf dryness, complete destruction.

Results

Effect of treatments on the density of *T. evansi*/tomato leaf over the study period

Boxplot comparison revealed that the overall density of mites/tomato leaf varied significantly depending on the treatments (χ^2=48.695, P<0.0001; Figure 3). The highest density of *T. evansi* (about 5 individuals per leaf) was recorded in the GI treatment where gravity irrigation was applied alone. Significantly lower densities were recorded in Acarius treatments combined with both irrigation techniques and in sprinkler irrigation alone or combined to Biopiq sprayings (Figure 3).

Leaf infestation by *T. evansi* according to the treatments

The average level of leaf infestation by *T. evansi* over the study period differed significantly depending on the treatments (χ^2=49.706, P<0.0001; Table 1). Gravity irrigation alone and in combination with Biopiq had the highest leaf infestation means. The lowest leaf infestations were obtained with the other treatments including Acarius associated with gravity irrigation and all sprinkler irrigation-based treatments (Table 1).

Leaf damage index (LDI) as a function of treatments

The Kruskal Wallis test showed a highly significant difference (χ^2=46.47, P<0.0001) between the treatments for Leaf damage index. Over the study period, the highest leaf damage indices were obtained in treatments where gravity irrigation was used alone or in combination with Acarius and Biopiq respectively (Boxplot analysis; Figure 4). On another hand, the lowest leaf damage indices were recorded in the Acarius-sprinkler irrigation and Biopiq-sprinkler irrigation combinations (Figure 4).

Effect of treatments on the production of leaves, flowers and fruits over the study period

The different treatments had significantly affected the production of leaves, flowers and fruits (Table 2). Leaf production was significantly higher in the Acarius-sprinkler irrigation treatment (χ^2=926.71, P<0.0001). Then, in decreasing order follow the Biopiq + sprinkler irrigation combination, the two treatments each combining acaricides with gravity irrigation and, finally, the two types of irrigation applied alone which produced significantly less leaves than all other treatments (Table 2).

Similar results were also obtained for flower production (χ^2=292.49, P<0.0001), with significantly higher production in the treatment combining Acarius with sprinkler irrigation. An interme-

Table 1. Mean number (±SE) of tomato leaves infested with T. evansi/5 leaves in the treatments under investigation over the study period.

Treatments	Mean number of infested leaves
GI	3.48±0.57A*
Biopiq+ GI	2.10±0.31B
Acarius +GI	1.14±0.25C
SI	0.89±0.18C
Biopiq+ SI	0.41±0.12C
Acarius +SI	0.32±0.10C
Kruskal Wallis (χ^2)	49.706
Df	5
P	<0.0001

SE: Standard error. *Means followed by the same capital letters are not significantly different according to the Student Newman Keuls test at the 5% probability threshold.

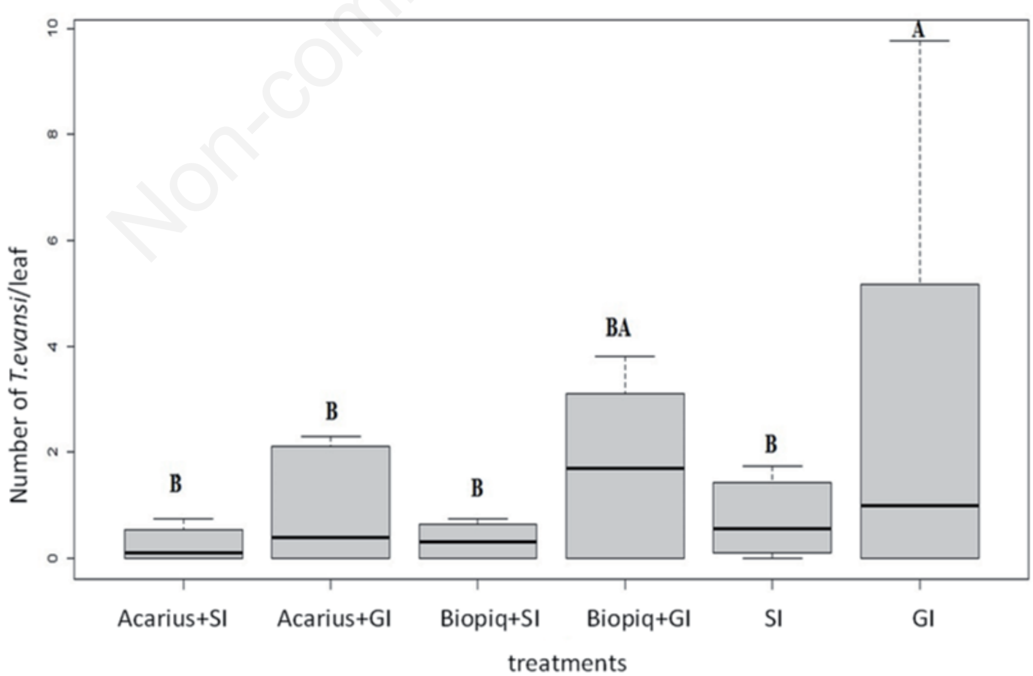

Figure 3. Boxplots (± SE) comparing the distribution of datasets on the density of *T. evansi*/tomato leaf in the treatments under investigation over the study period. Boxplots with the same capital letters are not significantly different according to the Kruskal Wallis test at the 5% probability threshold. SE: Standard error.

diate flower production was observed in the two treatments, each combining acaricides with the two irrigation techniques. The other three treatments had similar and lower flower production (Table 2).

The analysis of the mean number of fruits/plant made it possible to distinguish three significantly different levels of production depending on the treatments (χ^2=625.09, P<0.0001; Table 2). The first level, corresponding to the highest fruit production, included the 2 treatments combining acaricides with sprinkler irrigation; the second, intermediate level of production corresponded to 2 treatments combining both acaricides with gravity irrigation and sprinkler irrigation treatment. Gravity irrigation treatment applied alone yielded the lowest level of fruit production (Table 2).

Effect of the treatments on tomato yields

Comparison of tomato yields from harvested fruits indicates that treatments significantly affected tomato yields estimated per hectare (χ^2=40.018, P <0.0001; Table 3). The combination of acaricides with sprinkler irrigation produced the best yields. Those recorded in all other treatments were similar and significantly lower (Table 3).

Discussion

The results of the present study showed that treatments combining both acaricides with sprinkler irrigation have systematically reduced the level of *T. evansi* populations compared to that obtained from other treatments. This result also had an impact on the plant growth and the tomato production parameters, and, in particular, on the yields. So, both irrigation technique and acaricides affected mite density and tomato production. In addition, acaricide sprayings helped to control insect pests which also improved the tomato yields in treated plots.

Table 2. Average production (mean number ± SE) of tomato leaves, flowers and fruits over the study period according to the treatments.

Treatments	Leaves/plant	Flowers/plant	Fruits/plant
Acarius+ SI	38.05±7.83 A*	48.46±5.67A	39.05±7.80A
Biopiq+SI	35.01±7.20B	45.64±4.44B	35,91±6.44A
Acarius+ GI	30.12±7.19C	37.13±4.45B	25.47±5.46B
Biopiq+GI	29.60±6.94C	25.27±3.13C	18.75±4.71B
SI	23.34±6.49D	21.22±4.46C	16.35±3.19B
GI	22.72±6.30D	17.31±3.76C	11.87±2.45C
Kruskal Wallis (χ^2)	926.71	292.49	625.09
Df	5	5	5
P	<0.0001	<0.0001	<0.0001

SE = Standard error. *Means followed by the same capital letters in the same column are not significantly different according to the Student Newman Keuls test at the 5% probability threshold.

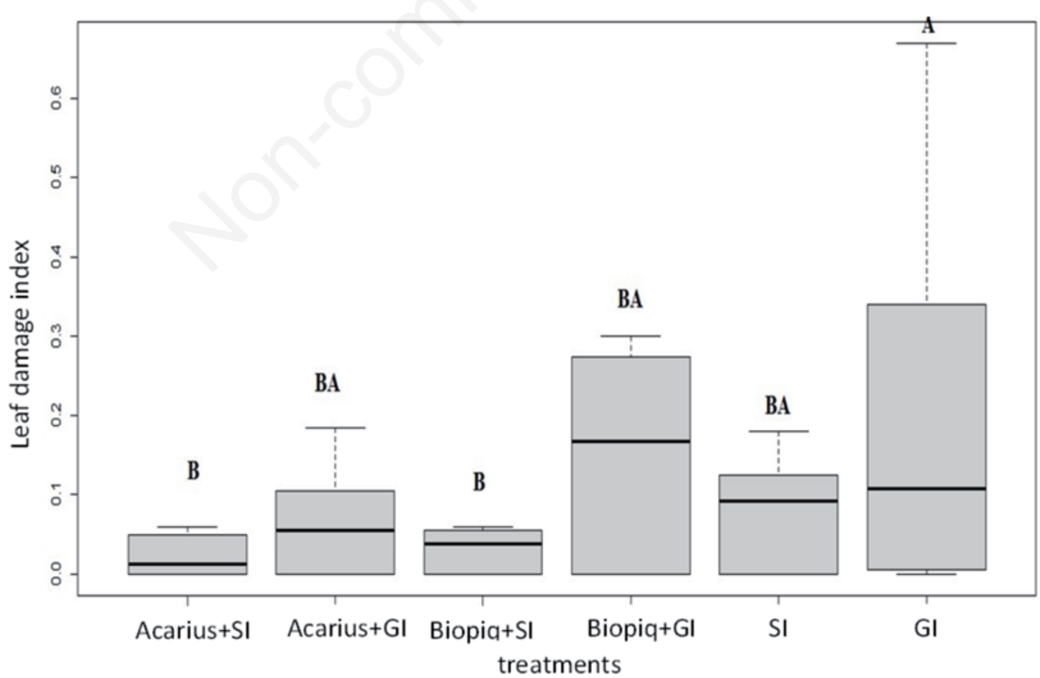

Figure 4. Boxplots (± SE) comparing the distribution of datasets on Leaf damage index in the treatments under investigation over the study period. Boxplots with the same capital letters are not significantly different according to the Kruskal Wallis test at the 5% probability threshold. SE: standard error.

The reference control acaricide Acarius 018 EC containing abamectin from the avermectin family acts by ingestion and, to a lesser extent, by contact on the mobile forms of mites. Lagziri *et al.* (2015) have shown that abamectin was highly effective in controlling *Tetranychus urticae*. In Burkina Faso, most producers use synthetic insecticides against mites without great effectiveness (Drabo *et al*., 2020), probably because they are ignorant of the specificity of these pests, or because adequate products targeting mites are not always available on the local markets. Therefore, Acarius, which is both a commercial insecticidal and acaricidal product, could be recommended in tomato crops provided its dissemination is accompanied by awareness-raising on good practices.

Biopiq, a natural acaricide based on extracts of *Sophora flavescens*, a shrub plant of the Fabaceae family, exhibited an efficacy close to that of Acarius against mobile forms of *T. evansi*. The reduction in the density of the red spider mite by the use of this plant-based bioacaricide is believed to be due to the presence of the matrin which acts by contact and by ingestion on the nervous system of pests by solidifying the albumin, which prevents their breathing, resulting in death from suffocation (Savana, 2020). The effectiveness of biopesticides against pest mites has also been confirmed by several authors (Sanguanpong and Schmutterer 1992; Lowery and Isman 1996; Kashenge 1999; Ogayo *et al.,* 2015; Yarou *et al.,* 2017; Adango *et al.,* 2020). Attention now seems to be focused on natural pesticides as a viable alternative to synthetic pesticides. In this view neem oil has been shown to be effective in controlling red spider mites, especially when preventively applied (Kithusi, 2005). Moreover, the use of plants with pesticidal effects is seen as a potential alternative in terms of crop protection against several pests in West Africa (Zakari, 2013). These biopesticides have a real advantage due to their low persistence, their low toxicity for humans and their mode of action on pests (Zakari, 2013).

Irrigation technique also appeared to play a crucial role in the control of *T. evansi* in irrigated tomato crops. In fact, sprinkler irrigation offered better results when combined with Acarius and Biopiq compared to gravity irrigation. Sprinkler irrigation not only brings moisture to the plots, creating an unfavorable environment for the development of *T. evansi*, but also eliminates a significant number by leaching. The tomato crop would be protected against red spider mites by splashing water droplets on the leaves, helping to leach a large number of mites. Moreover, the water from sprinkler irrigation could affect *T. evansi* by increasing moisture under the web produced by mites. Previous studies have shown the importance of rains in reducing mite populations by leaching plants (Azandémè, 2015). In addition, high relative humidity inhibits the activity of spider mites (Ferrero, 2009). Sprinkler irrigation has the advantage of adapting to all types of soil, many crops and small irregular plots. It also does not require skilled labor. However, it is labor intensive and seems more appropriate for small producers exploiting limited areas. To reduce the workload, the water source should also not be more than 50 m from the area to be irrigated. A modern irrigation system including a motor pump and flexible distribution pipes, on which the sprinklers are placed should be considered for large scale users. Sprinkler irrigation should be listed among the most effective resilient strategies for controlling mites in tomato irrigated crops in Burkina Faso and even in the West African region.

Table 3. Mean (± SE) tomato estimated yields in the different treatments under investigation.

Treatments	Mean tomato yield (Kg/ha)
Acarius+ SI	14,875±19A*
Biopiq+SI	14,687±92A
Acarius+ GI	8,521±19B
Biopiq+GI	8,479±34B
SI	7,542±73B
GI	6,550±18B
Kruskal Wallis (χ^2)	40.018
Df	5
P	<0.0001

SE: Standard error. *Means followed by the same capital letters are not significantly different according to the Student Newman Keuls test at the 5% probability threshold.

Conclusions

The combination of both acaricides tested in this study with sprinkler irrigation provided good protection of tomato crops against *T. evansi* and provided good yields. The use of the bioacaricide from plant origin Biopiq could be advised as an alternative for resistance management because mites are known to be resistant to synthetic acaricides. Sprinkler irrigation technique should be listed among the most effective resilient strategies for controlling mites in irrigated tomato crops in Burkina Faso and even in the West African region. However, it remains to define precisely the conditions for its large-scale use and its contribution to the integrated pest management in tomato irrigated crops.

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