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Inventory of Host Plants and Parasitoids of the Fall Armyworm (FAW), *Spodoptera frugiperda* (JE Smith), in the Southern Agricultural Zone of Niger

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Abstract

The fall armyworm, *Spodoptera frugiperda (JE Smith)*, is a polyphagous pest reported in sub-Saharan Africa since 2016 and has expanded rapidly in almost Africa. In Niger, *Spodoptera frugiperda (JE Smith)* is considered like a major pest of maize, to which it causes significant damage, in a context where proven control methods against this moth remain almost non-existent. The objective of the present study was to determine the economic importance of FAW through the damage caused to the different host plants and to identify the parasitoids of this caterpillar. The study was conducted in the southern agricultural zone of Niger, specifically in the regions of Dosso, Maradi, Tahoua and Zinder. FAW eggs and caterpillars were collected from six villages in each region and then incubated and reared in the entomology laboratory of INRAN in Maradi. The rate of infestation of the different crops by FAW was determined as well as the observation of the beneficiaries. The results obtained indicate the presence of FAW on millet with an attack rate varying from 45.7% to 68%, sorghum with 47.2% to 62.25% and sesame with 9.7%. This work also revealed an oophagous parasitoid, *Telenomus remus* with 138 ± 23 and larval parasitoids, *Cotesia sp* with 16 ± 1 maximum number of individuals emerged from the collected material. Also, it was identified the parasitoid *Cotesia icipe* with a rate of parasitism from 4.6% to 5.75%; the *Charops ater* whose rate of parasitism varies from 4.5% and 12.25% but for *Chelonus insularis* with 17.25% and Tachnidae with 53%. These very interesting results will constitute a basis for the development of biological control and a component of an agroecological management strategy of caterpillar.

Keywords

Inventory, Host Plants, *Spodoptera frugiperda*, Parasitoids, Niger

1. Introduction

Production of major commodities has dropped since 1980 due to global warming [1]. In addition to the inherent high climate variability, the latent threat of rising temperatures and more vicious droughts (again due to climate change) are a major concern [1]. In addition, parasitic plants, insufficient soil nitrogen, and high incidences of disease and insect pests also continually hinder grain productivity in Africa [2].

Among insect pests, a brand new pest is emerging in Africa "The Fall Armyworm" (FAW). It was first detected in 2016 in Central and West [3]-[13].

The fall armyworm (FAW) is a polyphagous and voracious pest, destroying maize plants on farms. The armyworm (FAW) resulted in losses in the range of 8.3 to 20.6 million tons of maize annually in the absence of effective control methods for the 12 largest maize producers in Africa [14] [15]. These losses are estimated to range from 15% to 78%, valued at US$2481 million to US$6187 million in Cameroon [16]. The threats are very significant and therefore the need to limit such damage. The control methods used so far by producers are essentially chemical control with adverse effects on agricultural production itself, health (human and animal) and the environment [17] [18]. Surveys conducted in Ghana in 2018 showed that households sprayed pesticides, including fall armyworm biopesticides up to 12 times, during maize growing seasons [19], which could negatively impact natural enemy populations and increase production costs.

In the search for ecological control methods, several parasitoids have been identified with different levels of parasitism [20]. Studies revealed about 150 different species of parasitoids on *Spodoptera frugiperda* of which the most common are *Telenomus remus* Nixon (Hymenoptera: Platygastridae), *Chelonus insularis* Cresson (Hymenoptera: Braconidae), *Cotesia marginiventris* Cresson (Hymenoptera: Braconidae), *Trichogramma spp*. (Hymenoptera: Trichogrammatidae) and Parasitoid flies: Archytas, Winthemia and Lespesia (Diptera: Tachinidae) [21] [22]. Several species of parasitoids have shown efficacy in controlling *S. frugiperda* [23]. Three parasitoids (*Aphidius spp*., *Encarsia spp*., and *Trichogramma spp*.), one predator (O*rius spp*.), and one predatory mite (*Phytoseiulus spp*.) are used extensively in biological control in Africa [22]. There is a diversity of natural enemies of FAW in maize fields in Kenya, Ethiopia Tanzania [20] and Niger [24]. This study aims to inventory the different winter crops attacked by FAW in Niger with its natural enemies.

2. Methodology

2.1. Study Site

The study was conducted during the 2020 winter season in the regions of Dosso, Maradi, Tahoua, and Zinder. These four regions represent the agricultural belt of the country with a variation in average annual rainfall from 300 to 1600 mm. In each region, 10 villages (Figure 1) were involved in the collection. The villages were selected systematically according to maize production in the area and the presence of the caterpillar in the fields.

2.2. Inventory and Sampling of Host Plants

An upstream investigation was carried out at the level of maize producers in their fields to collect information on the crops attacked by FAW. Observations were made in the fields to collect samples of the caterpillar. The samples were well labeled according to the host plant and the locality of collection and then sent to the laboratory for obtaining the imagos.

The investigation involved a total of 400 producers (400 fields) in the southern agricultural band of the country (Maradi, Tahoua, Dosso and Zinder), *i.e.* 100 producers per region. The simple random sampling technique was used to select

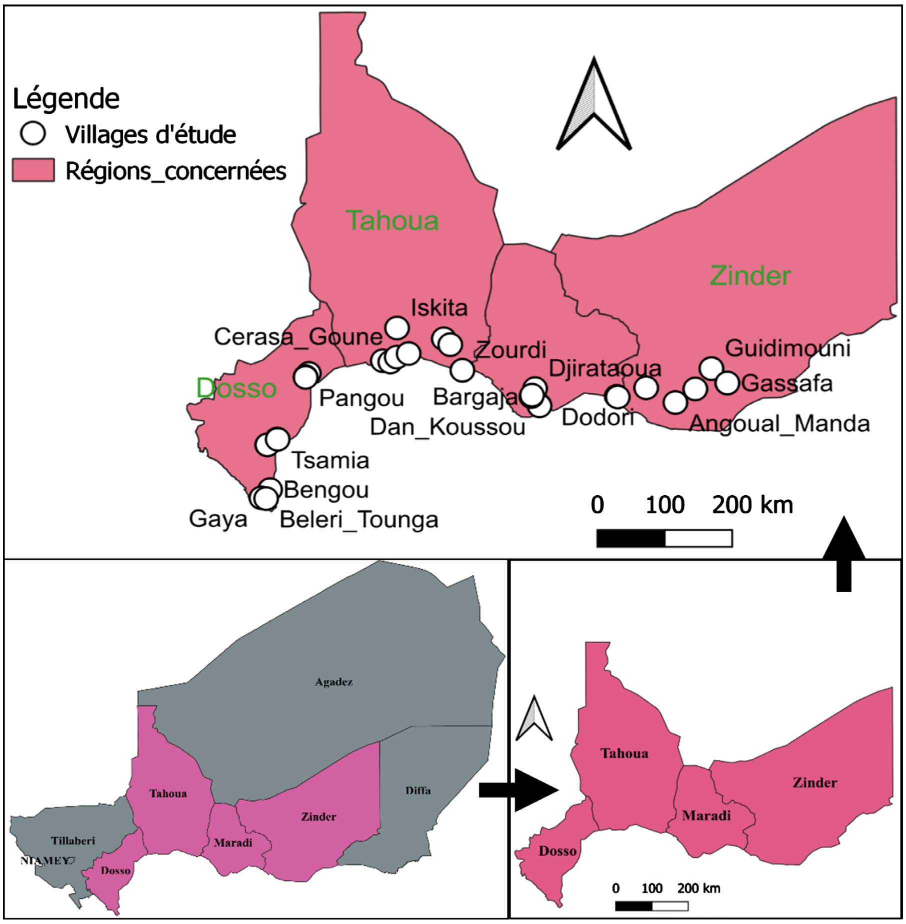

Figure 1. Location map of collection sites.

respondents.

2.3. Sampling of the Collection Points

Following the "Z" sampling technique (the method was inspired by [25]; and [26] readapted to the context of the present study), 25 caterpillar samples at the level of each maize field, *i.e.* 1000 samples, were collected only on maize and sorghum. In fact, in the Tahoua region and in certain collection localities, producers have substituted maize for sorghum, so samples were either collected entirely from maize or sorghum or from both crops, as in the Maradi region.

On the other crops, a sample of 1 to 20 caterpillars was collected depending on availability. A sample of 20 eggs was collected in the Dosso, Maradi and Zinder regions, *i.e.* a total of 60 clusters of eggs sent to the INRAN Entomology laboratory for incubation.

2.4. Technique for Determining FAW-Infested Plants

This information was collected by maize production site and not by locality. Respondents were randomly selected to belong to one or more sites per village.

At each site, three (3) quadrats of 16 m^2 (4 m × 4 m) separated from each other by 150 m on the diagonal were delimited (**Figure 2**). At each quadrat, the number of total plants and the number of plants with obvious signs of FAW attack were recorded.

2.5. Conditioning and Monitoring of Emergence

All the samples of FAW caterpillars and eggs were brought to the Entomology Laboratory of the Regional Center for Agricultural Research in Maradi (CERRA/Mi) for the monitoring of egg emergence and caterpillar evolution.

The caterpillars were monitored in the laboratory in their individual collection boxes and the diet was changed regularly with a frequency of 48 hours. The eggs were observed in the laboratory every 24H. Well before, it was used the

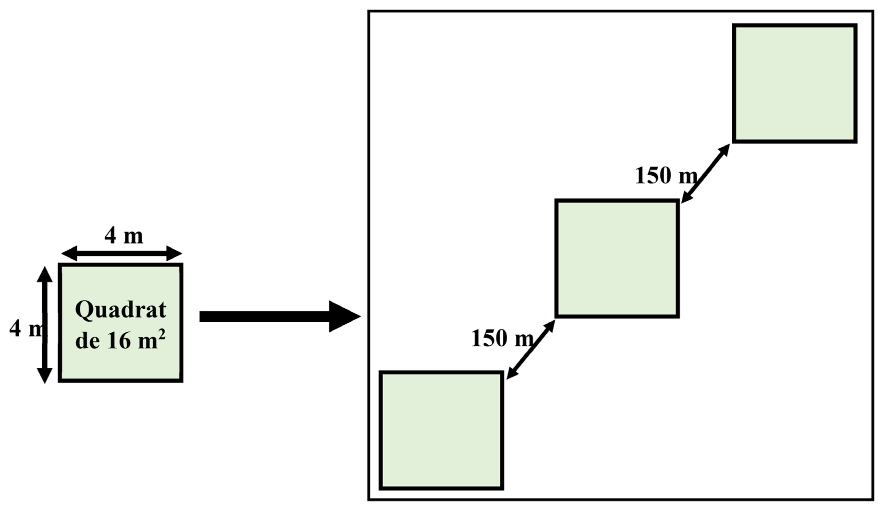

Figure 2. Spatial arrangement of the quadrats.

binocular microscope (Optika) and cold light to count the number of eggs per cluster and per collection site before putting them in the test tubes.

2.6. Identification of Emerged Parasitoids

Three (3) steps were followed for the identification of emerged parasitoids. The steps are as follows:

- Knowledge on the morphology and entomological characteristics of the species;
- Emerged parasitoids are brought to the CERRA collection to confirm the scientific name of the species;
- Identified samples are shared with other entomologists for confirmation. The unidentified samples were sent to the reference laboratory of IITA Cotonou, Benin of Professor Tamo Manuel for identification.

2.7. Data Collection

It concerned the following parameters:

- FAW infestation rate on the different speculations: The formula $T = (n/N) \times 100$ was used to calculate this infestation rate.

With T = infestation rate, n = Number of ears attacked; N = Total number of ears observed.

- Identification of winter specie attacked by FAW at the collection plot level;
- Collection of caterpillar samples and egg samples;
- Identification of natural enemies in the laboratory.

Observations of the natural enemies of the eggs began one week after collection and the following parameters were noted:

- Total number of eggs;
- Number of sterile eggs;
- Number of parasitized eggs;
- Number of each parasitoid species.

2.8. Statistical Analysis of the Data

The collected data were analyzed with SPSS v20 software. The average of parasitoids emerged in the collected eggs, the rates of larval parasitism and the rates of infestations of the specimens attacked by FAW. Then, Pearson's Chi-square test and analysis of variance (ANOVA) were used to compare the variables.

Prior to the analysis of variance (ANOVA), the ASIN transformation was firstly calculated using the formula below:

$\mathrm{Tr} = \mathrm{ASIN}\sqrt{\mathrm{Proportion}}$; the proportion was obtained by making the rate divided by 100 (Rate/100).Cependant, avant de procéder à l'analyse de la variance (ANOVA) il a été d'abord calculé la transformation ASIN à travers la formule ci-dessous:

$\mathrm{Tr} = \mathrm{ASIN}\sqrt{\mathrm{Proportion}}$; the proportion was obtained by making the rate divised by 100 (Taux/100).

3. Results

3.1. Average Number of Individuals

The number of samples collected did not differ between regions. Two (2) parasitoids were inventoried: *Telenomus remus* and *Cotesia sp* (species not yet identified). The parasitism rate was 30 ± 8 and 70 ± 12 respectively in Zinder and Maradi for *Telenomus remus* (Table 1). While *Cotesia sp* was only identified in the Dosso and Maradi regions with a parasitism rate of 7 ± 0.5 and 8 ± 0.5 respectively (Table 1).

3.2. Larval Parasitism Rate

In the four regions, four (4) types of parasitoids were identified (Table 2). The larval parasitoid, *Cotesia icipe* was identified in the Maradi and Zinder regions with a comparable parasitism rate between them (t = −1.86; P = 0.105). However, for *Charops ater*, the rate of parasitism shows a very significant difference with values varying between 4.5% and 12.25% (t = 20.3; P < 0.001). While *Chelonus insularis* was identified in all the study regions with a highly significant parasitism rate between regions (F = 55.2; P < 0.001) varying between 4.25% and 17.25% respectively in the Tahoua and Zinder regions.

A new parasitoid of the family Tachnidae was identified in Maradi and Zinder with a parasitism rate of 32% and 53% obtained in Maradi and Zinder respectively.

Table 1. Parasitism rate of eggs.

Regions	*Telenomus remus*	*Cotesia sp*
Dosso	-	7 ± 0.5
Maradi	70 ± 12	8 ± 0.5
Zinder	30 ± 8	-
Mean	52 ± 23	7.5 ± 1.07
Test	t = 5.22; P = 0.003	t = 3.5; P = 0.025

Table 2. Parasitism rate of larval parasitoids.

Region	*Cotesia icipe* F-T & F	*Charops ater* Szépligeti	*Chelonus insularis* Cresson	Tachnidae (not identified)
Dosso	-	12.25 ± 0.5^{b}	11.75 ± 0.5^{c}	-
Maradi	4.6 ± 1.14^{a}	-	8.2 ± 2.5^{b}	32 ± 0.7^{a}
Tahoua	-	4.5 ± 0.6^{a}	4.25 ± 0.5^{a}	-
Zinder	5.75 ± 0.5^{a}	-	17.25 ± 1^{d}	53 ± 0.82^{b}
Mean	5.1 ± 1	8.4 ± 4.2	10.24 ± 5	41.3 ± 11.1
Test	t= −1.86; P = 0.105	t = 20.3; P < 0.001	F = 55.2; P < 0.001	T = −41.4; P < 0.001

Means followed by the same letter in the same column are not statistically different.

3.3. Winter Crops Attacked by FAW

In addition to maize, three crops produced during the winter season in Niger were identified: sorghum, millet and sesame. The FAW infestation rate on maize ranged from 45% to 60% for all regions, with the highest being in Zinder (60%) and the lowest in Tahoua (45%) (**Table 3**). Attacked sorghum was identified in the Tahoua and Maradi regions with an infestation rate of 47.2% and 62.25% respectively.

Millet, the main food crop in Niger, was attacked in the Tahoua, Maradi and Zinder regions. The level of attack on millet did not differ statistically between regions (**Table 3**).

Attack on sesame was identified only in the Maradi region with a 10% attack rate by the Fall armyworm.

4. Discussion

This study showed that FAW attacks all major cereals produced in Niger (millet, maize and sorghum). Millet represents the main rainfed crop in Niger and also accounts for two-thirds (2/3) of the country's total agricultural production [27] [28]. The infestation rate obtained on millet, which varies from 45.7% to 68%, seems very high. Millet production, already weakened by the millet ear miner, can cause yield losses of 60% to 85% in years of heavy outbreaks [29] [30] [31] [32] [33].

Millet remains and continues to be the most cultivated cereal in the Sahel [34].

Most authors who have written about the armyworm have noted its polyphagous aspect. These include [35], they listed that the caterpillar can feed on more than 60 species of plants [36] [37]. This is for [38] more than 80 host species, causing severe damage to cereal and vegetable crops [22] [39] [40] [41]. It was found by [16] also that FAW is a polyphagous and voracious pest that damages several crops of about 76 plants with more than 106 plant species in the family Poacecae, 31 Fabaceae and 31 Asteraceae [42]. It also infests food crops such as maize (*Zea mays* L.), sorghum (*Sorghum bicolor* (L.) Moench), cotton (*Gossypium sp.* L), millet (*Panicum miliaceum*), groundnut (*Arachis hypogaea* L.), rice (*Oryza sativa*) [43] [44]. Furthermore, FAW is the major pest of maize [45], reducing its yield to 40% in a monoculture system [46].

The study also inventoried a diversity of natural enemies parasitizing armyworm.

Table 3. The wintering speculations attacked by region.

Région	Mais	Mil	Sorgho	Sésame	Test
Dosso	53.6 ± 5.2^{ab}	-	-	-	-
Tahoua	45 ± 2.7^{a}	68 ± 4	47.2 ± 11.5	-	F = 3.4; P = 0.06
Maradi	58 ± 7.3^{b}	62 ± 1^{b}	62.25 ± 8.8^{b}	9.7 ± 2^{a}	F = 42.5; P< 0.001
Zinder	60 ± 10^{b}	45.7 ± 7.8	-	-	t = 3.7; P = 0.001
Test	F = 3.2; P = 0.03	F = 6.86; P = 0.08	t = 3.6; P = 0.001	-	-

Means followed by the same letter in the same column or row are not statistically different.

This same diversity was obtained previously in a similar study by [24]. In this case, these are egg and larval parasitoids (*Chelonus sp.*) and caterpillar parasitoids (*Cotesia sp*. and *Charops sp.*).

In the present study, the highest rate of parasitism was obtained with the as yet unidentified caterpillar parasitoid of the family Tachnidae, followed by the parasitoid *Chelonus insularis*. It should be noted that all insects belonging to the family Tachnidae are parasitoids [47], which may in essence explain the parasitism rates obtained between the two parasitoids. These same results were obtained by [24] under the same conditions. On the other hand, [48] obtained the highest rate of parasitism with the parasitoid *Coccygidium luteum* of the family Braconidae followed by the parasitoid *Chelonus sp*.

As for the eggs, three (3) parasitoids are identified, *Spodoptera frugiperda*, *Cotesia sp* and *Telenomus remus*. The level of emergence at the eggs was higher for *Telenomus remus* with an average parasitism rate varying from 30 ± 8 and 70 ± 12. This level of natural parasitism seems very important in terms of ecological management of the pest. It would be due to its particularly remarkable high fecundity capacity [49]. It can parasitize the eggs of *S. frugiperda* located even in the internal layers at the level of the egg cluster [50]. In addition, the parasitoid (*T. remus*) has a strong dispersal and host-seeking ability [51] [52]. These results are supported by [53] who showed following a laboratory study that, *T. remus* parasitized an average of 78% of FAW eggs, compared to 25% for *Trichogrammatoidea sp*. They state that *Telenomus remus* was able to parasitize egg masses completely covered with scales, while *Trichogrammatoidea sp* only parasitized uncovered egg masses. Also, [54] showed that parasitism can be as high as 100% of eggs attacked in the laboratory. Variations in egg parasitism may be due to laboratory conditions, as *T. remus* performance is affected by temperature and humidity [50] [55]. According to [56], the presence of *T. remus* in Africa provides an excellent opportunity to develop augmentative biological control methods against *S. frugiperda*.

5. Conclusion

The results obtained show that the armyworm is a reality in Niger and constitutes a major threat to the country's food security, since millet is not spared from its attacks. The rate of infestations observed on millet is worrying, hence ecological control measures must be developed through the use of locally identified parasitoids. Among the caterpillar parasitoids, the use of Tachnidae and *Chelonus sp*, may be promising. For egg parasitoids, the study showed that *Telenomus remus* may be a useful candidate for the management of armyworm. However, these parasitoids should be maintained in rearing for possible augmentative releases in Niger.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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