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EVALUATION OF THE EFFECTIVENESS OF SHREDDED NEEM SEEDS (AzadirachtaIndica A. Juss) IN THE MANAGEMENT OF SPODOPTERA FRUGIPERDA J. & SMITH (Lepidoptera: Noctuidae) IN SORGHUM CULTIVATION IN MALI

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ABSTRACT

As part of the alternative management of Spodoptera frugiperda and for food security, a test of the effectiveness of crushed neem in sorghum cultivation was carried out at the Regional Agricultural Research Center of Sotuba during the rainy season from 2020 to 2022. The objectives were: to identify an effective intervention threshold against Spodoptera frugiperda compatible with the use of crushed neem seeds; to determine an effective spraying frequency of neem seed grind and to determine the effect of neem seed grind on sorghum grain yield. A total randomization design with five treatments in five repetitions was carried out. A significant average reduction in the population of the lowest Spodoptera frugiperda larvae was recorded by 0.00 larva/plant, an average incidence of 5.0948% and an increase in the highest average grain yields of 1703 kg-1ha and of straw of 4410 kg-1ha in the sorghum plots under protection. The use of shredded neem seeds can be recommended for the management of Spodoptera frugiperda in sorghum cultivation in Mali.

Keywords: Sorghum, Neem Seed Efficacy, Spodoptera frugiperda, Mali.

1. INTRODUCTION

Insect pests, disease-causing agents (fungi, bacteria or viruses) and weeds significantly contribute to the reduction in agricultural productivity which can reach 70% losses (Popp et al., 2013). To fight against these crop enemies, producers have often resorted to the use of chemical pesticides which provide benefits but sometimes destroy the environment and human health (Rice et al. 2007). Indeed, like any selection pressure, it causes the emergence of resistant genotypes (Kranthi et al., 2001; Pray et al., 2002; Shelton et al., 2002), pushing farmers to overdose or raising the frequency of use sometimes without respecting the conditions of application (stages of development of the pest, preventive or curative treatment, time before harvest, etc.) and using very toxic products thus aggravating the situation. The use of chemical insecticides can disrupt the environment and lead to the elimination of beneficial insects and the accumulation of residues in harvested products (Chinnaiah et al., 1998; Anand Prakash et al., 2008). As a result, this can increase pest problems, leading to economic losses (Khater, 2012). Azadirachtin, the active ingredient in neem extracts, affects the physiological activities of insects (MordueLuntz and Blackwell 1993) and does not affect other biological control agents. According to Xu et al., 2011, the use of biopesticides reduces the risks of developing resistance; they have greater specificity of action and are effective at very low quantities. Neem products are biodegradable and non-toxic to non-target organisms (Senthil-Nathan 2013). Malian producers are today facing a formidable insect pest, *Spodoptera frugiperda*, whose larva is commonly called fall armyworm, which is progressively affecting cereal, cotton and market gardening areas. Originally from America, *S. frugiperda (*JE Smith) Lepidptera, Noctuidae) was first reported in the African continent in January 2016 (Goergen et al., 2016). The perpetual spread of the fall armyworm towards new ecological niches raises regional and global concerns (Tepa-Yotto et al., 2021).

In Mali, the main sorghum production regions are Kayes, Koulikoro and Sikasso. The annual consumption of sorghum per capita is 61.2 kilos for sorghum (FAO 2013). Sorghum is generally more important for rural households than for urban households (Source FEWS NET). In 2021, Mali produced 1,239,656 tonnes on 1,546,030 hectares of cultivated area for a yield of 8,018 hg/ha (FAO stat 2023). In Mali, sorghum is grown in rainfed conditions between isohyets 400 and 1300 mm and in recession conditions in the north of the country. Corn being the preferred host plant, in Mali attacks on sorghum crops are becoming a concern due to damage from leafeating caterpillars of *S. frugiperda*. Faced with this new constraint which threatens precarious food security, it becomes necessary to test alternative methods to systematic chemical control in order to offer Malian producers those which are effective, economically profitable and not harmful to man, the environment and the agrosystem. Neem, a plant with an insecticidal effect, has long been used against pests and its effectiveness has been well documented by several researchers. This plant is available in several agro-ecological zones of Mali where sorghum is produced in quantity and consumed. Isman et al., 2006, reported that botanical insecticides have long been presented as attractive options to synthetic insecticides for pest control. Given the extent of environmentally friendly successes in managing pests, a test of the effectiveness of neem in controlling *S. frugiperda* in sorghum cultivation was carried out at the Regional Agricultural Research Center station. of Sotuba Bamako from 2020 to 2022. The objective of this work was (i) to identify an effective intervention threshold against *S. frugiperda* compatible with the use of crushed neem seeds in cultivation of sorghum, (ii) to determine a frequency of spraying of crushed neem seeds effective against S. frugiperda in sorghum cultivation and (iii) to determine the effect of crushed neem seeds on the grain yield of sorghum. Ground neem seeds could potentially be effective in the management of S. frugiperda in sorghum cultivation in Mali.

2. MATERIAL AND METHODS

2.1. Materials

2.1.1. Study site

The test was conducted at the Sotuba Regional Agronomic Research Center (CRRA) station located in Commune I of the Bamako District. It has the coordinates 12°39' 13" North and 7°55' 42" West and is 8 km east of the city center of Bamako on the left bank of the Niger River. The agronomic research station covers an area of 268 ha. It is located in the Sudanian zone, typically characterized by semi-arid tropical rainfall (800-1000 mm of rainfall). The average annualprecipitation is 969 mm. Precipitation occurs between the months of April and October. The maximum temperature varies between 30 and 45°C and more during the months of March and April. The minimum temperature varies between 24 and 14°C during December and January. The humidity varies between 19 and 78% and is higher during the rainy period. The soil types identified in the CRRA of Sotuba are tropical ferruginous soils leached in Gley, tropical ferruginous soils leached with stains, tropical ferruginous soils with depth hydromorphism, poorly evolved soils and hydromorphic soils (Samaké, 2013). The experiment was carried out in the plots of the CRRA Sorghum Program in Sotuba. The choice of this site is due to the fact that it constitutes a natural area of infestation of the armyworm.

2.1.2. Plant Material

The plant material used was the improved sorghum variety "Tiandougoucoura" coming from the sorghum selection program of the IER (Institut d'Economie Rurale) resulting from the combination of a cross derivative between an improved caudatum type variety (Bimbiri Soumalé / S34) and another improved variety of the guinea-caudatum type (97-SB-F5DT-154). Its cycle is 120 days and is photosensitive. Its potential grain yield is 2.5 t/ha and 12 t/ha for its fodder biomass. It tolerates *Striga hermonthica*, insect bites, molds and leaf diseases. The grains are glassy, the plant is tan. It keeps its green leaves after physiological maturity (Source technical sheet of the IER selection section sorghum program).

2.1.3. Pest Insect

The fall armyworm is a voracious and polyphagous pest (Pogue, 2002). It is an insect endowed with rapid invasion, endemic, and dynamic, recently seen in Africa including Mali. Adult females of S. frugiperda lay their eggs directly on maize (Sarmento et al., 2002) leading to economic losses.

2.1.4. Pesticide product used

The natural product used consisted of neem seeds. Neem (*Azadirachta indica* A. JUSS) is a tree found in several agro-ecological zones of Mali. It has insecticidal properties. The active ingredient is Azadirachtin A (Aza-A) belonging to the limonoid family. It is repellent, antipalatable (Faye 2010). The dose used in the test was 50g of shade-dried seeds for 1 liter of water, i.e. 5% concentration.

2.2. Methods

2.2.1. Preparation of neem seed grind and spraying period

500 g of clean grains, stripped of their pulp and well dried in the shade, were crushed in a traditional crusher with their hulls. The paste obtained was put in a double bag of gauze with a string and finally placed in a container filled with 10 liters of clean water. After spending a night in the water, the bag was removed and squeezed. A table spoon of unscented soap paste was mixed well with the contents of the tray. The homogeneous mixture obtained is filtered and put in a backpack sprayer (DEFI-Écologique internet source). The plots were sprayed early in the morning or in the evening before sunset. In case of rain immediately after a spraying, it was

resumed the next day. Spraying started as soon as *Spodoptera frugiperda* larvae were observed in the test plots 7 days after emergence.

2.2.2. Experimental Design

The total randomization device was applied at the Sotuba station in 5 repetitions with 5 treatments per repetition for conducting the test. The surface area of the elementary plot was 24 m2 which had 6 lines of 5 m. The spacings were 1.5 m between the elementary plots; 2 m between repetitions; 0.50 m between pockets and 0.80 m between rows. The total area occupied for the test was 1023 m^2.

2.2.3. Treatments of the experimental device applied in the station

Under natural infestation, five treatments compared with each other were as follows: T0-absolute control; T1-spraying of crushed neem seeds (50g/l of water) from 10% of plants attacked; T2-spraying of crushed neem seeds (50g/l of water) from 20% of plants attacked; T3-spraying ground neem seeds (50g/l of water) once every 10 days and T4-spraying ground neem seeds (50g/l water) once every 15 days. The seeds of T1, T2, T3 and T4 were treated with red caiman P fungicide (25 g/kg of seed). The fertilizer used was the cereal complex (17-17-17) provided at a micro-dose of 10 kg/ha, i.e. 0.4 g/pocket.

2.2.4. Observation made

The parasite readings were carried out every 3 days, 1 day before the spraying of crushed neem seeds and 4 days after. They started from the 7th day after emergence (DAL) and were continued until the appearance of the first spike. Observations were made per elementary plot on 30 plants chosen at random and marked with a dead wood stake arranged in the shape of a W. The plants were chosen at random in groups of 5 and for 6 groups. The plants were examined in their entirety. The number of caterpillars encountered and the leaf damage score per plant listed were entered in the observation sheet. Harvesting was done on 2 central rows. The number of pockets harvested, the number of panicles harvested, the fresh straw weight, the dry straw weight, the weight of the harvested panicles and the grain weight were recorded for the agronomic data.

2.2.5. Data collected

The entomological data were: the number of caterpillars per plant listed for the calculation of the average number of *Spodoptera frugiperda* larvae per plant before and four days after spraying the botanical pesticide and also the determination of the incidence of larval attacks according to the formula: Incidence (I) of CLA attacks

$I = Y^* 100 / X$

Where Y is the number of infested plants observed and X is the total number of plants observed
The agronomic data were: the number of pockets harvested, the number of panicles harvested, the fresh straw weight, the dry straw weight, the straw yield and the grain yield.

2.2.6. Data analysis

For the average number of caterpillars per plant and the average grain yield, the analysis of variance was carried out with the Gensat 15th edition statistical software. The separation of means for the data was done with the Tukey test at the 5% threshold. The agronomic data were analyzed using SPSS edition 16 software at a threshold of 5%.

3. RESULTS

3.1. Effectiveness of neem seed grinding on the population level of S. frugiperda larvae

3.1.1 Variation in the population level of *S. frugiperda* larvae in the treatments

The cumulative data from the test of the years 2021 and 2022 on the variation of the population level proves that all the treatments under protection demonstrated a significantly higher effectiveness of neem seed grind against *Spodoptera frugiperda* larvae with a decrease compared to the treatments of the witness. The statistical analysis revealed no significant difference between the treatments in relation to the variation in the larval population of S. frugiperda before and 4 days after spraying the botanical pesticide. But, it was significant 4 days after spraying in 2021. However, treatments T2 (attack threshold of 20%), T3 (spraying interval of 10 days) and T4 (spraying interval of 15 days) recorded a reduction very significant number of larvae.

Table 1: Effectiveness of crushed neem seeds on the population level of S. frugiperda larvae in the treatments.

	Nombre moyen de larves par plant			
	2021		2022	
Traitements	**1 jour avant pulvérisation**	**4 jours après pulvérisation**	**1 jour avant pulvérisation**	**4 jours après pulvérisation**
T0	0,0235	0,0230	0,0137	0,0081
T1	0,0060	0,0060	-0,0003	0,0058
T2	0,0000	0,0000	0,0057	-0,0002
T3	0,0130	0,0000	0,0042	-0,0002
T4	0,0030	0,0000	0,02	0,00
Moyenne	**0,00910**	**0,00580**	**0,00812**	**0,00341**
Probabilité	**0.162**	**0.016**	**0.347**	**0.088**
CV%	**167.76**	**186.19**	**177.89**	**153.19**
PPDS	**0.02047**	**0.01448**	**0.01913**	**0.007239**
SE±	**0.01527**	**0.01080**	**0.01377**	**0.005213**

3.1.2. Variation in the incidence of attacks by S. frugiperda larvae on sorghum plants in the treatments

The average attack rates of sorghum plants by S. frugiperda larvae increased slightly in the treatments under protection, while they increased in the control plots. T2 treatments in 2021 and T1, T3 and T4 treatments in 2022 showed a stable average incidence. The treatments under protection were effective against the attacks of the larvae of the pest. Statistical analysis revealed a significant difference between the treatments before spraying and 4 days after spraying the botanical pesticide in 2021. However, non-significant differences were recorded between the treatments in 2022.

Table 2: Effectiveness of shredded neem seeds on the variation in the incidence of attacks by S. frugiperda larvae on sorghum plants.

Traitements	Incidence des attaques des larves/plant			
	2021		2022	
	1 jour avant pulvérisation	4 jours après pulvérisation	1 jour avant pulvérisation	4 jours après pulvérisation
T0	60,17	64,5	5,78	6,78
T1	41	43	4,002	4,002
T2	44	44	6,336	9,336
T3	26,33	27	1,335	1,335
T4	37,33	39	4,021	4,021
Moyenne	41,77	43,50	4,2948	5,0948
Signification	0.013	0.006	0.690	0.533
CV%	31.16	29.82	135.20	148.26
PPDS	17.45	17.39	7.785	10.13
SE±	13.01	12.97	5.807	7.554

3.2. Effects of shredded neem seeds on straw and sorghum seed yields in treatments

For average straw yields, the effect of shredded neem seeds was recorded in treatments under protection. Thus, the T4 treatment recorded the highest straw yield of 4410 kg/ha. The highest average grain yield was recorded by the T1 treatment of 1703 kg/ha. For straw yield, the statistical analysis gave no significant difference between the 2021 and 2022 treatments. It was significant in 2021 for grain yield.

Table 3: Effect of shredded neem seeds on straw and grain yields of sorghum

Traitement	Rendement paille			Rendement grains		
	2021	2022	Moyenne	2021	2022	Moyenne
	Poids paille sec	Poids paille sec		Poids grains	Poids grains	
T0	4149	1911	3030	860	957	909
T1	4585	3310	3948	2231	1174	1703
T2	4511	3530	4021	1775	1009	1392
T3	4265	3780	4023	1250	1200	1225
T4	4620	4200	4410	1225	1234	1230
Moyenne	**4426**	**3346,2**	**3886**	**1468,2**	**1114,8**	**1292**
Probabilité	**1.000**	**0.085**		**0.034**	**0.845**	
SE±	**4296**	**1230**		**650.4**	**471.9**	

4. DISCUSSION

4.1. Effectiveness of crushed neem seeds on the population of *S. frugiperda* larvae in sorghum cultivation in Mali

This study has shown the insecticidal property of neem (*Azadirachta indica*) on plants in sorghum plots under station protection by significantly reducing the population of S. frugiperda larvae. The significantly higher reduction of larvae on the treated plots than those of the control showed that the crushed neem seeds control the pests more effectively. The superior efficacy of neem seed extract against pest larvae has been reported and well documented by several researchers and the results of our study were consistent with their findings.

Sané et al., 2018 in Senegal in a cotton pest study reported that neem oil extracts control carpophagous caterpillars (Helicoverpa armigera, Diparopsis watersi and Earias spp) with 75% effectiveness and leaf-eating caterpillars (Anomis flava and Spodoptera littoralis) with 91% efficiency. They noted that 1% azadirachtin controlled the major carpophagous caterpillar, pyrethroid-resistant H. armigera. Looli et al., 2022 in an experiment in the Democratic Republic of Congo (DRC), reported that the effectiveness of extracts from the seeds, leaves and bark of neem applied to the corn field at a concentration of 10 and 20% made it possible to effectively control S. frugiperda by 68.3-82.5% mortality compared to the control of 6.6% mortality. Akhigbe et al., 2021, in a study in Abuja, Nigeria demonstrated the effectiveness of neem extracts in the management of S. frugiperda on maize by recording a low level of the number of larvae per plant of 0.10 ± 0.05 after that of Lambdacyhalothrin of 0.05 ± 0.06 in other plots and compared to the control of 1.35 ± 0.09. kammo et al., 2019 confirmed that neem oil was most effective in reducing the number of larvae by 14.82% on maize. Usanga et al., (2015) obtained the same result during an experiment in Nigeria and found that the application of neem resulted in a greater number of dead pests. Venkat et al., from 2009 to 2011 demonstrated that the use of neem seed extracts at a concentration of 7.5% against the larvae of Sogetella furcufera in rice recorded an average reduction of 49.4% during an experimental study in the Warangal District of Andhra Pradesh (India).

Schmutterer, 1990, found that several constitutions of neem leaves and seeds have insect control potential, due to their relative selectivity. According to Gnago et al., (2010), neem seed extract is more effective than neem leaf extract in controlling insect pests, thanks to its high concentration of Azadirachtin. The work of Koul et al. (2004) demonstrated that Azadirachtin was effective against the survival of different species of noctuids.

The 5% concentration of ground neem seeds used in our plots is lower than that used by other researchers and the same effectiveness was recorded. This observation could be explained that the effectiveness of neem is related to its concentration, the targeted pest and the environment in which the biopesticide is used.

4.2. Variation in the incidence of attacks by *S. frugiperda* larvae on sorghum plants in the treatments

The reduction in the incidence of larval attacks is due to the insecticidal properties of neem. This character possessed by neem (thanks to the active ingredient which is azadirachtin) causes hunger and intoxication in larvae through their feeding on the leaves of the treated host plant which will lead to their death from lack of appetite. Our results are consistent with those obtained by other researchers. Akhigbe et al., 2021, in a study in Abuja, Nigeria to assess the impact of S. frugiperda infestation, reported that neem extracts were effective against attacks on maize plants with incidence of 20.30% ± 1.02 recorded. kammo et al., 2019) confirmed that neem oil was most effective in reducing the incidence by 81.21% on corn. Usanga et al., (2015) in Nigeria, reported that neem application resulted in an 80% reduction in pest attacks and the lowest numbers of damaged leaves were recorded.

Senthil Nathan 2013 found that the methanolic extract of the seeds of Melia azadarach (a meliaceae plant) at 1% led to a reduction in feeding observed in *S. frugiperda* which died from starvation. Breuer and Schmidt, 1995 demonstrated that the reduction in growth was due to the ingestion of toxic substances thus causing starvation to pests. Roy and Saraf, 2006 reported that azadirachtin and its contents have an anti-appetizing effect.

4.3. Effect of shredded neem seeds on straw and sorghum seed yields

During this study, the application of crushed neem seeds made it possible to record a significant yield of straw and sorghum grains. The test plots under protection (T1, T2, T3 and T4) recorded a high average straw yield and a high average sorghum grain yield. Similar results were reported by Tepa-Yotta et al., 2021 who obtained an increase in corn grain yield by using neem seed extracts in the management of S. frugiperda in Benin. Venkat et al., 2009 in 2011 obtained the same conclusion using neem seed extracts against Lepidoptera larvae on rice in India. Abdul Rehman and Soomro (2007), reported an increase in grain yield by using neem seed extracts against pest larvae on rice during work carried out in Nigeria. Thus, the increase in yield recorded in plots treated with crushed neem seeds demonstrates that neem not only serves as a biopesticide, but it also increases soil fertility.

5. CONCLUSION AND OUTLOOK

Although in this experiment it was impossible to completely prevent foliar damage caused by *S. frugiperda* larvae by application of neem seed mash at 5% concentration, it is evident that its use has effectively reduced the attacks of S. frugiperda larvae on the sorghum crop compared to the control. The results obtained largely justify the effectiveness of neem in the management of S. frugiperda and its effect on yield. This is reflected in an increase in sorghum yield performance. The results showed that when crops are carefully protected against pest attacks, their yield increases. Therefore, the use of neem seed grind can be a suitable alternative to chemical pesticides for the control of *S. frugiperda* in sorghum cultivation without disturbing the agroecosystem.

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