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Spodoptera frugiperda (Smith, 1797) (Lepidoptera: Noctuidae) expands its food spectrum in Senegal

Farma Fall Babou, Toffène Diome, Mbacké Sembène
Department of Animal Biology, Cheikh Anta Diop University of Dakar, Senegal

Abstract
The fall armyworm, *Spodoptera frugiperda* is an invasive pest in Africa in 2016 and in Senegal in 2017. This species is very voracious and polyphagous. During its development cycle, the larva can move from one refuge plant to another. Thus, it would be interesting to inventory new host plants of *Spodoptera frugiperda* in Senegal for a better management of the pest. It is in this context that surveys were carried out on crops and spontaneous vegetation inside and outside the fields, in one year, during the rainy and dry seasons in the Groundnut Basin, Casamance and Niayes. A total of 22 host plants divided into 11 families of which the most represented are the Poaceae (50%) were recorded. Among the species, *Zea mays* is the most attacked, followed by *Sorghum bicolor*, *Digitaria horizontalis* and *Capsicum annum* which are accessory hosts. According to the results obtained, *S. frugiperda* preferentially consumes foliage. This study revealed the existence of 4 new host plants inventoried in Senegal, namely *Eragrostis tremula* and *Pennisetum violaceum* in the Groundnut Basin, *Andropogon gayanus* and *Commelina forskalaei* in Casamance. All these species are weeds belonging to the Poaceae family and seem to play a major role in maintaining pest populations. However, species such as *Arachis hypogaea* (Fabaceae) in the Groundnut Basin and Casamance; *Mitracarpus villosus and Spermacoce chaetocephala* (Rubiaceae) in Casamance have been suspected to be hosts of *S. frugiperda* in Senegal. It should be noted that the latter has never been reported.

Keywords: fall armyworm, new host plants, weed, Groundnut basin, casamance, niayes

Introduction
The fall armyworm, *Spodoptera frugiperda* (Smith, 1797) (Lepidoptera: Noctuidae) is a pest native to tropical and subtropical regions of the Americas [25, 37]. It represents the most important noctuid in this continent [15, 37, 38]. The species has recently invaded Africa and was first identified in West and Central Africa in January 2016 [29, 30]. In Senegal, the first records of the species were made in 2017 in different agro-ecological zones : Niayes, Groundnut Basin, Senegal River Valley, Eastern Senegal and Casamance [6, 14].
Spodoptera frugiperda is a very voracious and polyphagous species [7]. Its polyphagy is very characteristic, especially at the individual level where a single caterpillar, during its development cycle, can feed on several different host plants. The fall armyworm attacks both cultivated and non-cultivated plants [15, 37]. Thus, through a literature review conducted by Casmuz *et al*. [15] in North and South America, 186 host plants were found. In 2018, by the same process in addition to additional 8-year surveys carried out in Brazil, 353 host plants were listed [37]. These plants are divided into 76 families of which the most cited are the Poaceae family (106), Asteraceae (31) and Fabaceae (31) [37]. Thus, the Poaceae family is undoubtedly the most damaged. Among these host plants are sorghum (*Sorghum bicolor* L.), rice (*Oryza sativa* L.), sugarcane (*Saccharum officinarum* L.). However, maize (*Zea mays* L.) remains the major host of *S. frugiperda* [15, 16, 37, 48]. It is well known for the damage that caterpillars cause on this crop. In Africa the assessed leaf damage varies between countries and years and can be severe affecting yields strongly [49].
Nevertheless, when food becomes scarce, caterpillars move from refuge plants to others throughout the year [43, 44]. These plants, whether growing spontaneously, as weeds or in established crops, can constitute important reservoirs for the caterpillar, making control difficult. Hence the importance of knowing all these refuge plants in order to develop control methods.
Thus, the present study aims to inventory the new host plants of the invasive pest *Spodoptera frugiperda* present in Senegal.

Material and methods
Presentation of the study site
In agro-ecological terms, Senegal is mainly subdivided into six zones: the Groundnut Basin, Casamance, Niayes, Eastern Senegal, the Senegal River Valley and the Sylvo-pastoral Zone [9, 22]. This study focused on three areas, namely the Groundnut Basin, Casamance and the Niayes area. The coordinates were taken using a Global Positioning System (GPS) device.

- Groundnut Basin: a distinction is made between the Northern Groundnut Basin and the Southern Groundnut Basin [9]. This zone includes the regions of Diourbel, Thiès, Kaolack, Fatick and Louga. The climate is Sudan-Sahel (hot and dry). The average annual temperature is between 27°C and 29°C and rainfall between 400 and 500 mm [5]. It is the main source of water for agricultural activities. The three main soil types found in this area are: leached tropical ferruginous soils with sandy characteristics (70%), hydromorphic clay soils (10%) and sandy-clay soils (20%) [20]. In the Groundnut Basin, 80% of the land is devoted to food crops (millet, sorghum, maize, cowpea) and cash crops (groundnut). However, groundnut and millet are the predominant crops [39]).
- Casamance is located in the south of the country. It is made up of three sub-zones: Upper Casamance (Kolda) in the upper reaches and on the borders of Eastern Senegal, Middle Casamance (Sédhiou) corresponding to the middle reaches of the river, and Lower Casamance (Ziguinchor), a zone of mangroves and multiple swamps adjacent to the Atlantic Ocean [45]. Different types of soil can be found here: hydromorphic, sandy, silty-sandy and sandy-silty [47]. The climate in this area is Sudano-Guinean to Guinean [13]. The lowest average monthly temperatures are recorded between December and January and vary from 25 to 30° C, the highest between March and September with variations of 30 to 40° C [4]. It is the rainiest area in the country with a rainfall that can exceed 1000 millimetres per year [9, 21, 47]. Due to this relatively good rainfall, the presence of the river and the diversity of soils, the natural region of Casamance is favourable to the development of fruit trees, food crops (millet, maize and especially rice) and cash crops (groundnuts, cotton) [9, 21, 31, 35, 45, 47].
- The Niayes area is a narrow coastal strip in the northwest, about 10 km wide [9, 24]. It is located between Dakar and Saint Louis. It is an area with a high concentration of the national population. It is characterised by a sub-canary climate, shallow water tables and intensive peri-urban agriculture [24]. It is a very favourable area for horticulture [17]. It provides more than 80% of the national vegetable production [17, 24]. The production systems are very diversified in terms of size and species. In the vegetable sector in particular, this diversification ranges from small traditional farms to very modern industrial farms [24].

In Senegal, rainfall divides the year into two cropping seasons: the rainy season (June to October) and the dry season (November to May). The length of the rainy season varies from one year to the next and also from one site to the next [46].

Sampling

The search for host plants was carried out on *Spodoptera frugiperda* larvae. The collection was done in one year and successively in dry and rainy periods. During each period the inventory concerned both rainfed and market garden crops in the study areas. In the fields, the observation was done randomly and all aerial parts of the plant were considered. Spontaneous vegetation inside and outside the crop plots as well as roadside vegetation was also surveyed in order to find hosts among this vegetation where *S. frugiperda* could remain active during periods when it was not infesting its cultivated hosts [41].

A survey was carried out on the sowing dates of the different crops on the plots in order to have a representative distribution of sowing dates used by the farmers.

Periods of observation

Search for larval populations of *Spodoptera frugiperda* during the dry period.

The larval population of *S. frugiperda* was searched during this period from December 2020 to May 2021. The observation was done 6 times on 1 month intervals. The crops were mostly vegetables. Weeds in and around the fields were also observed. In each agro-ecological zone, different crops were surveyed:

- Groundnut Basin : maize, Guinea sorrel, cassava and watermelon.
- Casamance : cabbage, sweet aubergine, African aubergine, pepper, chilli, lettuce, tomato, turnip, carrot, okra, cucumber, potato, parsley, leek, basil, celery, Guinea sorrel, spinach and maize;
- Niayes zone : cabbage, sweet aubergine, African aubergine, pepper, chilli, lettuce, tomato, turnip, carrot, bean, okra, cucumber, potato, parsley, leek, basil, lemon grass, celery, thyme, Guinea sorrel, cassava and maize.

Searching for larval populations during the rainy season

Sampling was carried out in three stages during this period, between the end of July and the end of November 2021:

- at the end of July-beginning of August: when vegetation starts to appear with the arrival of the rains, with the first herbaceous species and the emergence of some seedlings.
- in early September-mid-September with the emergence of almost all cultivated plants, vegetative development, fruiting and/or the beginning of ripening of certain crops,
- in late October- late November, which corresponds to the fruiting, ripening and/or harvesting of seasonal crops. After harvesting, only spontaneous vegetation persists for some time.

The crops in the different study areas were surveyed in addition to the weeds growing in and around the fields. The crops were mainly field crops or cash crops.

- Groundnut Basin : maize, millet, groundnuts, cowpeas, squash and Guinea sorrel;
- Casamance: maize, millet, groundnuts, cowpeas, sorghum, fonio, rice, okra, bitter aubergine, sweet aubergine, cucumber, Guinea sorrel and songe or violet arouille;
- Niayes areas : maize, millet, cabbage, onion, green onion, parsley, beetroot, basil, sweet potato, pumpkin and Guinea sorrel.

Identification of caterpillars

In the fields, the observation was done randomly and all aerial parts of the plant were considered. Caterpillars found on the plants were identified with the naked eye or
with a hand lens according to the identification key of [23]. Young caterpillars that were difficult or impossible to identify in the field were placed in Petri dishes, brought back to the Genomics laboratory and reared to a stage that allowed clear identification of the species.

Identification of host plants

Plants on which *S. frugiperda* was present were considered as hosts. Plants showing damage likely to be that of *S. frugiperda* and where armyworm was present on plants in their vicinity, were considered as suspected host plants. Also on a plant where the species is present, all parts showing damage were considered as consumed. Thus these plants were put in a press, brought back to the Dakar herbarium where the identification was made. The floras of [11] ; [32] were used to identify the plant species.
The nomenclature used was that of Lebrun & Stork [33].
Synonymous names were also checked.

Calculated parameter: Frequency of occurrence or Constancy

The frequency of occurrence is the ratio between the number of records where species i is present and the total number of records multiplied by 100 [18, 19].

Fo% = Pi/P*100

Pi: number of surveys where species i is present;
P: total number of surveys
According to Dajoz [18 ;19], depending on the values of Fo, we have several categories of species:
Rare species if Fo < 5%.
Accidental species if 5% < Fo < 25%.
Incidental species if 25% < Fo < 50%.
Regular species if 50% < Fo < 75%
Constant species if 75% < Fo < 100
Ubiquitous species if Fo = 100%.

Results

Host plants of S. frugiperda according to families

During the inventory a total of 22 host plants of *S. frugiperda* belonging to 11 plant families were identified. These are mainly Poaceae which are in the majority with 50% of the host plants encountered, Aizoaceae (4.5%), Alliaceae (4.5%), Amaranthaceae (4.5%), Asteraceae (4.5%), Brassicaceae (4.5%), Commelinaceae (9%), Convolvulaceae (4.5%), Fabaceae, Portulacacea (4.5%) and Solanaceae (4.5%).

Table 1: List of host plants surveyed with the presence of *Spodoptera frugiperda*

Families	Species
Aizoaceae	*Trianthema portulacastrum* L., 1753
Alliaceae	*Allium fistulosum* L., 1753
Amaranthaceae	*Amaranthus viridis* L., 1753
Asteraceae	*Lactuca sativa* L., 1753
Brassicaceae	*Brassica oleracea* var. *capitata* L., 1753
Commelinaceae	*Commelina benghalensis* L., 1753
	Commelina forskalaei Vahl, 1805
convolvulaceae	*Ipomoea batatas*
Fabaceae	*Phaseolus vulgaris* L., 1753
Poaceae	*Andropogon gayanus* L., 1753
	Dactyloctenium aegyptium L., 1753
	Digitaria horizontalis Willd., 1809
	Echinochloa colona (L.) Link, 1833
	Eleusine indica (L.) Gaertn, 1788
	Eragrostis tremula Hochst. ex Steud. 1854
	Oryza sativa L., 1753

	Pennisetum glaucum (L.) R. Br., 1810
	Pennisetum violaceum (Lam.) Rich., 1805
	Sorghum bicolor (L.) Moench, 1794
	Zea mays L., 1753
Portulacaceae	*Portulaca oleracea* L., 1753
Solanaceae	*Capsicum annuum* L., 1753

Frequency of occurrence of host plants and their attacked parts

The calculated frequency of occurrence shows that the host plant most attacked by *S. frugiperda* is maize, *Zea may* (constant) (Table II). Species such as *C. annum*, *D. horizontalis* and *S. bicolor* are incidental hosts while all other remaining species are incidentally attacked (*Amaranthus viridis*, *Lactuca sativa*, *Trianthema portulacastrum*, *Eleusine indica*, *Pennisetum glaucum*, *Echinochloa colona*, *Allium fistulosum*, *Phaseolus vulgaris*, *Pennisetum violaceum*, *Eragrostis tremula*, *Brassica oleracea var. capitata*, *Andropogon gayanus*, *Commelina benghalensis*, *Commelina forskaolii*, *Ipomoea batatas*, *Oryza sativa*, *Portulaca oleracea and Dactyloctenium aegyptium).*

For all host species the most consumed part of the plant is the foliage with the exception of *Dactyloctenium aegyptium* (inflorescences) and *Z. mays* (inflorescences and fruits) where in addition to the foliage other parts are also attacked.

Table 2: Frequency of occurrence of *Spodoptera frugiperda* host plants and plant parts attacked

Species	References	Frequency of occurrence	Parts consumed
Trianthema portulacastrum	[37]	accidental	Leaf
Allium fistulosum	[37]	accidental	Leaf
Amaranthus viridis	[15, 37]	accidental	Leaf
Lactuca sativa	[2, 3, 15, 37]	accidental	Leaf
Brassica oleracea var. *capitata*	[2, 3, 12, 15, 34, 37]	accidental	Fruit
Commelina forskaolii	New record	accidental	Leaf
Commelina benghalensis	[15, 37]	accidental	Leaf
Ipomoea batatas	[15, 37]	accidental	Leaf
Phaseolus vulgaris	[15, 37]	accidental	Leaf
Andropogon gayanus	New record	accidental	Leaf
Dactyloctenium aegyptium	[15, 34, 37]	accidental	Leaf, inflorescence
Digitaria horizontalis	[37]	accidental	Leaf
Echinochloa colona	[15, 37, 50]	accidental	Leaf
Eleusine indica	[3, 37]	accidental	Leaf
Eragrostis tremula	New record	accidental	Leaf
Oryza sativa	[3, 34, 37]	accidental	Leaf
Pennisetum glaucum	[15, 26, 34, 37]	accidental	Leaf
Pennisetum violaceum	New record	accidental	Leaf
Sorghum bicolor	[3, 15, 34, 37]	accessory	Leaf
Zea mays	[3, 34, 37]	constant	Leaf, inflorescence fruit
Portulaca oleracea	[15, 34, 37]	accidental	Leaf
Capsicum annuum	[15, 37]	accessory	Leaf

New host plants of *Spodoptera frugiperda*

The inventory carried out allowed to record 4 new host plants of *S. frugiperda* (Table III) namely: *Andropogon gayanus* (Poaceae) and *Commelina forskaolii* (Commelinaceae) found in Casamance, *Eragrostis tremula* (Poaceae) and *Pennisetum violaceum* (Poaceae) recorded in the Groundnut Basin. These species are weeds associated with the *Zea mays* crop.

Table 3: List of new host plants of *Spodoptera frugiperda*

Agro-ecological zones	Type of plant	Families	Species	GPS coordinates (x ; y)
Groundnut Basin	Weed	Poaceae	*Eragrostis tremula*	(437871.3014 ; 1558596.4345)
			Pennisetum violaceum	(437713.7814 ; 1558632.2129)
Casamance	Weed	Poaceae	*Andropogon gayanus*	(600066.3736 ; 1449434.7850)
		Commelinaceae	*Commelina forskalaei*	(435937.4953 ; 1422038.2910)

Fig 1: Causualties of *Spodoptera frugiperda* on new host plants (a : *Eragrostis tremula* ; b : *Pennisetum violaceum*, c : *Andropogon gayanus* ; d : *Commelina forskalaei*;
: damage; :individual of *S. frugiperda*)

Host plants with damage by *Spodoptera frugiperda*

Table IV shows the result of the plants showing damage by the armyworm without the presence of the armyworm on the plant. A number of 3 host plants belonging to 2 families were suspected: *Arachis hypogaea* (Fabaceae) in the Groundnut Basin and Casamance*; Mitracarpus villosus* and *Spermacoce chaetocephala* (Rubiaceae) in Casamance. However, the latter has never been reported.

Table 4: List of supposed host plants of *Spodoptera frugiperda*

Agro-ecological zones	Families	Species	References
Groundnut Basin, Casamance	Fabaceae	*Arachis hypogaea*	[37]
Casamance	Rubiaceae	*Mitracarpus villosus*	[37]
Casamance		*Spermacoce chaetocephala*	Not reported

Discussion

The study conducted in the Groundnut Basin, Casamance and Niayes with the aim of inventorying new host plants of *Spodoptera frugiperda*, revealed the existence of 22 host plants divided into 11 families. Among these families the most represented is the Poaceae. Indeed, *S. frugiperda* is a very polyphagous species [7, 29]. According to Casmuz *et al*. [15] and Montezano *et al*. [37], it prefers to attack species belonging to the Poaceae family.

The calculated frequency of occurrence shows that except for Z. *mays* which is constantly attacked, C. *annum*, D. *horizontalis* and *S. bicolor* which are accessory hosts for the fall armyworm, the others are attacked accidentally. This would be explained by the fact that *Z. mays* is one of the first and is the main host of the pest ravageur [16, 34, 48]. Being polyphagous as well, the other plants attacked less frequently, can be explained by the oviposition behaviour of the female but also by the movement of the larvae. Females lay a mass of up to 200 eggs on a plant or leaf usually [43]. Upon hatching, the young larvae move to other plants in search of food and to avoid intra-specific competition, hence cannibalism [1, 10]. It should be noted that a single *Spodoptera frugiperda* caterpillar can move from one plant to another and generally colonise those that are closer to their original plant [28, 40]. Therefore, it can colonise a plant belonging to the same species as the original one or a different species. For all the plants inventoried their leaves were attacked. This confirms the work of Babou [6] and Garba *et al*. [27]

who show that caterpillars attack plants from emergence onwards and that the damage is very characteristic on the leaves. According to the same authors, the inflorescence and the fruit can be furrowed.

Of the 22 host plants recorded, 4 are new hosts of *Spodoptera frugiperda.* These are : *Andropogon gayanus*, *Commelina forskalaei*, *Eragrostis tremula and Pennisetum violaceum.* All these plants are from the Poaceae family and are all weeds associated with the *Z. mays* crop. Our results confirm those of Portillo *et al*. [42] which show that under certain conditions the species can show a clear preference for non-crop hosts. The presence of Poaceae as new host plants could on the one hand be explained by the preference of the pest to hosts belonging to this family [15, 37]. It could also be due to the availability of these species for the armyworm. Indeed, while moving, it falls on nearby plant species [28, 40], thus on the maize weed flora where Poaceae are more represented, i.e. more than 20% according to Bassene [8] and Noba *et al*. [39]. These same authors in addition to Diatta *et al*. [20] confirm the dominance of Poaceae such as *Andropogon gayanus*, *Commelina forskalaei*, *Eragrostis tremula* and *Pennisetum violaceum* on herbaceous vegetation in Senegal.

On the other hand, the invasion of the species being a new phenomenon in Senegal, its installation has certainly been accompanied by adaptability and behavioural change [6]. Our results corroborate those of Montezano *et al*. [37] who, in 8 years of surveys in Brazil, were able to record 82 new host plants increasing the number of hosts to 353. This shows the capacity of the species to expand its hosts. However, the absence of new host plants in the Niayes would probably be related to the orientation of the species towards other plants already reported as hosts of the fall armyworm.

Conclusion

At the end of this study whose objective was to inventory new host plants of the invasive pest *Spodoptera frugiperda* present in Senegal, 22 host plants divided into 11 families were recorded. The main families are the Poaceae which are more attacked, the Aizoaceae, the Alliaceae, the Amaranthaceae, the Asteraceae, the Brassicaceae, the Commelinaceae, Convolvulaceae, Fabaceae, Portulacacea and Solanaceae. The species *Andropogon gayanus*, *Commelina forskalaei*, *Eragrostis tremula* and *Pennisetum violaceum* were recorded as new hosts of the invasive pest. These species show the preference of *S. frugiperda* for species of the Poaceae family. The study also revealed that weeds can constitute important reservoirs for the armyworm. Thus, thanks to these weeds and other cultivated plants, the caterpillar maintains its population at times when its main hosts are not available. It would therefore be interesting to deepen this research by including other agro-ecological zones of the country and over a larger number of years.

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References

1. Andow DA, Farias JR, Horikoshi RJ, Bernardi D, Nascimento ARB, Omoto C. Dynamics of cannibalism in equal-aged cohorts of *Spodoptera frugiperda*. Ecological Entomology,2015:40(3):229–236.
2. Andrews KL. The Whorlworm, *Spodoptera frugiperda*, in Central America and Neighboring Areas. The Florida Entomologist,1980:63(4):456.
3. Andrews KL. Latin American Research on *Spodoptera frugiperda* (Lepidoptera: Noctuidae). The Florida Entomologist,1988:71(4):630.
4. ANSD. *Situation économique et sociale régionale*. ANSD-SRSD, Kolda/Sénégal, 2015, 16.
5. Ba K, Tine E, Destain J, Cissé N, Thonart P. Étude comparative des composés phénoliques, du pouvoir antioxydant de différentes variétés de sorgho sénégalais et des enzymes amylolytiques de leur malt. BASE,2010:14(1):131–139.
6. Babou FF. *Evaluation de l'efficacité de biopesticides sur le ravageur invasif, Spodoptera frugiperda (J.E. Smith) (Lepidoptera : Noctuidae) sur le maïs (Zea mays L.) en Haute Casamance*. Mémoire No. 503. Université Cheikh Anta Diop de Dakar, Faculté des Sciences et Techniques, 2018, 33.
7. Barcelos LM, Fernandes FO, Lopes C, Emygdio BM, Valgas R, Carvalho IF de, Rosa APSA da. Biology and Nutritional Indexes of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in Saccharine Sorghum. Journal of Agricultural Science,2019:11(4):126.
8. Bassene C. *La flore adventice dans les cultures de maïs (Zea mays L.) dans le Sud du Bassin Arachidier : structure, nuisibilité et mise au point d'un itinéraire de désherbage*. Thèse de doctorat, Sénégal: Université Cheikh Anta Diop de Dakar, 2014, 150.
9. Benoit G, Cazaubon J-L, Brayer-Mankor J, Tran M. *Accompagnement du Sénégal dans sa réflexion sur la création de Chambres d'agriculture et le développement agricole et rural*. No. 16101. CGAAER, Sénégal, 2017, 34.
10. Bentivenha JP, Montezano DG, Hunt TE, Baldin EL, Peterson JA, Victor VS, Pannuti LE, Vélez AM, Paula-Moraes SV. Intraguild interactions and behavior of *Spodoptera frugiperda* and *Helicoverpa* spp. on maize. Pest Management Science,2017:73(11):2244–2251.
11. Berhaut J. *Flore du Sénégal.*, (2nd edition). Dakar: Clairafrique,1967, 485.
12. Biezanko CM, Ruffinelli A, Link D. Plantas y otras sustancias alimenticias de las orugas de los Lepidopteros Uruguayos. Revista do Centro de Ciências Rurais,1974:4(2).

13. Bonfiglioli A. *Developpement local, institutions et changement climatique au Senegal : Analyse de la situation et recommandations opérationnelle*. Banque Mondiale, Sénégal, 2010, 80.
14. Brevault T, Ndiaye A, Badiane D, Bal AB, Sembene M, Silvie P, Haran J. First records of the fall armyworm, *Spodoptera frugiperda* (Lepidoptera, Noctuidae), in Senegal. Entomologia Generalis,2018:37(2):129–142.
15. Casmuz A, Juárez ML, Socías MG, Murúa MG, Prieto S, Medina S, Willink E, Gastaminza G. Revisión de los hospederos del gusano cogollero del maíz, *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Revista de la Sociedad Entomológica Argentina,2010:69(3–4):209–231.
16. Chormule, A, Shejawal N, Sharanabasappa, Kalleshwaraswamy C, Asokan R, Mahadeva Swamy H. First report of the fall Armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera, Noctuidae) on sugarcane and other crops from Maharashtra, India. Journal of Entomology and Zoology Studies,2019:7(1):114–117.
17. Cissé I, Tandia AA, Fall ST, Diop EHS. Usage incontrôlé des pesticides en agriculture périurbaine : cas de la zone des Niayes au Sénégal. Cahiers Agricultures,2003:12(3):181-186.
18. Dajoz R. *Précis d'écologie*. 560. Paris: Dunod université,1985, 560.
19. Dajoz R. *Précis d'écologie, (8th edition)*. Paris: Dunod, 2006, 640.
20. Diatta AA, Ndour N, Manga A, Sambou B, Faye CS, Diatta L, Goudiaby A, Mbow C, Dieng SD. Services ecosystémiques du parc agroforestier à Cordyla pinnata (Lepr. ex A. Rich.) Milne-Redh. dans le Sud du Bassin Arachidier (Sénégal). International Journal of Biological and Chemical Sciences,2016:10(6):2511–2525.
21. Diedhiou I, Mering C. D'une rive à l'autre du fleuve : changements d'occupation du sol et dires d'acteurs en Basse-Casamance. LEspace geographique,2019:48(2):117–137.
22. Dione A, Sarr O, Ngom S, Diallo A, Guisse A. Perceptions pastorales des ligneux fourragers par les agropasteurs et les transhumants au centre du Sénégal Pastoral perceptions of fodder ligneous by agro-pastoralists and transhumants in central Senegal. International Journal of Biological and Chemical Sciences,2020:14:772–787.
23. EPPO. PM 7/124 (1) Spodoptera littoralis, Spodoptera litura, *Spodoptera frugiperda*, Spodoptera eridania. EPPO Bulletin,2015:45(3):410–444.
24. Fall AA, Lo M. *Etude de référence sur les céréales : mil, sorgho, maïs et fonio au Sénégal*. CORAF/WECARD, Sénégal, 2009, 138.
25. FAO. *Gestion intégrée de la chenille légionnaire d'automne sur le maïs: Un guide pour les champs-écoles des producteurs en Afrique*. FAO, Rome, 2018, 135.
26. Favetti B, Braga-Santos T, Massarolli A, Specht A, Butnariu A. Pearl Millet: A Green Bridge for Lepidopteran Pests. Journal of Agricultural Science,2017:9(6):92-97.
27. Garba M, Adamou H, Bibata A, Aïssa K, Patrick Delmas P, Salissou O. *La chenille légionnaire du maïs Spodoptera frugiperda*. RECA, Niger, 2017, 4.
28. Garcia AG, Malaquias JB, Ferreira CP, Tomé MP, Weber ID, Godoy WAC. Ecological Modelling of Insect Movement in Cropping Systems. Neotropical Entomology,2021:50(3):321–334.
29. Goergen G, Kumar PL, Sankung SB, Togola A, Tamò M. First Report of Outbreaks of the Fall Armyworm *Spodoptera frugiperda* (J E Smith) (Lepidoptera, Noctuidae), a New Alien Invasive Pest in West and Central Africa. PLOS ONE,2016:11(10):1–9.
30. Jacobs A, Van VA, Rong IH. Characterisation of the fall armyworm (*Spodoptera frugiperda* J.E. Smith) (Lepidoptera: Noctuidae) from South Africa. African Entomology,2018:26(1):45–49.
31. Konta IS, Djiba S, Sane S, Diassi L, Ndiaye AB, Noba K. Etude de la dynamique de *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae) dans les vergers de mangues en Basse Casamance : influence des facteurs climatiques. International Journal of Biological and Chemical Sciences,2016:9(6):2698–2715.
32. Le Bourgeois T, Merlier H. *Adventrop: les adventices d'Afrique soudano-sahelienne*. CIRAD-CA, Montpellier, 1995, 637.
33. Lebrun JP, Stork A. *Enumération des plantes à fleurs d'Afrique Tropicale*, (Edition des conservations et jardin botanique de la ville de Genève), 1997.
34. Luginbill P. *The Fall Army Worm*. U.S. Department of Agriculture, 1928, 100.
35. Manzelli M, Fiorillo E, Bacci M, Tarchiani V. Lowland rice production in southern Senegal (Middle Casamance): challenges and prospects for sustaining their restoration and development. Cahiers Agricultures,2015:24(5):301–312.
36. Merlier H, Montegut J. *Adventices tropicales*. ORSTOM-GERDAT-ENSH, 1982, 490.
37. Montezano DG, Specht A, Sosa-Gómez DR, Roque-Specht VF, Sousa-Silva JC, Paula-Moraes SV, Peterson JA, Hunt TE. Host Plants of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in the Americas. African Entomology,2018:26(2):286–300.
38. Murúa G, Molina-Ochoa J, Coviella C. Population dynamics of the fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae) and its parasitoids in northwestern Argentina. Florida Entomologist,2006:89(2):175–182.
39. Noba K, Ba AT, Caussanel J-P, Mbaye MS, Barralis G. Flore adventice des cultures vivrières dans le sud du Bassin arachidier (Sénégal). Webbia,2004:59(2):293–308.

40. Pannuti LER, Paula-Moraes SV, Hunt TE, Baldin ELL, Dana L, Malaquias JV. Plant-to-Plant Movement of *Striacosta albicosta* (Lepidoptera: Noctuidae) and *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in Maize (Zea mays). Journal of Economic Entomology,2016:109(3):1125–1131.
41. Portakaldalı M, Oztemiz S, Kütük H. A New Host Plant for Tuta absoluta (Meyrick) (Lepidoptera: Gelechiidae) in Turkey. Journal of Entomological Science,2013:15:21–24.
42. Portillo H, Pitre H, Meckenstock D, Andrews K. Feeding Preferences of Neonates and Late Instar Larvae of a Lepidopterous Pest Complex (Lepidoptera: Noctuidae) on Sorghum, Maize, and Noncrop Vegetation in Honduras. Environmental Entomology,1996:25(3):589–598.
43. Prasanna BM, Huesing JE, Eddy R, Peschke VM. Fall Armyworm in Africa: a guide for integrated pest management. No. First Edition. Feed The Future, Mexico, 2018, 106.
44. Ramirez-Cabral NYZ, Kumar L, Shabani F. Future climate scenarios project a decrease in the risk of fall armyworm outbreaks. The Journal of Agricultural Science,2017:155(8):1219–1238.
45. Sané T. *Vulnérabilité et adaptabilité des systèmes agraires à la variabilité climatique et aux changements sociaux en Basse-Casamance (Sud-Ouest du Sénégal)*. Géographie: Université Sorbonne Paris Cité,2017, 376.
46. Sané T, Diop M, Sagna P. Étude de la qualité de la saison pluvieuse en Haute-Casamance (Sud Sénégal). Sécheresse,2008:19(1):23–28.
47. Sané T, Mering C, Cormier-Salem M-C, Diedhiou I, Ba BD, Diaw AT, Tine AK. Permanences et mutations dans les terroirs rizicoles de Basse-Casamance (Sénégal). LEspace geographique,2018:47(3):201–218.
48. Sisay B, Simiyu J, Malusi P, Likhayo P, Mendesil E, Elibariki N, *et al*. First report of the fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidae), natural enemies from Africa. Journal of Applied Entomology,2018:142(8):800–804.
49. Sisay B, Simiyu J, Mendesil E, Likhayo P, Ayalew G, Mohamed S, *et al*. Fall Armyworm, *Spodoptera frugiperda* Infestations in East Africa: Assessment of Damage and Parasitism. Insects,2019:10(7):195.
50. Zhang B-C. *Index of economically important Lepidoptera*. Wallingford : CABI, 1994, 599.