Identification of alternative weed hosts of the fall armyworm (*Spodoptera frugiperda* J.E. Smith) in maize crops at several infestation sites in Yamoussoukro, Central Côte d'Ivoire

Kouamé Kra F.[1], Mangara Ali[2], Baka Yapi Richmond[3,] Touré-Déruoth Alassane Ismaël [2]
[1]*Research Manager, National Center for Floristics (C.N.F.), University of Félix Houphouët-Boigny, 22 Po Box 582 Abidjan 22 Côte d'Ivoire*
[2]*Research Professor, Botany and Plant Diversity Development Laboratory (LaBVDiV), Department of Biology, University Nangui Abrogoua - Abidjan (Côte d'Ivoire) 02 Po Box 801 Abidjan 02*
[3] *Laboratory «Natural Environments and Biodiversity Conservation , Université Félix Houphouët-Boigny, Biosciences Department, Abidjan, Côte d'Ivoire.*
Corresponding author: Kouamé Kra Frédéric. Email : fredykouame@yahoo.fr

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1 SUMMARY

Maize is an important cereal crop in Côte d'Ivoire but its production has serious constraints, like invasion of the fall armyworm, *Spodoptera frugiperda*. This caterpillar is hosted by spontaneous plants growing in and around maize crops. The aim of this study was to identify alternative host plants for the fall armyworm, *Spodoptera frugiperda* of maize in infestation sites in Yamoussoukro, Côte d'Ivoire. Sampling was carried out in 15 plantations in different parts of the city. The inventory method used was the "tour de champ", which is a floristic inventory technique making it possible to identify the different species in a plot as exhaustively as possible by covering the basic surface unit in different directions. At the end of this study, the results revealed that there are indeed alternative hosts of the armyworm that contribute to the infestation of maize crops. It identified 69 plant species belonging to 53 genera and 17 families. The species most heavily attacked by the armyworm were *Amaranthus spinosus* (Amaranthaceae), *Croton hirtus* (Euphorbiaceae), *Brachiaria lata* (Poaceae), *Panicum maximum* (Poaceae) and *Rottboellia cochinchinensis* (Poaceae). The impact of the armyworm is that it affects the development of maize plants, resulting in lower yields. The presence in the field of a wide variety of alternative hosts amplifies this scourge. The results obtained provide information on various aspects that favour invasion, in particular the presence of grassy species in and around maize crops. This main aspect should be taken into account when selecting control methods.

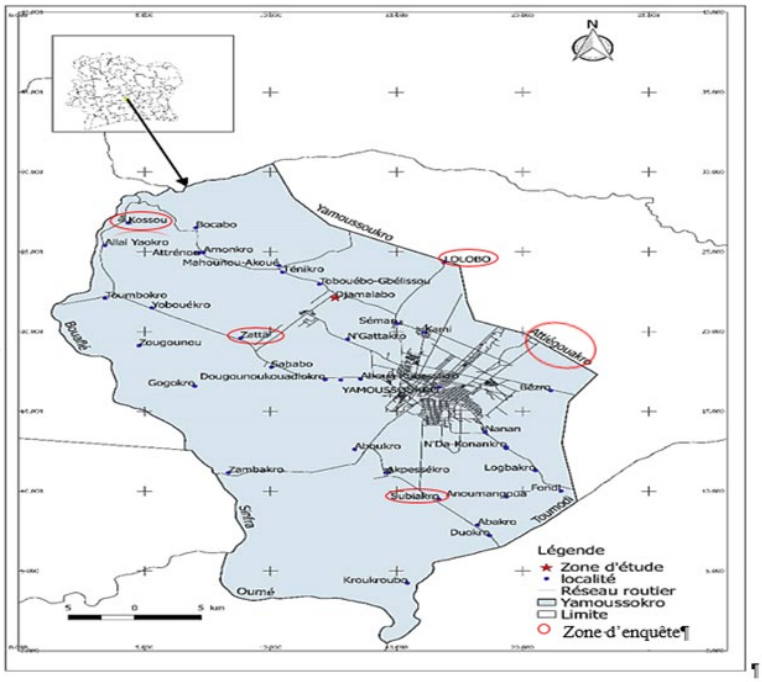
2 INTRODUCTION

Maize (*Zea mays* L.) is one of the world's most widely grown cereals, either for human consumption and livestock (cattle, poultry), or for the manufacture of certain agro-industrial and pharmaceutical products (CIRAD and GRET, 2002). In Côte d'Ivoire, maize is one of the most important crops, providing food for many communities (CNRA, 2024). National maize production in 2021 will be around 1,140,000 tonnes (CNRA, 2024). However, production remains insufficient, hence the need to import this commodity (Taondyande *et al.,*2011). Producers face several difficulties, notably the effect of weeds, granivorous birds

and insect pests. According to FAO (2018), the impact of weeds and insect pests generate yield losses estimated at over 75% in maize cultivation. Indeed, the upright structure and spacing of this plant's seedlings favour the proliferation of weeds. As far as insect pests are concerned, corn growers are faced with the invasion of a formidable pest known as the fall armyworm (*Spodoptera frugiperda* J.E. Smith), native to tropical and subtropical regions of the Americas. According to the FAO (2018), this pest, which is a polyphagous insect, is considered extremely dangerous in maize cultivation. It feeds on leaves and stems of over 80 plant species belonging to 27 families (CABI, 2017), with a preference for maize (Prasanna *et al.,*2018). This caterpillar can travel up to over 100 km per night, and lays eggs generally on the underside of leaves. These hatch into larvae that feed on plant organs. High infestations can lead to significant yield losses, in the order of 8.3 to 20.6 million tonnes of maize each year in Africa (Day *et al.,*2017). It was first reported there in early 2016, specifically in Nigeria, Sao Tomé, Benin and Togo (Germain *et al.,*2017). In Côte d'Ivoire, the first suspicions about its presence appeared from October 2016, when maize growers reported the invasion of their respective crops, by a certain caterpillar of which they had no knowledge. Following morphological and biological observations, field surveys confirmed its presence for the first time in crops in 2017 (NATESC, 2019). In addition to corn, the armyworm devours several other plant species, including herbaceous plants. The latter can be potential hosts for these crop pests (Nageleisen *et al.,*2002). In this context, the aim of the present study is to identify the accompanying flora, particularly those likely to be hosts or habitats of the armyworm in the Yamoussoukro district of Côte d'Ivoire. This is with a view to preventive and curative control in maize crops.

3 MATERIALS AND METHODS

3.1 Study area : The present study was carried out in central Côte d'Ivoire, in the Yamoussoukro district, 248 km from Abidjan (Figure 1). The climate in this area is equatorial (Brou *et al.,*2005). It is characterized by two rainy seasons (March-June and September-October) and two dry seasons (November-February and July-August). The average temperature is around 26 °C and rainfall varies from 1,200 to 1,600 mm/year (BNETD, 2001). The plant landscape is that of a pre-forest transition zone between forest and savannah (Krogba *et al.,*2016). This District is traversed by a dense hydrographic network including the Bandama River and its tributaries, the Marahoué and the N'Zi (BNETD, 2001). The soil in this area is ferralitic and humus-bearing (Gnago *et al.,*2017).



Picture 1: Location of study areas

3.2 METHODS

3.2.1 Data collection: Data collection took place in fifteen maize fields. It consisted in inventorying all potential weed hosts of the armyworm in the maize fields. The basic area unit chosen for the inventory was 1/4 ha for all crops sampled. The inventory method used was the "tour de champ" method, which has been used by many authors (Lebreton and Le Bourgeois, 2005; Touré, 2009, Baka, 2015). Field tour is a floristic inventory technique that allows us to identify the different species in a plot as exhaustively as possible by covering the basic surface unit in different directions (Chicouène, 2000).

3.2.2 Data analysis: In this study, two types of analysis were used to characterize the weed flora : a qualitative study and a quantitative study.

3.2.2.1 Qualitative flora study: This study made it possible to establish the floristic richness of the plots surveyed and the diversity of weeds found. It also enabled us to distinguish the different phytogeographical origins of the species studied. Chorological affinities of the different species were determined using chronological subdivisions for Africa (Saadou, 1990). The following phytogeographical types were selected: Guinean-Congolese-Sudanese-Zambesian (GC-SZ) species; Sudanese-Zambesian (SZ) species; Guinean-Congolese (GC) species; and introduced species (i).

3.2.2.2 Quantitative flora study: This study focuses on the frequencies and specific contribution of the alternative hosts of the armyworm.

- Frequency is a measure of the regularity of a species' distribution in a plant community. Absolute and relative frequencies are distinguished. The absolute or specific frequency (Fa) of a species is the number of times it has been encountered in a number of surveys (N) constituting a sampling. The relative frequency (Fr) of a plant species is calculated using the following formula:

$$Fr = Fa / N$$

Fa : Absolute frequency
N : Number of elementary samples

- The specific contribution (CsF) highlights the amplitude of a species' dynamics and aggressiveness in a phytocenosis. This contribution, expressed as a percentage, is defined as the ratio between the specific frequency (FS(e)) and the sum of the specific frequencies (∑ (FS(e)) of all species recorded during sampling (Daget and Poissonet, 1969). It was obtained using the following formula :

$$CsF = FS(e) / \sum (FS(e)) \times 100$$

∑ (FS(e)) : sum of the absolute frequencies of all species recorded during sampling at plantation level ; Fs(e): absolute frequency of the species considered.

According to Daget and Poissonet (1969), a species whose specific contribution is less than 1% is called a minor weed, where its depressive effect on plants is more or less negligible. On the other hand, any species with a specific contribution of between 1 % and 4 % is called a potential weed (Daget and Poissonet, 1969). In this case, the depressive effect of weeds on plants is relatively high, and weeds are said to be aggressive. Above 4 %, the species is said to be a major weed, with a particularly high depressive effect on other species. It is therefore considered very aggressive towards plants.

4. RESULTS

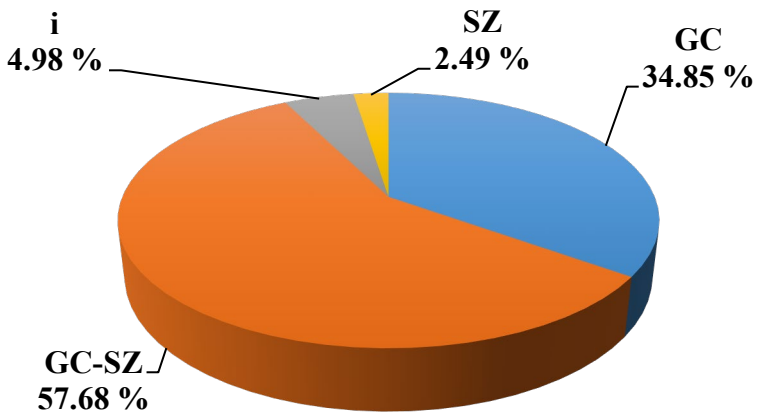
4.1 Characterization of weed flora

4.1.1 Floristic richness: The floristic inventory identified 69 weed species that are alternative hosts for the armyworm in maize, divided into 53 genera belonging to 17 families. Of these, the most noteworthy are the Poaceae, Euphorbiaceae, Cyperaceae, Fabaceae and Asteraceae (Chart 1). The taxa inventoried belong to the classes Dicotyledons (51.87 %) and Monocotyledons (48.13 %).

Chart 1: Weed families as alternative hosts for armyworms

Families	types	Species
Aizoaceae	1	1
Amaranthaceae	4	5
Asteraceae	6	6
Commelinaceae	1	1
Convolvulaceae	1	3
Cyperaceae	4	8
Euphorbiaceae	4	8
Fabaceae	6	7
Lamiaceae	1	1
Loganiaceae	1	1
Malvaceae	2	2
Nyctaginaceae	1	1
Poaceae	16	20
Portulacaceae	1	1
Rubiaceae	1	2
Solanaceae	2	2
Tiliaceae	1	1

4.1.2 Phytogeographical origin of inventoried weeds: Four phytogeographical types were determined according to the weeds present, with a predominance of Guineo-Congolese-Sudano-Zambézian (GC-SZ) species (57.68 %). Guinéo-Congolese (GC) species accounted for 34.85 %, while introduced species (i) were moderately represented at 4.98 %. Species from the Soudano-Zambéziennes (SZ) region were the least represented at 2.49 %. Picture 2 shows the different phytogeographical types of weeds recorded.



Picture 2: Species distribution by phytogeographical type

4.2 Species frequencies : Species frequencies ranged from 6.25 % to 100 %. Species such as *Erythrina similis* and *Hibiscus cannabinus* were encountered only once, while species such as *Brachiaria lata*, *Digitaria horizontalis* and *Panicum maximum* were found in all plots. Chart 2 shows weeds with a centesimal frequency (Fc) greater than or equal to 30 %.

4.3 Specific contribution of species surveyed: Of the 69 alternative weed hosts of the armyworm, four have a specific contribution greater than 4. These are *Brachiaria lata*, *Digitaria horizontalis*, *Croton hirtus* and *Panicum maximum.* These four weeds contribute 5.80 % to the weed flora of maize crops. Species with a specific contribution greater than 1 account for 43.48 % of the weed flora (Chart 3). These include *Cyperus difformis* and *Amaranthus spinosus*. Species with a specific contribution of less than 1 account for 50.72 %, including *Acanthospermum hispidum, Cenchrus biflorus, Chloris pilosa and Sporobolus pyramidalis.*

Chart 2: Some characteristics of the major weeds in the study

N°	species	Families	TB	Choro	TM	Fa	Fr	Fc (%)	Cs
1	*Amaranthus spinosus* Linn.	Amaranthaceae	Th	GC-SZ	h	6	0.38	37.5	2.49
2	*Bidens pilosa* Linn.	Asteraceae	Th	GC-SZ	h	6	0.38	37.5	2.49
3	*Brachiaria lata* (Schumach.)	Poaceae	Th	GC-SZ	h	12	0.75	75	4,98
4	*Chromolaena odorata* (L.)	Asteraceae	np	GC	b	9	0.56	56.25	3.73
5	*Croton hirtus* L'Hérit.	Euphorbiaceae	np	GC	b	10	0.63	62.5	4.15
6	*Cyperus difformis* L.	Cyperaceae	Th	GC-SZ	h	6	0.38	37.5	2.49
7	*Cyperus rotundus* L.	Cyperaceae	Gr	GC-SZ	h	6	0.38	37.5	2.49
8	*Dactyloctenium aegyptium* (Linn.) Willd.	Poaceae	H	GC-SZ	h	6	0.38	37.5	2.49
9	*Digitaria horizontalis* Willd.	Poaceae	Th	GC-SZ	h	11	0.69	68.75	4.56
10	*Digitaria insularis*	Poaceae	Th	GC	h	5	0.31	31.25	2,07
11	*Eleusine indica* (Linn.)	Poaceae	H	GC-SZ	h	5	0,31	31.25	2.07
12	*Euphorbia heterophylla* Linn.	Euphorbiaceae	Th	GC	h	6	0.38	37.5	2.49
13	*Euphorbia hirta* Linn.	Euphorbiaceae	Ch	GC-SZ	h	6	0.38	37.5	2.49
14	*Panicum maximum* Jacq.	Poaceae	H	GC	h	16	1	100	6.64
15	*Phyllanthus amarus* Schum. & Thonn.	Euphorbiaceae	np	GC	b	6	0.38	37.5	2.49
16	*Pueraria phaseoloides* (Roxb.) Benth.	Fabaceae	Lmp	i	l	5	0.31	31.25	2.07
17	*Rottboellia cochinchinensis* (Lour.)	Poaceae	Th	GC-SZ	h	9	0.56	56.25	3.73

TB: Biological type; choro: chorology; TM: Morphological type; Fa: Absolute frequency; Fr: Relative frequency; Fc: Centesimal frequency; Cs: Specific contribution

Chart 3 : Number of species by specific contribution

Specific contributions (Cs(e))	Number of species	Percentages (%)
Cs(e) < 1	**35**	**50.72**
1 ≤ Cs(e) < 4	30	43.48
Cs (e) ≥ 4	**4**	**5.80**
Total	69	100

4.4 Importance of armyworm attacks on maize : The extent of armyworm attacks depends on the species present. The species most heavily attacked by the armyworm are: *Amaranthus spinosus* (Amaranthaceae), *Croton hirtus* (Euphorbiaceae), *Brachiaria lata* (Poaceae), *Panicum maximum* (Poaceae) and *Rottboellia cochinchinensis* (Poaceae). The species *Chromolaena odorata* and *Pueraria phaseoloides*, belonging respectively to the Asteraceae and Fabaceae families, were the least attacked (Chart 4). Several species were found to be the least attacked by the armyworm. These included *Commelina benghalensis*, *Ipomea coccinea*, *Cyperus difformis* and *Mitracarpus hirtus*.

Chart 4 : Importance of the attack according to the families of the species inventoried

species	Families	Importance of the attack
Amaranthus spinosus Linn.	**Amaranthaceae**	+++
Chromolaena odorata L.	Asteraceae	++
Commelina benghalensis Linn	Commelinaceae	+
Ipomea coccinea L.	Convolvulaceae	+
Cyperus difformis L.	Cyperaceae	+
Croton hirtus L'Hérit.	**Euphorbiaceae**	+++
Pueraria phaseoloides (Roxb.) Benth.	Fabaceae	++
Ocimum gratissimum Linn.	Lamiaceae	+
Sida acuta Burm.f.	Malvaceae	+
Brachiaria lata Schumach.	**Poaceae**	+++
Panicum maximum Jacq.	**Poaceae**	+++
Rottboellia cochinchinensis (Lour.)	**Poaceae**	+++
Mitracarpus hirtus (L.) DC	Rubiaceae	+
Solanum distichum Thonn.	Solanaceae	+

+: Weakly attacked families; ++: Less-attacked families; +++: Families severely attacked

During the study, it was observed that caterpillar damage occurs during the larval stage. Caterpillar waste is reddish-brown in color (Picture 3). Corn leaves perforated by the armyworm were observed. On *Brachiaria lata* and *Mitracarpus hirtus* leaves attacked by armyworms, small holes giving the appearance of skeletons or windows were noted (Picture 4).

Picture 3: Fall armyworm waste and egg masses on corn leaves

Picture 4: Signs of armyworm attack on *Brachiaria lata* (a) and *Mitracarpus hirtus* (b) leaves

5 DISCUSSION

The present study has established a list of alternative weed hosts of the armyworm in maize. The weed flora is diverse and comprises 69 species in 53 genera belonging to 17 families. The low number of overall species obtained is the result of the specific nature of this study. In fact, the inventories were carried out only in maize crops and targeted one category of plants, namely the alternative hosts of the armyworm. This specificity reduces the type and number of species to be counted, even though the crops offer a wider range of weeds. This finding is similar to that obtained by Kouamé *et al.* (2022) in their study of insect pests in maize crops in central Côte d'Ivoire. In this work, the weed flora in maize plots was composed of 55 species divided into 49 genera and 22 families. This finding is similar to that obtained by CNRA (2011), whose study involved identifying the host species of the Swollen shoot virus in cocoa production. In the course of this research structure's study, 47 species divided into 26 genera and 15 families were inventoried. Studies by Singo (2016) on the inventory of alternative weed hosts of the armyworm *Achaea catocaloides* in cocoa trees in the Toumodi and Taabo Departments also confirmed this finding. In the course of his work, this author identified 61 species in 55 genera belonging to 34 families. On the other hand, work carried out in the M'Bahiakro department in east-central Côte d'Ivoire in 2016 by Kouakou on floristic studies of weeds and the effects of *rottboellia cochinchinensis* on the agronomic traits of maize showed a difference in floristic richness. In the course of his work, he inventoried a wealth of genera (183) and species (299). Within this floristic diversity of alternative weed hosts for the armyworm *Spodoptera frugiperda* in autumn maize, the families Poaceae, Asteraceae, Fabaceae, Euphorbiaceae, Cyperaceae and Amaranthaceae are relatively important in terms of the number of species in the weed flora. These families are also on the list of families considered by Akobundu (1987) as "major weeds of the world". Of all these families, the Poaceae are the most represented, with a significant number of species in the inventoried flora. This can be explained by the fact that maize-growing areas are open zones, so that the dispersal of mainly herbaceous species is highly developed, which explains the strong presence of Poaceae. The predominance of these families is therefore linked to their adaptation to different environments (Kouakou, 2016). The high representativeness of Dicotyledons (51.87%) in this work, was also observed in cocoa cultivation in the Agneby-Tiassa and Bélier regions by Singo (2016), with 94%. According to Déat (1976), there is no weed flora specific to a given crop, but rather ecological parameters and agronomic factors favorable to their development. The species most heavily attacked by this autumn armyworm were *Amaranthus spinosus* (Amaranthaceae), *Croton hirtus* (Euphorbiaceae), *Brachiaria lata* (Poaceae), *Panicum maximum* (Poaceae) and *Rottboellia cochinchinensis* (Poaceae). The impact of armyworms on species in the Poaceae family could be justified by the fact that maize belongs to the same family. These species develop botanical characteristics similar to those of maize. The work of Madougou *et al* (2017) in Niger has also shown that the Tuta absoluta caterpillar, which attacks potatoes, tomatoes and eggplants, all Solanaceae, also develops on weeds from the same family, such as *Solanum nigrum* and *Datura stramonium*. Weeds in plantations are also attacked by pests, just like the crop itself, and thus contribute to their proliferation. For example, the work of Kouamé *et al* (2022) has shown that insect pest damage in maize cultivation is accentuated when the rate of weed cover increases. According to these authors, the insect pest *Rhopalosiphum maidis* causes a great deal of damage in maize crops when grass cover is around 50%.

6 CONCLUSION

Corn (*Zea mays* L) crop is subject to numerous constraints, one of the most recent being the fall armyworm. This caterpillar causes numerous problems for the crop, leading to a drop in yield. It is hosted by weeds in maize farmss, from which it infests the maize plants. This study was initiated with the aim of identifying the alternative host plants of the armyworm in infestation sites in Yamoussoukro, with a view to developing possible control methods. A floristic inventory identified 69 species divided into 53 genera and belonging to 17 families. The species most heavily attacked by this autumn armyworm were *Amaranthus spinosus* (Amaranthaceae), *Croton hirtus* (Euphorbiaceae), *Brachiaria lata* (Poaceae), *Panicum maximum* (Poaceae) and *Rottboellia cochinchinensis* (Poaceae). These results show that fall armyworm infestation in maize is accentuated by the presence of these weed hosts in and around maize plots.

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