

Agronomic performance and pest susceptibility of four maize cultivars (*Zea mays* L.) in Lower Casamance (South-West Senegal)

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Abstract

In Senegal, maize is the third most widely produced cereal. However, maize productivity is low due to a number of constraints, including the problem of adaptability of varieties to environmental conditions. The aim of this study is to show the agro morphological performance and pest susceptibility of four maize varieties (V1: Obatmapa, V2: Suwan, V3: Eraly Thai and V4: DMR ESR White) in Lower Casamance. A randomised complete block design with four replications was adopted. Production data (number of ears and yield) and entomological data (insect diversity, abundance of pests and natural enemies, incidence and severity of pests). Pests and natural enemies were sampled on 25 plants taken at random every 15 days. The larvae found were incubated in the laboratory until the emergence of adult pests or parasitoids. The Early Thai (4.46 t/ha) and DMR ESR White (4.54 t/ha) varieties gave the best yields. The specie *Rhopalosiphum maidis* has the higher abundance (1255 individuals) followed by the specie *Spodoptera frugiperda* (596 individuals) and the specie *Busseola fusca* (77 individuals). The varieties Suwan (incidence 29,5%; severity 15,7%) and Early Thai (incidence 31%, severity 6,2%) were more susceptible to the pests *Spodoptera frugiperda* and *Busseola fusca* respectively. DMR ESR White is a promising variety because it has given a good yield and was less susceptible to pests. Its use in food self-sufficiency programmes could reduce malnutrition in Africa.

Keywords: Resilience, biodiversity, adaptation, agronomy, food security

Introduction

Maize is one of the most important crops for human consumption. In West Africa, maize is a base in people's diets (Semassa *et al.*, 2016) [31]. It is used for feeding and as a raw material in some industries (Boone *et al.*, 2008) [5]. In Senegal, maize is the third most produced cereal (ANSD, 2019) [3]. National production is 530.705 tons on an area of 258.391 ha with a yield of 2.054 kg. ha⁻¹ (ANSD, 2019) [3]. However, this production generally has a low level of productivity due to multiple constraints, including the problem of adaptability of maize varieties to environmental conditions (Cairns *et al.*, 2013) [7] mainly the poor spatial and temporal distribution of rainfall, the poor-quality soils, weeds and pest pressure. Insects that attack cereals are generally beetles and lepidopterans (Benlameur, 2016) [4]. The damage they cause leads to grain weight loss, reduction of grain quality (Pimentel, 2002) [28] and loss of germination power (Dabire *et al.*, 2008) [11]. among insect pests attacking maize crop, the stem and ear borer *Busseola fusca* and *Spodoptera frugiperda* are the most damaging pest (Boucher, 2014) [6]. The species *Busseola fusca*, native to Africa, is a pest whose damage is exclusively caused by the larval stages. The larvae tunnel into thick stems and ears (Alavo *et al.*, 2010) [2]. The pest, *Spodoptera frugiperda* J.E Smith, first reported in West and Central Africa in 2016 (Goergen *et al.*, 2016) [17] is a pest that causes countless damages to economically important cereals such as maize,

rice and sorghum, but also to vegetable crops and cotton (FAO, 2017) [17]. Thus, to fight against these pests, producers use synthetic pesticides which have a harmful impact on humans and the environment and often cause insect resistance (Yarou *et al.*, 2017; Sene *et al.*, 2020) [32, 40]. The search for alternative solutions that involve varietal resistance or the use of natural enemies such as parasitoids is necessary to protect crops, the environment and contribute to increase grain yields (Snyder *et al.*, 2020) [36]. Thus, several studies have been conducted in different countries to improve maize production to enable producers to make the right choice of maize varieties to grow (Moussa *et al.*, 2018; Golabaye *et al.*, 2019) [18, 26]. In Senegal, improving maize productivity is urgently needed to contribute to food security. The objectives of the study are to evaluate the agronomic performance of 4 maize cultivars and to determine the incidence and severity of pests on the 4 cultivars.

Materials and method

Experimental site

The experiment was conducted at the Djibélôr Agricultural Research Center (12°33'39"N; 16°18'25"W) located on the Cap Skiring road in the commune of Niaguis, Ziguinchor region (Figure 3). The soils are of a slightly denatured red ferralitic nature with a higher clay content at depth (Ngom *et al.*, 2018) [27].

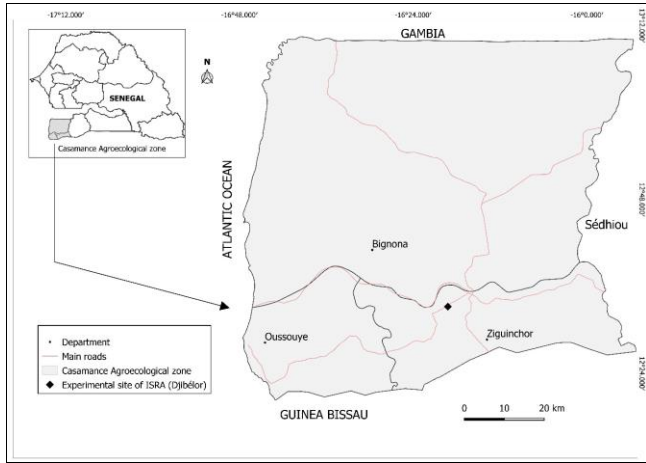


Fig 1: Location of the experimental site

The climate of the region is of the Sudanian South Coastal type (Sagna, 2005; Sagna *et al.*, 2021) [29, 30]. Ziguinchor has two seasons: a rainy season lasting around 4 months (July to October) and a dry season lasting around 8 months (November to June) (With an average of 1300 mm between 1991 and 2021. Figure 2, which shows rainfall variability in

Ziguinchor between 1991 and 2022, highlights 1999, 2008, 2015 and 2020 as the years with the highest rainfall (with more than high rainfall (over 1700 mm/year) and 1992, 2002, 2007 and 2021 as the years with the lowest rainfall (under 1300 mm/year).

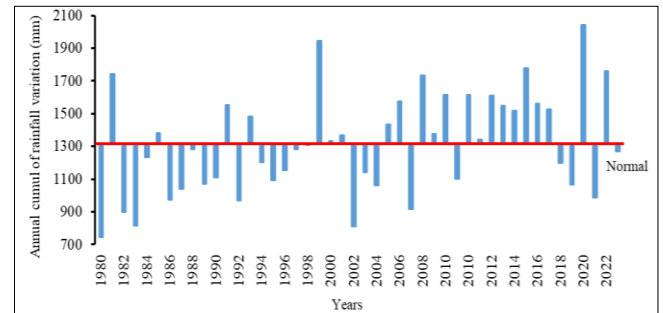


Fig 2: Rainfall variation at Ziguinchor Airport station from 1980 to 2023 (data source: ANACIM Zurich)

Plant material

The plant material used consist of four (4) varieties of maize which the characteristics of each presented in Table 1 (ISRA, 2012)

Table 1: Characteristics of maize varieties used (FAO, 2012) [14]

Code	Variety Name	Genetic nature	Maturity cycle (days after sowing)	Potential grain yield (t. ha ⁻¹)	Grain type	Seed color
V1	Obatampa	Composite	95-100	3	Horny-toothed	white
V2	Suwan	Composite	90-100	3-4	Horny	yellow
V3	Early Thai	Composite	80	2-3	Horny	yellow
V4	DMR ESR white	Composite	80	2.5	Horny-toothed	white

Factor studied and experimental design

Only one factor was studied, namely the variety (V) with four modalities (V1: Obatampa; V2: Suwan; V3: Early Thai V4: DMR ESR white) randomized in a Fischer block device with four replicates. The blocks was spaced 1.5m apart. Each elementary plot was 4m long and 3m wide. The elementary plots was separated by 1m. In each elementary plot was delimited a useful plot of 6m² where the harvest was carried.

fertilizer (15-15-15) was applied at a rate of 240g per elementary plot. Urea was applied with a quantity of 120 grams per elementary plot respectively 15 and 45 days after sowing. weeding were perform twice 26 days and 41 days after sowing.

Data collection and sampling

The parameters of production such as number of ears and grain yield were counted and calculated. In order to determine the influence of pests on maize varieties, leaf samples were randomly taken every 15 days from 25 maize plants per elementary plot until harvest. Larvae were collected manually. Each larva collected, was maintained in a holed plastic box containing fresh maize leaves and taken to the laboratory for incubation. Predators as well as other pests collected were also taken to the laboratory for identification. Adult insects were captured and killed with ethyl acetate. The severity of insect pest damages was evaluated by scoring the level of damages on leaves with a score scale from 0 to 5 and then the severity index was estimated using Cooke *et al.*, (2006) [9] formula.

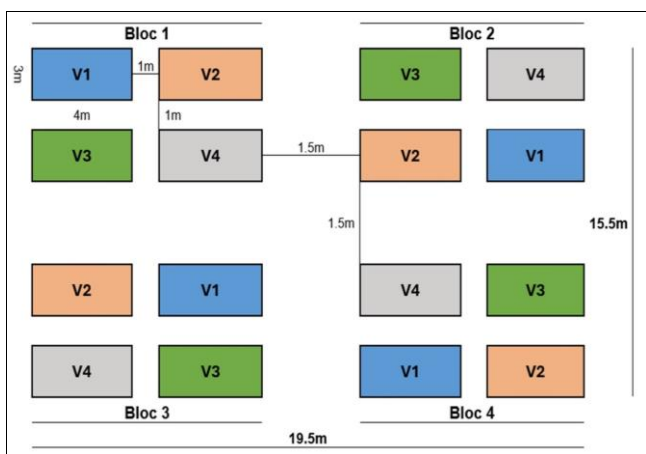


Fig 3: Experimental design

Trial management

for each variety, two grains were sown per hill. sowing was made by hand with seedling points distant from 0.75m between rows and 0.25m between pockets. The NPK base

Laboratory monitoring

In the laboratory, incubated larvae were followed until the emergence of adult insect pest or parasitoid. The adult pests and the parasitoids were put in vials containing an ethyl acetate absorbent tissue in order to kill them to facilitate preservation. The parasitoids collected were counted, stored in tubes containing 70% alcohol and then identified.

Estimate of variable

Incidence

The incidence corresponds to the proportion of plants attacked in relation to the number of total plants observed. It is determined using the following formula

$$I (\%) = \frac{AP}{PT} \times 100$$

I: incidence; AP: number of plants attacked; PT: total number of plants observed.

Severity

The plants of each variety were classified according to score scale of severity 0 - 5 where 0= no damage to the leaves; 1= very low damage on leaves, very severe on ears; 2= low leaf damage; 3= average leaf damage; 4= severe leaf damage; 5= very severe leaf damage.

The severity index was calculated using the following formula (Cooke *et al.*, 2006) ^[9]

$$\text{Severity index } (\%) = \frac{\sum (Ni \times Si)}{(Nt \times 5)} \times 100$$

Ni: Number of plants in severity class i, i ranging from 1 to 5.

Si: Number of the severity class.

Nt: Total number of plants observed by variety

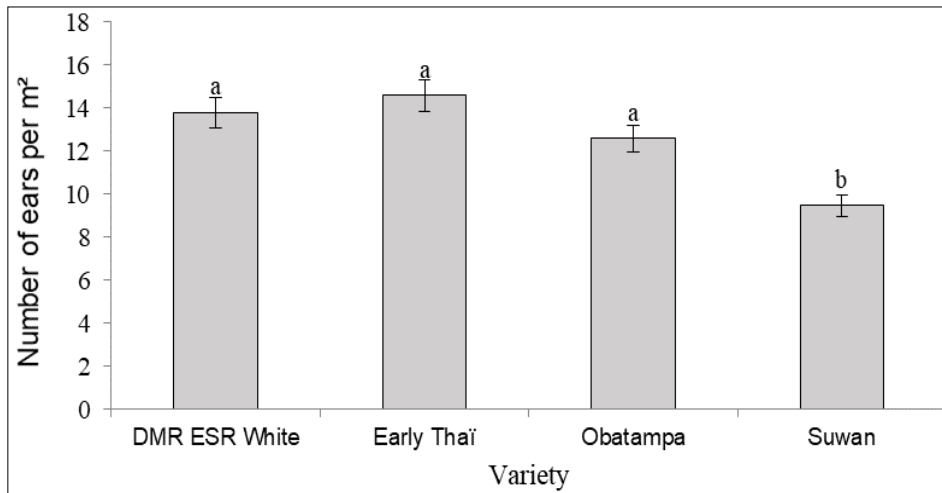
Statistical analysis

An analysis of variance was carried out with the XLSTAT 5.03 2014 edition software. The Fischer test has been used for means comparison at the 5% threshold (Dagnelie, 1992) ^[12].

Resultats

Yield and components

The production of ears depended significantly on the type of variety (P<0.0002***) (Figure 4). The varieties Early Thai (14.5 ears/m²), DMR ESR white (13.7 ears/m²) and Obatampa (12.5 ears/m²) gave the highest and statistically equivalent ear productions. The most reliable productions are recorded on the Suwan variety (9.5 ears/m²).

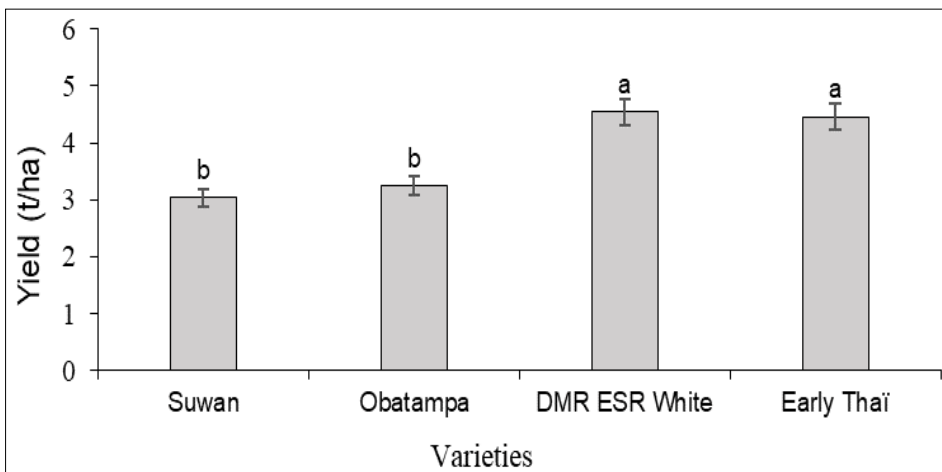


The values of each histogram with the same letters are not significantly different when p<0.05 in the Fischer test

Fig 4: Number of ears per m² according to varieties

The results show a significant difference in grain yield between varieties (P < 0.0001***) (figure 5). Indeed, the DMR ESR white (4.54 t/ha) and Early Thai (4.46 t/ha)

varieties have the higher yields than the Obatampa (3.25 t/ha) and Suwan (3.04 t/ha) varieties



The values of each histogram with the same letters are not significantly different when p<0.05 in the Fischer test

Fig 5: Maize yields according to varieties

Diversity of insects of insect pests

In this study, total of 6 species of insect pests, 7 species of predators and 2 species of parasitoids were collected from maize. The pest *Spodoptera frugiperda* were found in all

varieties of maize. Similarly, predators are recorded in all varieties. The parasitoids encountered were only associated with the pests *Spodoptera frugiperda*. (Table 2).

Table 2: Insect pests and their natural enemies associated with four maize varieties

Functional group	Species	Varieties of maize			
		Obatampa	Suwan	Early Thai	DMR ESR white
Pest	<i>Spodoptera frugiperda</i>	+	+	+	+
	<i>Mythimna loreyi</i> Walker	-	-	+	+
	<i>Chaetocnema pulicaria</i> Melsheimer	+	+	+	+
	<i>Rhopalosiphum maidis</i> (Fitch)	+	+	+	+
	<i>Busseola fusca</i> (Fuller)	+	+	+	+
	<i>Spodoptera litoralis</i> (Boisd.)	+	+	-	-
Predator	<i>Forficula</i> sp.	+	+	+	+
	<i>Harpalus</i> sp.	+	+	+	+
	<i>Cheilomenes sulphurea</i> (Olivier, 1791)	+	+	+	+
	<i>Harmonia octomaculata</i> (Fabricius, 1781)	+	+	+	+
	<i>Coranus</i> sp.	+	+	+	+
	<i>Spilostethus</i> sp.	+	+	+	+
	<i>Camponotus sericeus</i> (Fabricius, 1798)	+	+	+	+
Parasitoids	<i>Hexameris</i> sp.	+	+	+	+
	<i>Chelonus insularis</i> Cresson	+	+	+	+

+: Presence; -: absence



Spodoptera frugiperda (adult female)



Mythimna loreyi Walker



Chaetocnema pulicaria



Forficula sp.



Cheilomenes sulphurea



Hexameris sp.

Photos: Insect pests and their natural enemies associated at maize variety

Abundance of insect pests

The species *Rhopalosiphum maidis* has a higher abundance (1255 individuals) followed by the species *Spodoptera frugiperda* (596 individuals) and the species *Busseola fusca* (77 individuals). (*Spodoptera frugiperda* and *Busseola fusca* were the main pests that caused damage on

all four varieties of maize. The abundance of *S. frugiperda* is higher on the Suwan variety compared to the other varieties (Obatampa, Early Thai, DMR ESR white). On the other hand, *Busseola fusca* is more abundant on Early Thai and DMR ESR White varieties.

Table 3: Abundances of insect pests associated with four maize varieties

Order	Family	Species	Varieties of maize				Total abundance
			Obatampa	Suwan	Early Thai	DMR ESR white	
Coleoptera	Chrysomelidae	<i>Chaetocnema pulicaria</i>	19	26	17	10	72
Lepidoptera	Noctuidae	<i>Spodoptera frugiperda</i>	127	245	102	122	596
		<i>Mythimna loreyi</i>	0	0	5	1	6
		<i>Spodoptera litoralis</i>	1	1	0	0	2
		<i>Busseola fusca</i>	11	13	31	22	77
Hemiptera	Aphididae	<i>Rhopalosiphum maidis</i>	215	342	325	173	1255
Total abundance			373	627	480	328	2008

Abundance of natural enemies

Predators such as ants (Formicidae) and ladybugs (Coccinellidae) were the most important, respectively

(Table 4). Only two species of parasitoids have been identified, namely *Hexameris* sp. and *Chelonus insularis* with 73 and 28 individuals recorded respectively.

Table 4: Abundances of natural enemies associated with pest of four maize varieties

Natural enemies	Order	Families	Species	Varieties of maize				Total abundance
				Obatampa	Suwan	Early Thai	DMR ESR white	
Predator	Coleoptera	Carabidae	<i>Harpalus</i> sp.	12	12	13	6	43
		Coccinellidae	<i>Cheilomenes sulphurea</i> (Olivier, 1791)	9	10	15	10	44
			<i>Harmonia octomaculata</i> (Fabricius, 1781)	6	6	10	12	34
	Dermaptera	Forficulidae	<i>Forficula</i> sp.	3	1	4	1	9
	Hemiptera	Reduviidae	<i>Coranus</i> sp.	2	1	2	1	6
	Hymenoptera	Formicidae	<i>Camponotus sericeus</i> (Fabricius, 1798)	60	69	73	41	243
	Heteroptera	Lygaeidae	<i>Spilostethus</i> sp.	1	1	5	11	18
Parasitoids	Namatoda	Mermithidae	<i>Hexameris</i> sp.	15	21	11	26	73
	Hymenoptera	Braconidae	<i>Chelonus insularis</i> Cresson, 1865	2	18	4	4	28
Total abundance				110	139	137	112	495

Incidence and severity of major insect pests

The fall armyworm *Spodoptera frugiperda* and the maize Borer *Busseola fusca* are very harmful insect pests causing significant damage on maize. The incidence (29.5%) and severity (15.7%) of *S. frugiperda* were higher on Suwan variety, while for *B. fusca*, the incidence (31%) and severity (6.2%) were higher on Early Thai variety (Table 5).

Table 5: Incidence and severity of two main pest attacks on four maize varieties

Varieties of maize	Pests			
	<i>B. fusca</i>		<i>S. frugiperda</i>	
	Incidence (%)	Severity (%)	Incidence (%)	Severity (%)
Early Thai	31	6.2	27	15.2
DMR ESR white	26	5.2	17	9.1
Obatampa	22	4.4	16.2	9.1
Suwan	15	3.0	29.5	15.7

Discussion

The number of ears per plant of Obatampa, Early Thai, and DMR ESR White varieties was higher compared to Suwan variety. This is due to the fact that each of these varieties produced two ears per plant. These results are contrary to those of (Monneveux, 1991) [24], who states that grain productivity is more or less important in tall stem varieties compared to short-stem varieties. The good yields of Early Thai and DMR ESR White strains can be explained by the fact that each plant has produced two ears. Indeed, Smith & Hamel, (2012) [35] shown that the number of ears is the most decisive component of yield. In addition, (Gheith et al., 2022) [16] reported that the number of ears/plant and the number of grains/ears play a decisive role in achieving grain yield. The yield of Suwan variety is also lower. This is due to the fact that each plant bears a single ear. According to insect pests study a total of 6 species of pests, 7 species of predators and 2 species of parasitoids were collected from maize. This shows that maize is associated with a very high entomological diversity. Indeed, nine species of natural enemies participate in the natural regulation of 6 species of pests. The entomological diversity associated with maize contributes to the species richness of the agroecosystem.

This would promote the balance of the environment thanks to the presence of many species in the environment. In an agroecosystem, the greater the diversity, the more balanced the environment (Lawson et al., 2019; Mohammedi et al., 2019) [22]. The result show that *Spodoptera frugiperda* attacks all varieties of maize. The specie *S. frugiperda* is a polyphagous pest (more than 80 host plants) but preferably attacks maize crop (FAO, 2017) [17]. This highly polyphagous pest feed on maize and survives on more than 274 crop plants (Montezano et al., 2018) [25]. in parallel, predators are encountered on all varieties and the parasitoids were only associated with *Spodoptera frugiperda*. The presence of predators on all varieties could be explained by the availability of resources. Indeed, several species of pests are associated with natural enemies. In an agroecosystem, the presence of pests favours the presence of natural enemies (Veres et al., 2013; Hatt et al., 2018) [19, 38]. Most often parasitoids are associated with larvae. The fact that the parasitoids are only associated with the pest *S. frugiperda* is partly explained by the fact that the larvae collected were more abundant than those of *B. fusca*. On the other hand, *B. fusca* is a borer whose larvae develops exclusively within the host plant (Delvare & Polaszek, 2000) [13]. This shows that they are less exposed and therefore more difficult to be parasitized compared to the pest *S. frugiperda*. Indeed, the larvae of *S. frugiperda* attacks all above-ground parts of maize such as the stalks, leaves, flowers and ears (Hong et al., 2020) [20]. *S. frugiperda* and *Busseola fusca* were the main pests that caused damage to all four varieties of maize. The abundance of *S. frugiperda* is higher on Suwan variety compared to the other varieties “Obatampa”, “Early Thai”, “DMR ESR white”. On the other hand, *B. fusca* is more abundant on the Early Thai and DMR ESR White varieties. This is due to the availability of resources that promote the attraction of pests. The specie *Rhopalosiphum maidis* has a higher abundance (1255 individuals) followed by the specie *Spodoptera frugiperda* (596 individuals) and the specie *B. fusca* (77 individuals). *S. frugiperda* and *B. fusca* are the main insect pests of the four maize varieties. In its biology, the aphid *Rhopalosiphum maidis* gives a very high offspring, which explains the abundance of individuals (Kos et al., 2008) [21]. The pest *S. frugierda* has been found in the environment since 2017 (Tendeng et al., 2019) [37]. The

abundance of this pest is explained by the availability of resources. The abundance of *B. fusca* is less important because this pest appeared towards the end of the maize cycle with rare infestations.

The abundance of natural enemies is not significantly different between the four varieties. This is explained by the fact that pests were present on all four varieties. There is a close relationship between the population of natural enemies and pests (Veres *et al.*, 2013) [38]. Among predators, the number of ants was higher followed by and ladybugs. The high number of ants is explained by the fact that each female gives a very high offspring and is surrounded by males who mate successively with her. Indeed, ants are social insects that organize themselves into colonies ranging from a few dozen individuals to several thousand (Wheeler, 2015) [39]. The abundance of ladybugs is explained by the phenomenon of a dependent population between aphids and ladybugs. This phenomenon shows that the abundance of aphids explains that of predatory ladybugs. Indeed, these ladybugs play an important role in protecting crops against aphids (Ahmed & Majeed, 2016; Singh & Singh, 2016, 2021) [1, 33, 34]. Only two species of parasitoids have been identified, namely *Hexamermis* sp. and *Chelonus insularis*. Natural enemies grow at the expense of host organisms and kill them at the end of the cycle. The parasitoid *Hexamermis* sp. is more important than *Chelonus insularis*. This is because two to three nematodes can parasitize a single larva. Indeed, nematodes lay their eggs on the leaves, and larvae can ingest three to four eggs by consuming the leaves (Tendeng *et al.*, 2019) [37] (Tendeng *et al.*, 2019) [37]. In contrast, *C. insularis* is a solitary endoparasitoid koinobiontal parasitoid (Cuny *et al.*, 2018) [10]. Only one individual of the parasitoid *C. insularis* is obtained per larva.

The susceptibility of “Suwan” (incidence 29.5% and severity 15.7%) to *S. frugiperda* attacks and that of “Early Thai” to *B. fusca* pest can be explained by the low vigour of the plants during growth. Indeed, the good vigour of the plant at emergence reduces pest attacks (Charmet, 2017) [8].

Conclusion

The present study evaluated the agronomic performance and susceptibility of four maize varieties to pests in Lower Casamance. The results obtained have shown that there is a great deal of variability between the different varieties of maize. Indeed, the “Early Thai” (4.46 t/ha) and “DMR ESR White” (4.54 t/ha) varieties are much more productive in terms of yield. “Suwan” and “Early Thai” are more susceptible to pests *S. frugiperda* (incidence 29.5% and severity 15.7%) and *Busseola fusca* (incidence 31% and severity 6.2%) respectively. The use of these results in programmes to improve maize productivity would be an asset in achieving food self-sufficiency.

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