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RESEARCH

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Evaluation of the resistance of three maize varieties to *Spodoptera frugiperda* (J.E. Smith) and *Ostrinia nubilalis* Hübner in the Tonkpi region (Man, Côte d'Ivoire)

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Abstract

Background The corn borer *Ostrinia nubilalis* and the fall armyworm *Spodoptera frugiperda* larvae feed on the aerial parts of maize. It is responsible for significant yield losses and are therefore a cause of food insecurity. This study carried out to evaluate the resistance of three maize varieties (EV8766 SR-MRP, PR9131-SR, CEW-SR), in Tonkpi region's, to *S. frugiperda* and *O. nubilalis* damages. Each maize variety seeds were sown on a one hectare plot subdivided into 6 elementary plots with 75 cm between rows and 40 cm between bunches. Sampling of *S. frugiperda* and *O. nubilalis* larvae on maize plants was carried out according to the FAO method, from the third to the fifth week after planting. Maize plants damaged, the intensity of infestation and the number of larvae on maize plants were recorded. Maize plants damaged by the insect pests were marked to avoid recounting. At maturity, 100 maize cobs were harvested per elementary plot, then the larvae number and the attacked cobs by *S. frugiperda* and *O. nubilalis* larvae were recorded.

Results The lowest damage rate by *S. frugiperda* were recorded in maize variety EV8766-SR-MRP (23.33%); while, the highest damage rate were in the varieties PR9131-SR (43.33%) and CEW-SR (55%). There are no significant difference values of the density of *S. frugiperda* larvae per maize plant attacked between the three varieties. The index of intensification of maize plant damaged by *S. frugiperda* larvae was lower for the variety EV8766-SR-MRP (7.50%) and was moderate for the varieties PR9131-SR (15.42%) and CEW-SR (21.67%). The damage rates of *O. nubilalis* larvae on maize cobs varied between 9.6 and 22.0%. These damage rates were higher for the varieties PR9131-SR (21.83%) and CEW-SR (17.50%) and were lower for EV8766-SR-MRP (9.66%). There was not significantly different from the density of *O. nubilalis* larvae per maize cob attacked between the three varieties. It was between 1 to 1.2 larvae. Crop losses were lower for EV8766 SR-MRP (10.228%) than those of PR9131-SR and CEW-SR (19.338%).

Conclusions The maize variety EV8766-SR-MRP is found to be the best variety in the control of, *O. nubilalis* and *S. frugiperda*.

Keywords Attack rate, Larval density, *Ostrinia nubilalis*, Resistance, *Spodoptera frugiperda*, Zea mays

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Background

Maize (*Zea mays* Linnaeus, 1753) is the most important cereal crop in the world after wheat and rice, with a production of 1.2 billion tons on an area of about 200 million hectares (Konan et al. 2023). In Côte d'Ivoire, maize is the second most important cereal crop after rice, with an estimated annual production of 840,000 tons for a yield of 1.9 tons per hectare (Yoboué et al. 2022). This crop was an important source of macronutrients and micronutrients. Unfortunately, maize cultivation is affected by two major insect pests belonging to the order of Lepidoptera. These pests are the maize borer *Ostrinia nubilalis* Hübner (Lepidoptera: Crambidae) and the fall armyworm *Spodoptera frugiperda* (J.E. Smith, 1797) (Lepidoptera: Noctuidae), which has appeared in maize fields since 2016 (Goergen et al. 2016; Sisay et al. 2018; Kouakou et al. 2019; Jamil et al. 2021). The larvae of these pests were essentially phytophagous, feeding on the aerial parts of maize and causing significant yield losses to farmers (Paini et al. 2016; Russianzi et al. 2021; Kumar et al. 2022). Yield losses due to *O. nubilalis* and *S. frugiperda* in Africa has been estimated to range from 8.3 to 20.6 million tons/ha when no control measures were applied (Abrahams et al. 2017; Day et al. 2017). *S. frugiperda* is established across the African continent and is a highly polyphagous and destructive pest of maize crops (Kalyebi et al. 2023).Yield losses due to *S. frugiperda* larvae ranged from 21 to 100% in Africa (Goergen et al. 2016; Prasanna et al. 2018; Russianzi et al. 2021; Kumar et al. 2022). The sixth instar larva has the major pest, causing heavy damage on maize plants (Kalyebi et al. 2023). It feeds on maize leaves and causes 100% of maize defoliation (Ramzan et al. 2021). The larvae of *O. nubilalis* is a key pest of maize. It creates holes on the stems, on the leaves, on the panicles or eats the grains of cobs (Pintilie et al. 2022). The galleries created in the stems and panicles by *O. nubilalis* weaken maize plants and break the stem (Sanane 2020). The larvae also feed on young milky grains, making galleries in the ears and then leaving streaks (Piesik et al. 2013; Sanane 2020; Magagnoli et al. 2021). In sweet maize, *O. nubilalis* damage ranged from 89 to 93% on maize plants and 53.5 to 76% of ears (Piesik et al. 2013). Direct damage was yield reduction and indirect damage was the reduction in maize quality due to contamination of grain production with mycotoxins produced by the fungi (fumonisin and zearalinone), which have a negative impact on food security (Paini et al. 2016; Magagnoli et al. 2021). Since its invasion, insecticides has been used by farmers to protect maize plants in Côte d'Ivoire. However, maize production has decreased. The methods used to protect crops against these two pests need to be more ecological which protects the environment, farmers' health and food security (Zhang et al. 2020). In Côte d'Ivoire, particularly in the Tonkpi region, studies have not been carried out on the resistance of cultivars to the attacks of these pests. The aim of this study is therefore to evaluate the level of resistance of three maize varieties (CEW-SR, EV8766-SR-MRP and PR9131-SR) to attack by the pests *Spodoptera frugiperda* and *Ostrinia nubilalis* and to assess the damage caused. The aim is to assess attack rates, larval density and yield losses caused by *Spodoptera frugiperda* and *Ostrinia nubilalis* larvae in maize crop.

Methods

Study site

The experiment was conducted during April 25, 2022, to July 30, 2022, in maize farms of Man locality in the west of Côte d'Ivoire, between 7°24′45″N and 7°33′13″W (Fig. 1). The climate of the region is subequatorial. This climate is characterized by two seasons, a rainy season (April to October) and a dry season (November to March). The average annual rainfall is 1632 mm and the average annual temperature varies around 25 °C (Ahoussi et al. 2018).

Experimental plot

The three varieties of maize used in this study were grown in field experiment. These varieties were CEW-SR (75 day cycle, 1 to 1.2 t/ha, white grain), EV8766-SR-MRP (90 to 95 days, 2 to 4 t/ha, yellow grain) and the variety PR9131-SR (90 day cycle, 2t/ha, yellow grain). An experimental plot of one hectare, 10,000 square meters, was established for each maize variety. Three seeds of each maize variety of maize were planted per planted hole at a distance of 75 cm between rows and 40 cm between clusters, with 2 plants per planting hole after stripping. Each experimental plot was divided into 6 plots of equal size. Maize plants located 2 m from the boundary were not included in the establishment of the elementary plots and in the sampling to avoid boundary effects. Each replicate plot was 1536 m^2 (96 m × 16 m) with 21 lines and 5120 maize plants. The lines were spaced longitudinally. Sowing took place on 25 April 2022.

Identification of *Spodoptera frugiperda* and *Ostrinia nubilalis* larvae

The larvae were collected and preserved in 70° alcohol for identification in the laboratory. Identification of the insects was carried out using a binocular magnifying glass to reveal the distinctive characters.

Evaluation of *Spodoptera frugiperda* and *Ostrinia nubilalis* larvae attacks on maize at farm

Sampling method of maize plants attacked by S. frugiperda and O. nubilalis larvae

The evaluated of *S. frugiperda* and *O. nubilalis* larvae infestation for three maize variety was carried out using the FAO method (FAO 2018). This method consists

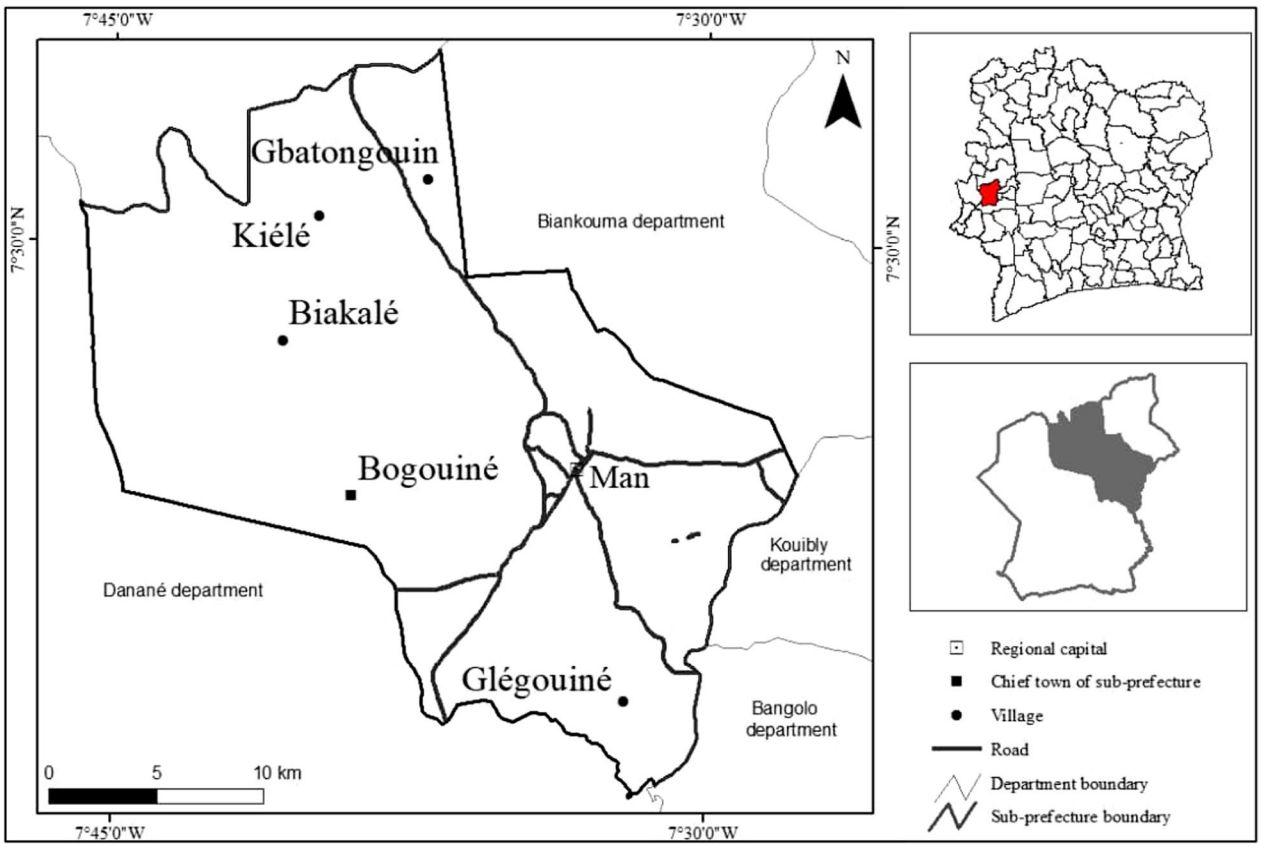

Fig. 1 Location of study site (Man)

of drawing the letter "W" across the entire field (FAO 2018). At the beginning and at each turn, 10 plants were inspected in a row. Thus, in each elementary plot, 10 consecutive maize plants were observed from the third week after to the fifth week after planting. Maize whorls and leaves were inspected. The maize plants damaged, the number of larvae on maize plants and the severity of the attacks were also recorded. Maize plants damaged by the insect pests were marked to avoid recounting. According to the estimates of Kuate et al. (2019), 4 types of attacks were defined. There were:

- *Low*: 1 to 10% of leaves were consumed, cuticle and maize plants have stripes (< 5 mm diameter), *Spodoptera frugiperda* or *Ostrinia nubilalis* larvae were present on flowers (DT1);
- *Moderate*: 11–25% of leaves are damaged, leaves have small holes (> 5 mm diameter), *Spodoptera frugiperda* or *Ostrinia nubilalis* larvae were on flowers and mature leaves (DT2);
- *Severe*: 26–50% of leaves are infested, leaves have holes (> 1 cm diameter), *Spodoptera frugiperda* or *Ostrinia nubilalis* larvae were on flowers, mature leaves and on stems (DT3);
- *Very severe*: 100% of maize leaves are infested or, *Spodoptera frugiperda* or *Ostrinia nubilalis* larvae were on all parts of maize plant (DT4).

Sampling method of ears attacked by S. frugiperda and O. nubilalis larvae

Sampling for *S. frugiperda* and *O. nubilalis* larvae in mature maize cobs was carried out on maize plants 2 m from the field edge to avoid edge effects. In each elementary plot, 100 mature maize cobs were randomly recorded, i.e., 600 cobs per hectare. The cobs were observed and the husks removed. The cobs infested by *S. frugiperda* or *O. nubilalis* larvae and the number of larvae on maize cobs were recorded.

Damage rate of maize plants and ears by *Spodoptera frugiperda* and *Ostrinia nubilalis* larvae

The damage rate (Dr) by the two insect pests' larvae on each maize variety was calculated according to the following formula:

$$Dr = \frac{Nat \times 100}{Nt}, \quad (1)$$

where Dr = damage rate (%); Nat = number of maize plants or cobs damaged by the larvae of the Lepidoptera; Nt = total number of maize plants or cobs harvested.

Damage intensification index

The damage intensification index (I) by the insect pests' larvae was used to assess the level of insect attack on maize plants. It was calculated using the following formula from Aléné et al. (2006):

$$I = \frac{[(P1 \times 25\%) + (P2 \times 50\%) + (P3 \times 75\%) + (P4 \times 100\%)]}{[Ps + P1 + P2 + P3 + P4]} \quad (2)$$

where I: damage intensification index per plot; Ps = number of healthy plants; P1 = number of plants with type 1 damage (DT1); P2 = number of plants with type 2 damage (DT2); P3 = number of plants with type 3 damage (DT3); P4 = number of plants with type 4 damage (DT4).

This method consists in assigning percentages to the levels of attack. The values assigned to the low level of attack (DT1), moderate levels of attack (DT2), less severe levels of attack (DT3) and severe levels of attack (DT4) were 25%, 50%, 75% and 100%, respectively.

Aléné et al (2006) group the values of the damage intensification index into 4 classes:

- *Class 1*: $1 \leq I < 10\%$, damage intensity is low;
- *Class 2*: $10 \leq I < 30\%$, damage intensity is moderate;
- *Class 3*: $30 \leq I < 50\%$, damage intensity is less severe;
- *Class 4*: $50 \leq I < 100\%$, damage intensity is severe.

Yield loss due to *Spodoptera frugiperda* and *Ostrinia nubilalis* larvae on the three maize varieties

In each elementary plot, the weight of 100 mature maize cobs more than 2 m from the edge was randomly selected. This method avoids edge effects. The batches of cobs from each elementary plot were first weighed and then divided into two groups (healthy cobs and cobs damaged). Each group of cobs was then weighted and the yield loss (WL) was calculated using the following formula:

$$WL(\%) = \frac{(Wt - Wn) * 100}{Wt} \quad (3)$$

where: WL = yield loss,
Wt = average weight of 100 harvested maize cobs (kg),
Wn = average weight of healthy maize cobs (kg).

Data analysis

Data on damage rate by *Spodoptera frugiperda* and *Ostrinia nubilalis* larvae, larval density on maize plants damaged and the weight losses by the insect pests were subjected to Microsoft SPSS software version 22.0 (IBM, New York, USA). The means were discriminated using the Fisher test (LSD) with a significance level of 5% using XLSTAT 2016.

Results

Number of *Spodoptera frugiperda* and *Ostrinia nubilalis* larvae found on maize plants

S. frugiperda larvae was recorded only on the maize leaves of the three varieties. The lowest number occurred in variety EV8766-SR-MRP (3.00 ± 1.673 larvae), the moderate number in the variety PR9131-SR (5.50 ± 2.510 larvae) while the highest number of *S. frugiperda* larvae were recorded in the variety CEW-SR (9.17 ± 1.602 larvae) ($F = 14.843$; $p = 0.000$) (Fig. 2).

O. nubilalis larvae were only recorded in the maize cobs of the three varieties. The lowest number of *O. nubilalis* larvae was recorded from the mature maize cobs of the variety EV8766-SR-MRP (10.50 ± 2.073 larvae) while the highest number occurred in the varieties PR9131-SR (23.17 ± 5.776 larvae) and CEW-SR (18.83 ± 6.369 larvae) ($F = 9.536$; $p = 0.002$) (Fig. 3).

Damage by *Spodoptera frugiperda* and *Ostrinia nubilalis* larvae on the three maize varieties and their larvae density

Damage by S. frugiperda larvae and their larvae density

The attack produced by the larvae of *S. frugiperda* was on maize leaves where it creates holes in the leaves (Fig. 4). The highest damage was occurred during the third to fifth week after maize emergency. The lowest number of maize plants damaged by *S. frugiperda* were recorded in maize variety EV8766-SR-MRP (2.33 ± 1.633) while the highest number were in the varieties PR9131-SR (4.33 ± 1.633) and CEW-SR (5.50 ± 0.547) ($F = 8.195$; $p = 0.004$) (Table 1). Consequently, the attack rate of maize plants by *S. frugiperda* larvae was lower for the variety EV8766-SR-MRP (23.33%) and was higher in the varieties PR9131-SR (43.33%) and CEW-SR (55%) ($F = 8.195$; $p = 0.004$) (Table 1).

There are no significant difference values of the density of *S. frugiperda* larvae per maize plant attacked between the three varieties. It was 1.139 ± 0.590 larvae/plant for EV8766-SR-MRP, 1.261 ± 0.236 larvae/plant for PR9131-SR and 1.667 ± 0.223 larvae/plant for CEW-SR ($F = 3.0022$; $p = 0.79$) (Fig. 5).

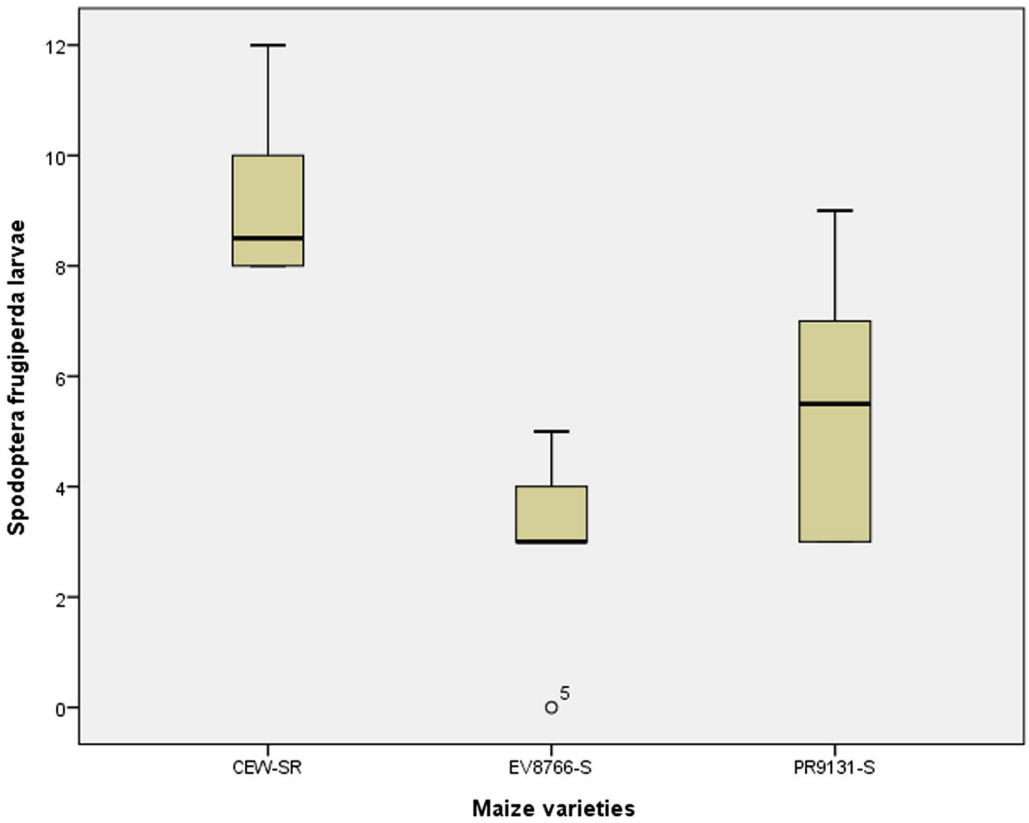

Fig. 2 Average number of *Spodoptera frugiperda* larvae per 10 maize plants

Damage intensification index

The damage intensification index to maize plants by *S. frugiperda* larvae was lower (DT1) with a value of 7.50% for the variety EV8766-SR-MRP. The damage intensification index obtained for the varieties PR9131-SR (15.42%) and CEW-SR (21.67%) showed moderate damage (DT2) ($F = 10.648$; $p = 0.001$) (Table 1).

Damage by O. nubilalis larvae and larvae density

Damage by *O. nubilalis* larvae on maize crop was only observed on mature cobs of the three maize varieties. *O. nubilalis* larvae damage cobs and grains. Female of *O. nubilalis* lay their eggs on the silks of the cobs. These eggs hatched and the larvae were sheltered in the maize cobs and caused significant damage. *O. nubilalis* larvae feed on maize grains and tunnel into the cobs (Fig. 6). Damage to maize cobs ranged from 9.6 to 22.0%. The lowest damage rate on maize cobs by *O. nubilalis* larvae was recorded in the variety EV8766-SR-MRP (9.66%) compared to the other two varieties PR9131-SR (21.83%) and CEW-SR (17.50%) ($F = 9.516$; $p = 0.002$) (Table 2). Consequently, the number of healthy cobs of the variety EV8766-SR-MRP was higher (90.33 ± 2.338 healthy ears) than those of the varieties PR9131-SR (78.16 ± 5.307 healthy cobs) and CEW-SR (82.50 ± 6.188 healthy cobs), which were statistically identical ($F = 6.516$; $p = 0.002$) (Table 2).

There was not significantly different from the density of *O. nubilalis* larvae per attacked cob between the three varieties. The larvae density were 1.111 ± 0.194, 1.061 ± 0.087 and 1.083 ± 0.041 larvae/ attacked cob for the varieties EV8766-SR-MRP, PR9131-SR and CEW-SR, respectively ($F = 0.242$; $p = 0.788$) (Fig. 7).

Yield loss due to *Spodoptera fugiperda* and *Ostrinia nubilalis* larvae attacks in the three maize varieties

Crop losses were lower for the maize variety EV8766 SR-MRP with a value of 10.228%. The crop losses of the varieties PR9131-SR and CEW-SR were the same and were 19.338% (Table 3).

Discussion

S. frugiperda larvae were recorded on the three maize varieties. The lowest number of *S. frugiperda* larvae were recorded on the variety EV8766-SR-MRP (3.00 ± 1.673 larvae), moderate for the variety PR9131-SR (5.50 ± 2.510 larvae) and highest number on the variety CEW-SR (9.17 ± 1.602 larvae). These results could be explained by a lowest reproduction of *S. frugiperda* on the variety

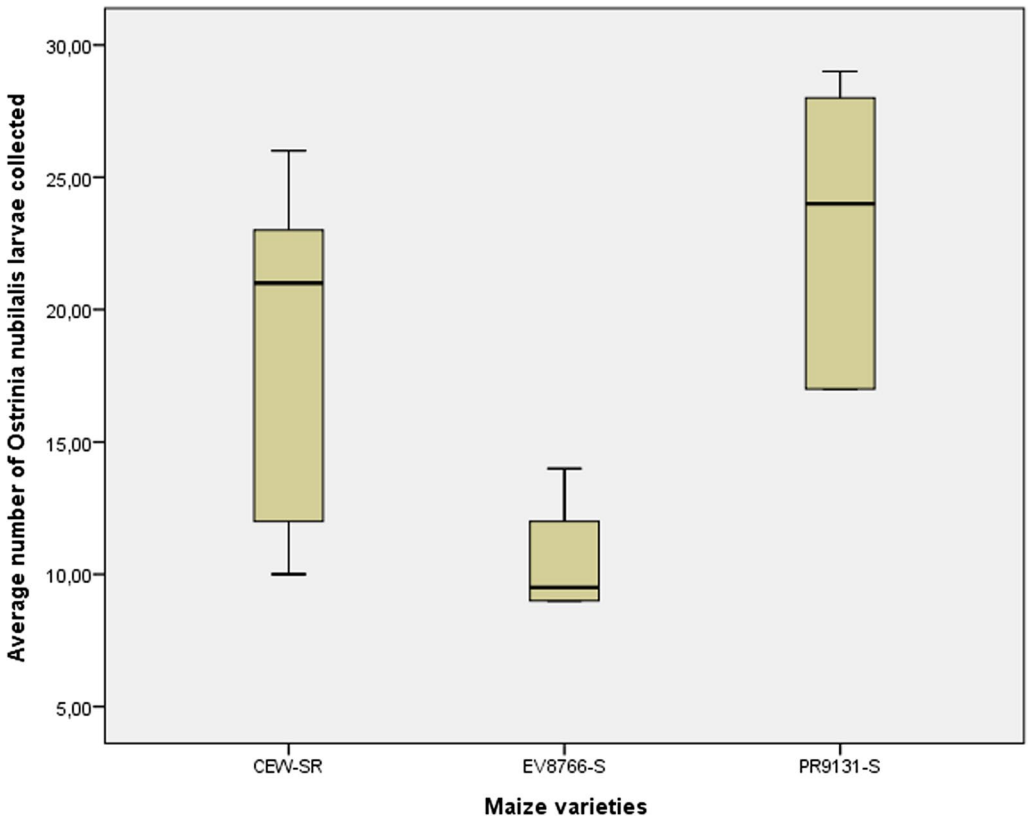

Fig. 3 Average number of *Ostrinia nubilalis* larvae recorded per 100 cobs of each maize variety

EV8766-SR-MRP. The density of *S. frugiperda* larvae per infested maize plant was similar for the three varieties EV8766-SR-MRP (1.139 ± 0.590 larvae/plant), PR9131-SR (1.261 ± 0.236 larvae/plant) and CEW-SR (1.667 ± 0.223 larvae/plant). These densities were lower than those obtained by Jamil et al (2021). According to these authors the density of *S. frugiperda* larvae on maize plants were between 2.70 ± 0.33 and 3.4 ± 0.40 larvae per maize plant infested in Malaysia. This difference would be linked to the highest temperatures during the night in the Tonkpi region which influences the reproduction of *S. frugiperda*. According to Assefa (2018), mating, spawning and hatching of *S. frugiperda* eggs take place only at night, between 6.00 pm to 11 pm, where temperatures were lower.

Damage by the larvae of the armyworm *S. frugiperda* was observed on the three maize varieties from the third to the fifth week after emergence. The larvae of *S. frugiperda* attack the leaves and creates holes in the leaves. The imago is active during the night. Similar results were reported by several authors such as Evans and Stanly (1990), Kouakou et al. (2009) and Konan et al. (2023). Damage to maize plants by *S. frugiperda* larvae ranged from 23 to 55%. The lowest attack rate on maize plants by *S. frugiperda* larvae was obtained with EV8766-SR-MRP (23.33%) compared to the other two varieties PR9131-SR (43.33%) and CEW-SR (55%). The lowest attack rate on the variety EV8766-SR-MRP was due to its resistance to *S. frugiperda* attack, which could explain the lowest reproduction of *S. frugiperda*. Indeed, insect larvae have difficulties for developing on plants with resistance characters (Chen et al. 2009; Goldstein et al. 2010; Razze et al. 2011; Romeis et al. 2019). The intensity of attack by *S. frugiperda* larvae on maize plants was lower on maize variety EV8766-SR-MRP and moderate on maize varieties PR9131-SR and CEW-SR. Indeed, maize variety EV8766-SR-MRP significantly reduced the number of maize plants damaged by *S. frugiperda* larvae compared to the other two varieties tested, PR9131-SR and CEW-SR. The lowest attack intensity on the variety EV8766-SR-MRP (7.5%) by *S. frugiperda* larvae classifies these larvae as non-dangerous pests for this variety.

Ostrinia nubilalis larvae were the pests of the cobs and milky kernels of all three varieties of maize. The number of *O. nubilalis* larvae collected from 100 cobs were between 10 and 25 larvae. The number of *O. nubilalis* larvae collected from the cobs of mature maize was lower in the EV8766-SR-MRP

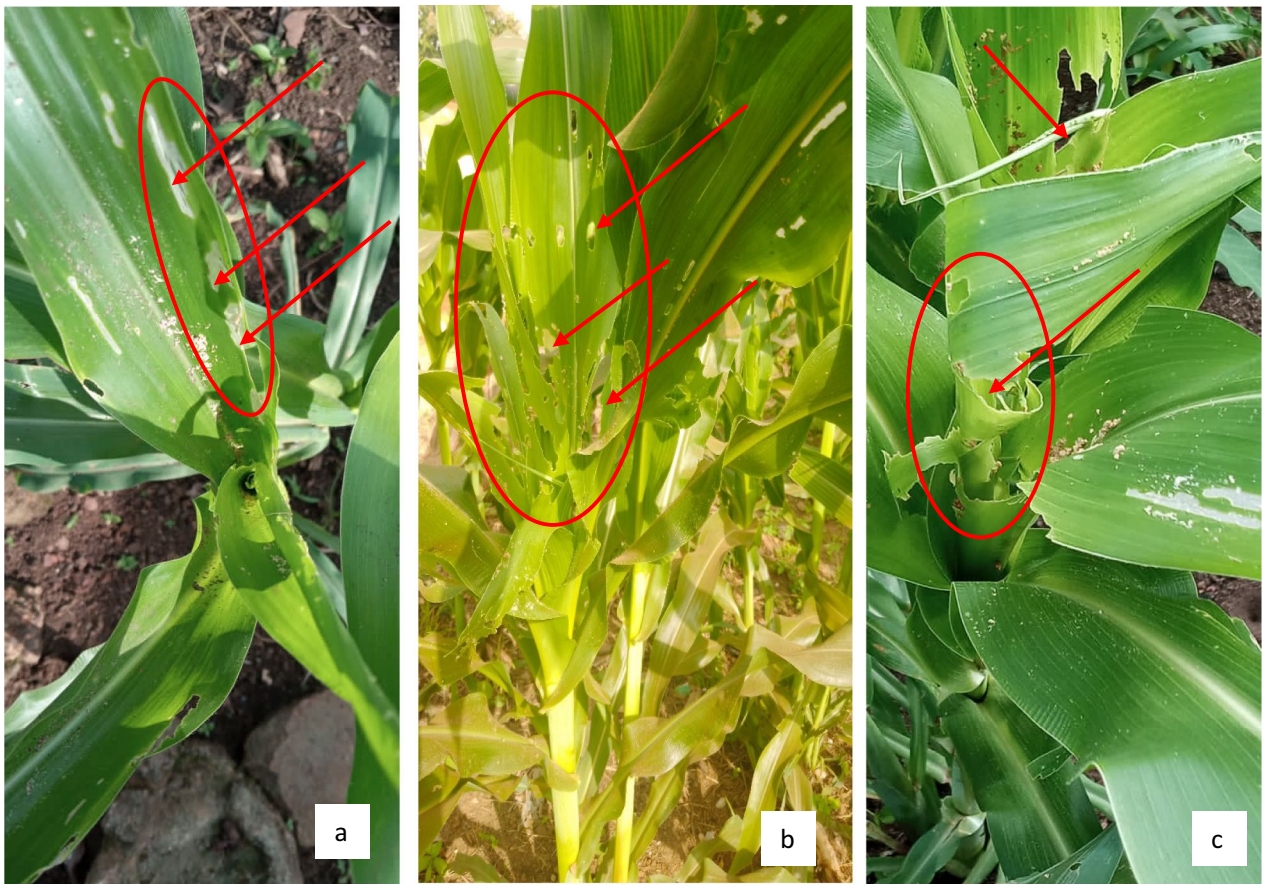

Fig. 4 *Spodoptera frugiperda* larvae damage to leaves of three maize varieties (a: EV8766-SR-MRP, b: PR9131-SR and c: CEW-SR)

Table 1 Attack rate and damage intensity index on maize plants by *Spodoptera frugiperda* larvae

Maize varieties	Average number of healthy plants/10	Average number of damaged plants/10	Damage rate (%)	Damage intensitification index (I) (%)
EV8766-SR-MRP	7.67a ± 1.633	2.33b ± 0.633	23.33 b	7.50b
PR9131-SR	5.67b ± 1.633	4.33a ± 1.633	43.33a	15,42a
CEW-SR	4.50b ± 0.548	5.50a ± 0.547	55.00 a	21.67a
F	8.195	8.195	8.195	10.648
P	0.004	0.004	0.004	0.001

SE = Standard error.

The means assigned to the same letter within the same column are not significantly different (Fisher test (LSD), $p < 5\%$).

variety (10.50 ± 2.073 larvae) and higher for the varieties PR9131-SR (23.17 ± 5.776 larvae) and CEW-SR (18.83 ± 6.369 larvae). The lowest proliferation of *O. nubilalis* on the variety EV8766-SR-MRP could be linked to the resistance of the variety EV8766-SR-MRP against *O. nubilalis*. Indeed, insect larvae have difficulty staying on plants that show resistance characters (Goldstein et al. 2010; Kasoma et al. 2020; Li et al. 2020). The density of *O. nubilalis* larvae per cob attacked was statistically identical for the three varieties EV8766-SR-MRP (1.111 ± 0.194 larvae/plant), PR9131-SR (1.061 ± 0.087 larvae/plant) and CEW-SR (1.083 ± 0.041 larvae/plant). These results were in agreement with those of Trotus et al. (2018), who showed that the density of larvae on maize cobs ranged from 1 to 2 per maize cobs damaged.

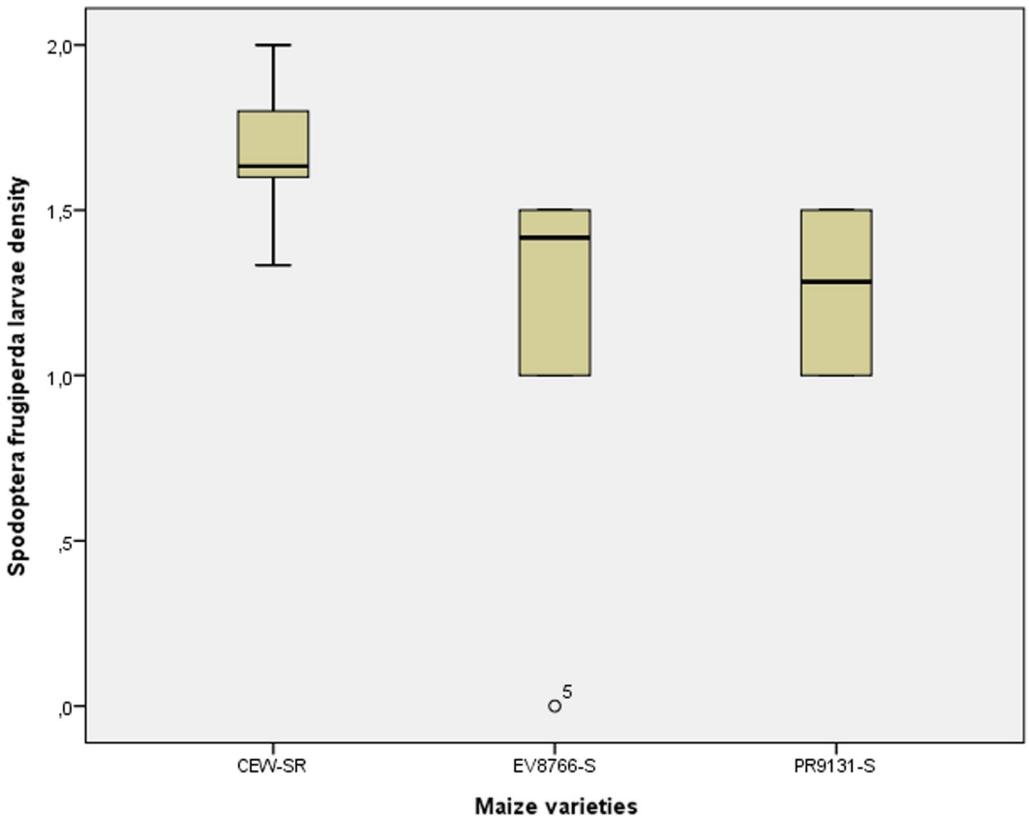

Fig. 5 Density of *Spodoptera frugiperda* larvae on maize plants

Damage rates by *O. nubilalis* on cobs of the three varieties ranged from 9.6 to 22%. These damage rates were lower than those of Pintilie et al. (2022), who obtained damage rates ranged from 23 to 33%. The maize variety EV8766-SR-MRP, with a rate of 9.66% of cobs attacked, significantly reduced the number of cobs attacked by *O. nubilalis* larvae compared to the other two varieties PR9131-SR (21.83%) and CEW-SR (17.50%). These rates are lower than those obtained by Piesik et al. (2013), who obtained 53.5 to 76% of ears attacked by *O. nubilalis* larvae in maize fields. The maize variety EV8766-SR-MRP (9.66%) would be the most resistant variety to the attacks of *O. nubilalis* larvae compared to the varieties PR9131-SR (21.83%) and CEW-SR (17.5%). The presence of *O. nubilalis*, only at the heading stage, would be due either to its attraction by the hormones produced by the maize plant during this stage, or to their interest in maize grains.

Yield losses by *S. frugiperda* and *O. nubilalis* were between 10.2 and 19.4%. These two insect pests reduced both the quality and yield of maize. The lowest crop losses were obtained with the variety EV8766 SR-MRP (10.228%). The varieties PR9131-SR and CEW-SR had similar crop losses of 19.338%. These crop losses were lower than those obtained by Piesik et al. (2013) in a maize farm. According to these authors, yield losses ranged from 29 to 42%. *O. nubilalis* larvae damage was observed on the mature cobs of the three maize varieties. According to Pintilie et al. (2022), *O. nubilalis* is one of the dangerous pests of maize which causes production losses by the attack on the cobs. In fact, *O. nubilalis* females lay their eggs on maize cobs. The larvae hatch from the eggs. Then, *O. nubilalis* larvae eats the grains on the cobs. It creates galleries and cause severe damage. *S. frugiperda* larvae feed on maize leaves, creates holes on the leaves, reduces maize plant's nutrient and therefore reduce photosynthesis and the yield.

Conclusions

The number of maize plants attacked, the damage rate of maize plants and the number of *S. frugiperda* larvae recorded on maize plants were lower for the maize variety EV8766-SR-MRP compared to the varieties PR9131-SR and CEW-SR. The intensification index of maize plant damaged by *S. frugiperda* larvae for the EV8766-SR-MRP variety were lower and moderate for the varieties PR9131-SR and CEW-SR. The number of maize cobs attacked, the maize cobs attack rate and the number of *O.*

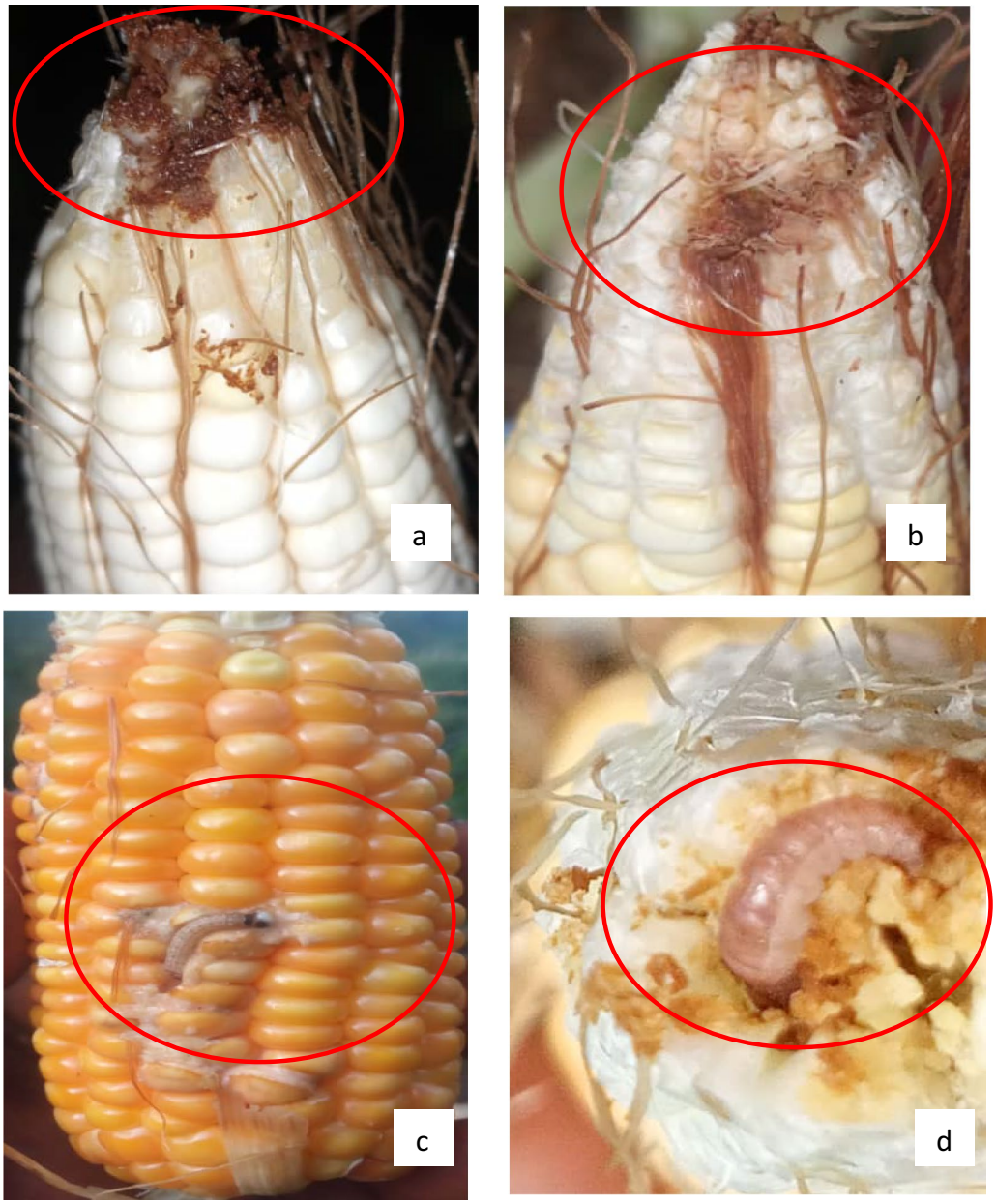

Fig. 6 Maize cobs damaged by the corn borer *Ostrinia nubilalis* Hübner (a: CEW-SR, b and c: EV8766-SR-MRP, d: PR9131-SR)

Table 2 Average number of healthy and attacked cobs and, the damage rate of maize plants by *Ostrinia nubilalis* larvae per 100 cobs harvested

Maize varieties	Average number of healthy cobs	Average number of damaged cobs	Damage rate (%)
EV8766 SR-MRP	90.33a ± 2.338	9.66b ± 2.338	9.66b
PR9131-SR	78.16b ± 5.307	21.83a ± 5.307	21.83a
CEEY-SR	82.50b ± 6.1887	17.50a ± 6.188	17.50a
F	6.516	9.516	9.516
p	0.002	0.002	0.002

SE Standard error

The means assigned to the same letter within the same column are not significantly different (Fisher test (LSD), $p < 5\%$)

nubilalis larvae collected from the maize cobs were significantly reduced for the EV8766-SR-MRP variety compared to the varieties PR9131-SR CEW-SR and CEW-SR. The density of *S. frugiperda* larvae per maize plant attacked and of *O. nubilalis* per maize cobs attacked were similar for the three varieties EV8766-SR-MRP, PR9131-SR and CEW-SR. Crop losses were lower for the EV8766 SR-MRP variety compared to the PR9131-SR and CEW-SR varieties. It would be important to propose integrated control methods from the EV8766-SR-MRP variety for better management of these two maize pests.

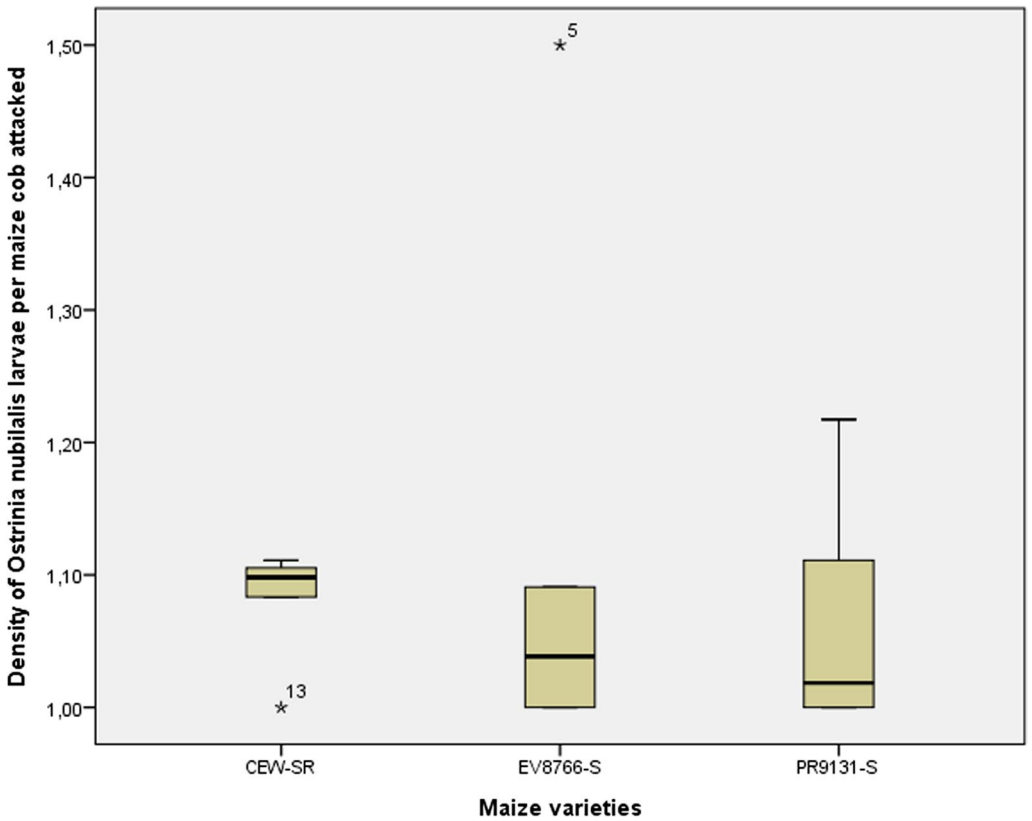

Fig. 7 Density of *Ostrinia nubilalis* larvae per attacked cob for the three maize varieties

Table 3 Weight of attacked cobs by *Ostrinia nubilalis* and yield loss due to *Spodoptera frugiperda* and *Ostrinia nubilalis* larvae

Maize varieties	Weight of healthy cobs (kg)	Weight of attacked cobs (kg)	Weight of 100 cobs harvested (kg)	Weight loss (%)
EV8766 SR-MRP	25.00a ± 1.843	2.833b ± 0.823	27.833a ± 1.469	10.228b
PR9131-SR	20.41b ± 0.735	4.950a ± 1.321	25.367b ± 1.593	19.338a
CEW-SR	18.91b ± 2.792	4.517a ± 1.154	23.433b ± 1.794	19.338a
F	15.401	3.184	11.059	4.218
p	0.000	0.07	0.001	0.035

SE Standard error

The means assigned to the same letter within the same column are not significantly different (Fisher test (LSD), $p < 5\%$)

Abbreviations

ANOVA	Analysis of variance
DTx	Damage level
FAO	Food and Agriculture Organization
IBM	International Business Machines Corporation
SPSS	Statistical Package for the Social Sciences
SE	Standard Error
°C	Degree centigrade
USA	United States
XLSTAT	Statistical Software for Excel
EV8766-SR-MRP, PR9131-SR and CEW-SR	Maize varieties

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Author contributions
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Availability of data of materials
The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

Declarations

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Not applicable.

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Competing interests
The authors declare that they have no competing interests.

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