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Influence of the Season on Armyworm (Spodoptera frugiperda J.E. Smith) Attacks on Some Bio-fortified maize (Zea mays L.) Varieties Introduced in Kisangani Eco-region (Democratic Republic of the Congo)

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Abstract: *The present study was conducted in the Kisangani region of the northeastern Democratic Republic of Congo in 2018-2019. The objective was to evaluate the influence of the seasons in the face of armyworm attacks on the behavior of three new biofortified maize varieties being introduced in the Tshopo Province. These trials were conducted using a split plot design with three replications and the results were analyzed using R Studio version 3.6 statistical software. The results at (p<0.05) show that all three varieties were attacked by armyworms. The overall average incidence was significantly similar to that of the control. During two cropping seasons, the maize varieties tested showed variable armyworm attack rates: Yellow Plata (14.16%) SAM4 VITA/A (18.05%) SAM4 VITA/B (16.44%) and PVA SYN-18 F2'' (14.66%). As for the variation of attack between seasons, the results of the statistical analysis showed that season B had a higher attack rate (25.54%) than season A (6.11%).*
Keywords: *season; attack rate; armyworms; Biofortified maize; Kisangani*

I. Introduction

It was in 2016, that alerts on the emergence of the fall armyworm [Spodoptera frugiperda Smith, 1797(Lepidoptera: Noctuidae) were launched in Kambove in the province of Haut-Katanga and Libenge in the province of South- Ubangi. From there, the Democratic Republic of Congo (DRC) was rapidly colonized by infestations of this fall armyworm (CLA). It is a highly polyphagous insect, preferentially developing on the maize crop (Mukwa, 2018).

From the observations made by these missions, it appears that CLA was already present in all of the areas surveyed. At least 400 hectares were already ravaged in Libenge territory alone in South Ubangi Province and 600 hectares in Kambove territory in Haut Katanga (Minagri et al., 2017). Preliminary results from the 2017-2018 agricultural season in the DRC indicate that losses caused by CLA attacks are enormous. They are estimated at 64%, or 1.68 million tons of maize, equivalent to a financial loss of 617,400,000 USD. If no additional control action is taken against this caterpillar, the losses may worsen and reach greater proportions (Mukwa, 2018).

However, the current CLA situation in DRC is not well elucidated due to lack of actual damage assessments and insufficient information available. Considering the importance of maize for food production and the current increase in CLA attacks, Tshopo province should be among the priority provinces for intervention. Thus, it is necessary to strengthen the capacity of farmers to reduce yield losses caused by this pest (FAO-CD, 2018). Observations made in Tshopo province show that CLA attacks vary according to season and maize varieties under cultivation.

The objective of the present study was to evaluate the influence of season in the face of CLA attacks on some maize (Zea mays L.) varieties biofortified in introduction in the Kisangani eco-region (DRC). During this research, it was hypothesized that the new improved biofortified maize varieties would be resistant to CLA attacks and would give higher yields than local varieties. To confirm this hypothesis, the specific objectives of this research were to identify maize varieties from CIAT-Harvest-Plus that would be well adapted to the edaphoclimatic conditions of the Kisangani eco-region and would be less susceptible to CLA attack.

II. Research Methods

2.1 Setting

The choice of the village of Malimba is mainly dictated by the fact that maize is one of the main crops and occupies a considerable place in the population's diet. Malimba is one of the localities in the territory of Banalia, located 31 km from the city of Kisangani, the capital of the Tshopo Province.

District and location of the study area

The study area is located in the Territory of Banalia in the Province of Tshopo in the North East of the Democratic Republic of Congo, where the GPS coordinates of the experimental field are: 00° 42' 47.3" North Latitude, 025° 15'43.8 East Longitude, Altitude 381m.

Being in the Tshopo Province, the locality of Malimba is therefore located in the equatorial climatic zone influenced by the Af type climate according to Köppen's classification, dominated by abundant rainfall and constant humidity, with rainfall varying between 1800 and 2000 mm per year. Although it rains all year round, the rainfall is distinguished by two periods: the period of low water due to the decrease in precipitation (November, December, January, February) and the period of flooding due to the increase in precipitation.

In this nomenclature, "A" designates a hot climate with an average temperature of over 18 °C and "f" designates a humid climate with no absolute dry season and where the monthly rainfall in the driest month is over 60 mm.

The rainy year is divided into two cropping seasons: from January to July (Season A) and from August to December (Season B). Thus, the soil is of sandy-clay type, sometimes swampy, suitable for agricultural activities. The vegetation is formed essentially by Chromolaena odorata and Tithonia diversifolia. Crossed by two rivers, the forests of Malimba are in a state of degradation, particularly due to overexploitation of wood (Source: personal observations).

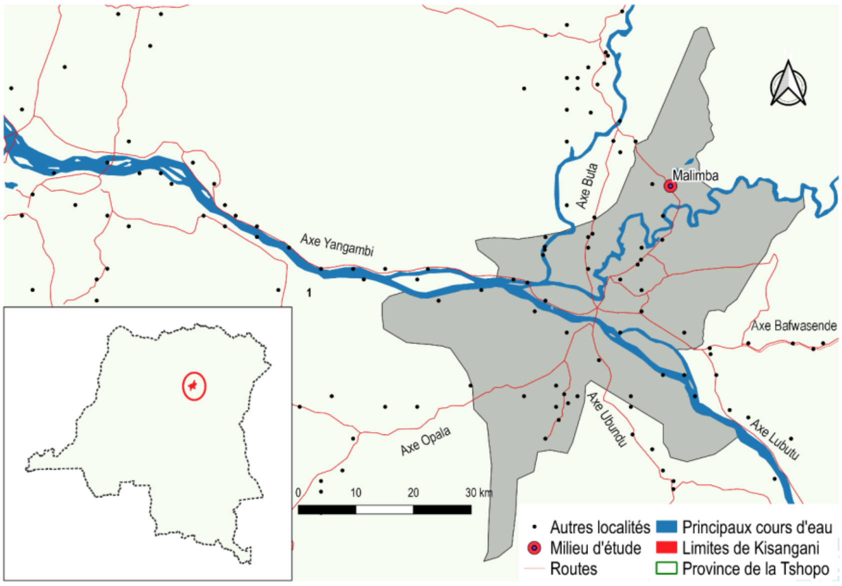

Figure 1. *Study Environment*

The climatic conditions that prevailed during the trial are recorded in Table 1 below:

Table 1. Climatic Data for the Experimental Period

Crop seasons / **Climatic parameters**		**2018**			**2019**			
		November	**December**	**January**	**February**	**March**	**April**	**May**
		Trial 1			Trial 1			
Precipitation	Quantity (mm)	150	145	146	268,8	556,6	393,4	665,8
	Number of rainy days	10	7	2	5	8	11	11
Temperature	Max (°C)	28	22	32	34	32	32	31
	Average (°C)	26	18	20,5	20	26	26	25
	Min (°C)	24	21	20,1	19	21	21	21

Source: Mini-station installed at the experimental site

2.2 Plant Material

The materials consisted of three biofortified maize varieties with yellow-orange grains, one of which was introduced by the International Institute of Tropical Agriculture (IITA), (PVA SYN- 18 F2), the other two were developed by CIMMYT - Zimbabwe (SAM4 VITA/ A; SAM4 VITA B) and were distributed in DRC by CIAT-HarvestPlus. They are tolerant to biotic factors with a good and average resistance to armyworms of Composite-Synthetic varieties (resulting from multiple crossing) enriched in provitamin A, Zinc and Iron. They have an average yield in real environment ranging from 3.5 to 5 tons/ha adapting to different agroecologies (Low, Medium and High Altitude). These exotic varieties are among those newly introduced in DRC on the basis of their agronomic performance. And a local variety (Plata Jaune) served as a control. It is a local variety with yellow, horny grains, with a sweet taste, easy to grind, rich in amino acids. Its cultural cycle is 3 months and it bears one to two ears per plant. It is the variety widely cultivated in the Kisangani region with a yield of 800 to 1000 kg/ha (SENASEM, 2008).

2.3 Methods

This study was conducted during two cropping seasons, namely in season B (mid-November-2018). The choice was made for this period of the year for its short rains (less than 30 days of rainfall) to coincide with the flowering period with the decrease in rainfall. In season A2019, (mid-March) the choice was made for this period of the year for its long and abundant rains.

The experimental design used was a split-split design with three replications. Two factors were used; the main factor, season, consisted of two levels, namely cropping season B2018 and cropping season A2019. The sub-factor, variety, consisted of four levels: M0, a local yellow-grained variety used as a control. M1, M2 and M3 represent respectively the varieties SAM4 VITA A, SAM4 VITA B and PVA SYN- 18 F2 for a total of 48 experimental plots of 4m x3m per season. The distances were 1.5m between plots and 2m between blocks. Each plot consisted of 5 rows of 6 patches in total 30 patches for each plot. The corn was grown according to the requirements of the experimental design and under all the good agronomic conditions required in corn production, for a vigorous growth of the crop.

The sowing was manual at the distances of 80 cm between the rows and 50 cm in the row. Three grains were put in each poquet for a total of 90 grains per plot. After emergence, the plants were dismantled in pairs to make the different plots homogeneous, i.e. 2880 plants for the whole study. Two sarclo-buttings were done manually to control weeds.

Phenological observations

During growth, observations were made on vegetative parameters:

- Emergence rate was determined by the ratio of number of emerged plants/number of seeds sown x100.
- Diameter at the collar (cm) measured with a caliper.
- Plant height (cm) measured with a tape measure.
- The leaf area (cm2) was obtained by assigning a corn correction factor of 0.70.

2.4 Yield Analysis

Yield was determined by the unit area of 1.2 m² at harvest on six feet located in the center of the plots and expressed in tons per hectare (t/ha).

2.5 Epidemiological Parameters

The measurements of the epidemiological parameters consisted in making daily observations on the infestation of all the plants three weeks after emergence, by actually observing the presence of larvae and by counting the total number of attacked feet. These larvae are collected according to the plots that constitute the block, and are stored in the box. The larvae collected in the box were used to determine the density of the infestation. The density of caterpillars is obtained by counting all the feet on a plot carrying caterpillars

The rate of infestation in the plot was evaluated by applying the following formula:

$$Infestation\ rate = \frac{\text{Number of plants attacked}}{Total\ number\ of\ plants} X100$$

The number of attacked leaves was used to determine the severity. The observation was carried out on all the leaves which led to assess the infestation rate on the plants. The Davis scale used varies from 1 to 9 and is adapted to the conditions of our study. Healthy plants have a severity index of 1.

Attacked plants have an index varying from 1 to 9, from the least to the most severe. This scale led to the rating of the severity of the symptoms as follows:

- Degree 1: Only pinhole damage
- Degree 2: Pinhole and circular damage on the leaves
- Degree 3: Small circular and elongated lesions, rectangular in shape and reaching a maximum of 1.3 cm
- Degree 4: Several elongated lesions of 1,3 to 2,5 cm size present on some leaves and rolled up
- Degree 5: Large elongated lesions of 2.5 cm in length on leaves and small and irregular holes
- Degree 6: Presence of several lesions on several whorled and rolled leaves and presence of large irregularly shaped holes
- Degree 7: Presence of numerous elongated lesions of all sizes on leaves and large holes of identical and irregular shape
- Degree 8: Presence of numerous elongated lesions of all sizes on almost all leaves and numerous holes of identical or irregular shape, medium to large size
- Degree 9: The whorled and rolled leaves are almost totally destroyed

Figure 2. *Categories of Leaf Damage Commonly Observed in the Field*

2.6 Data Processing and Statistical Analysis

The data processing of the different parameters studied (phenology, growth parameters, phytosanitary parameters and yield) was carried out with the help of Excel spreadsheet. This spreadsheet was also used to draw the tables. The analysis of variance (ANOVA) was performed with the statistical software R Studio version 3.6. The Fisher's Least Significant Difference (LSD) test was considered for the classification of the means at the 5% threshold in case of significant difference.

III. Discussion

3.1 Results

The detailed results of the influence of season on the vegetative parameters of the trials as well as the variation of CLA incidence according to variety and season are recorded in Tables 2 and 3.

Table 2. Vegetative Parameters of 4 Maize Varieties from the Experimental Site

Varieties	Emergence rate (%)	Diameter at crown (mm)	Plant height (cm)	Leaf area (cm²)
M_0	95,33	2,20	244, 37	600,86[a]
M_1	90,83	2,28	245,50	580,97[a]
M_2	95,70	2,26	237,25	530,97[b]
M_3	95,45	2,22	239,25	539,99[b]
Average	94,33	2,24	241,60	563,20
LSD	3,86	0,06	16,86	30,93
Cv (%)	10,08	6,90	9,22	9,50

Table 2 indicates that the emergence rate of the seeds varied from 91 (M1) to 96% (M2) with an overall average of 94%. This shows that the germination power of the seeds used was good and slightly higher than that recommended by the National Seed Service (SENASEM, 2008).

The diameter at the collar varied from 2.2 to 3 mm while the height of the plants varied from 237 to 246 cm. The maize plants tested in Kisangani showed a height greater than that observed in the high-altitude regions (79 cm).

Leaf area ranged from 531 to 601 cm2 greater than that observed in the high-altitude area.

Table 3. Influence of the Season on Vegetative Parameters

	Paramètres			
Seasons	Emergence rate (%)	Diameter at crown (mm)	Plant height (cm)	Leaf area (cm²)
B	95,35[a]	2,40 [a]	257,02 [a]	585,38[a]
A	93,31[a]	2,08 [b]	226,29 [b]	541,01[b]
Average	94,33	2,24	241,65	563,20
LSD	5,40	0,08	9,00	21,80
Cv (%)	10,00	6,90	9,20	9,50

The reading of this table indicates that the three varieties of maize compared are significantly different in terms of vegetative parameters. On the other hand, the difference is observed at the level of emergence rate whose average is 94.33% followed by diameter at the collar 2.24 cm while the height of the plants varied from 241.65 cm exceeding that observed in the altitude zone.

Table 4. Variation of CLA Incidence According to Variety and Season at 5% Threshold

Varieties	**Incidence (%)**	**Number of caterpillars per plant**	**Abundance**
M_0	14,16[a]	10[a]	36[a]
M_1	18,05[a]	15[a]	51[a]
M_2	16,44[a]	10[a]	35[a]
M_3	14,66[a]	8[a]	28[a]
LSD	10,87	7,30	25,40
Variation between seasons			
season **B**	**25,54[a]**	**18[a]**	**62[a]**
season **A**	**6,11[b]**	**3[b]**	**13[a]**

Average	**15,83**	**10,75**	**37,26**
LSD	**7,69**	**5,20**	**18,00**
Cv(%)	**119,60**	**119,40**	**119,00**

The results recorded in the table above show respectively that the incidence of CLA on the local variety was 14.16% compared to the three new varieties in introduction. Compared from the point of view of incidence, we notice that the variety PVA SYN- 18 F2" (M3) is weakly attacked that is to say 14,66% while the variety Sam4Vita A (M1) relatively more attacked that is to say 18,05%. Moreover, during the two cropping seasons, the highest incidence was recorded in season B (25.54%) and the lowest in season A (6.11%), with an average of 15.83% for both seasons.

3.2 Discussion

a. Biofortified Maize Showed High Vegetative Growth in Kisangani

The results of the analysis of variance showed that there is a difference between the three biofortified maize varieties tested with respect to vegetative parameters compared to the local variety (yellow Plata). In the current context of climatic disturbances, the early flowering varieties are the most recommended. As for the height of the plant, these three varieties expressed a superior height in Kisangani. As maize is a megatherm plant, its preferred area is normally the hot lowlands. Like most tropical Poaceae, maize has a C4-type photosynthetic metabolism, which gives the plant a higher efficiency than temperate Poaceae in converting light energy (Gallais, 1984; Gay, 1984). Maize is a short-day plant, whose tropical varieties are often photoperiodic. In the variety choice criteria, Nyembo (2010) suggests the diffusion of small-sized varieties and this criterion would facilitate the adoption of these three varieties in introduction. Indeed, tall varieties are susceptible to lodging (Useni et al., 2012; Nyembo et al., 2013) and the ears of lodging-susceptible plants fall, rot or are ravaged by termites especially in the tropical zone constituting a loss of harvest (Ilunga et *al.*, 2016). However, the increase in size can induce high production (Mohammadi et al; 2003) especially in the absence of strong winds.

In addition, the varieties showed a higher average emergence rate (94.33%) than that obtained by Useni et al. (2013) on the Babungo variety (88.9%) in Katanga province. This may be due to the better germination power of each variety. However, in our conditions in Kisangani, the maximum emergence rate obtained would be due to the better adaptation of the improved varieties to extreme conditions and its varietal plasticity that secures the production (Nyembo, 2014).

b. Biofortified Maize has Adaptive Potential to Climate Change

Improved seeds make it possible to make better use of other agricultural production factors such as fertilization, irrigation and mechanization. In addition to tolerance to abiotic factors, the introduced varieties have revealed their capacity to adapt to different agrosystems. This reveals that the ecological conditions that prevailed during the trial (rainfall, temperature) strongly influenced plant height. This implies that the development of new varieties should not only be oriented towards the sole objective of productivity but also towards adaptation to climate change.

Regarding the average height of maize plants, the results obtained showed that the influence of the genotype was more masked by that of the environment. Indeed, the large amounts of rainfall positively influenced the growth of the plants in height. However, the difference in similarity observed between the varieties is probably due to the season. In crop season B, the number of rainy days (24 days) or 441mm and the amount of water harvested during the trial appeared to be lower than crop season A 2019 (58 days) or 3360mm. It has been shown that maize requires a lot of water, due to its high biomass. Norman et al, (1995) found that the water requirement of the maize crop in the plains is at least 500 mm of well-distributed rainfall throughout the season.

As for leaf area, the leaf area index of the plants was significantly affected by the water regime during the B cropping season.

The reduction in leaf area could be explained by a reduction in leaf size and number of green leaves due to early senescence under very limited water conditions.

Lebon (2006) showed that the decrease in leaf area under the water-limited regime is an adaptive mechanism of plants to limit their leaf transpiration when water conditions become unfavorable. This is not the case for our results.

However, the comparison of the varieties between them shows that the varieties under evaluation showed a similar behavior to that of the local variety.

c. The incidence of CLA decreases with Rainfall Abundance

This observation explains the difference between our two study seasons from a climatic point of view. Two elements explain this variability: temperature and rainfall. All epidemiological parameters that explain the incidence of CLA are associated with these two elements. With temperature extremes of 21 to ± 34°C, the Kisangani region (low altitude) is a more favorable environment for CLA. The degree of attack is average on both biofortified varieties and the local variety.

Among these three varieties, the PVA SYN- 18 F2" (M3) is weakly attacked and the two varieties Sam4Vita A (M2) and B (M1) relatively more attacked, it is the same for the abundance of caterpillars and the number of caterpillars per plant between these three varieties. According to the studies of Sisay et al. (2019), the incidence varied from 5 to 100% while the severity of damage on leaves varied from 1.8 to 7.0 Our observations coincide with that of Louis Looli et al. (2021), found in the same study area an incidence rate of 64.5 - 75.5% for a severity of level 7 (50-75% of leaves attacked per infested plant).

The high incidence observed in season B is related to the lack of rainfall and preceded by a short dry season during which there is less rainfall. As a consequence, wild alternative plants are still present and allow a relay between the populations of two seasons. For this reason, one can observe the high rate of populations from season B to season A.

While the low incidence is observed during season A, the explanatory hypotheses are the abundance of rain and the long dry period in the environment. According to our personal observations, a lot of rain, less infestation: CLA caterpillars remain on the surface of the plants. In case of heavy rains, the washout effect creates a high mortality due to caterpillars being washed away by the driving rain.

This effect is also recorded in corn stalk borer caterpillars during their migration from one stalk to another, the larvae always hide between the whorled leaves (funnel) to infest the plants at night (Day et al., 2017). Heavy rains fill the whorled leaves with water and cause mortality, especially in young CLA larvae. Similar observations were noted in Early et al. (2018). Indirectly, rains cause larvae to fall to the soil level where eventual contact is made with entomopathogenic microorganisms.

d. The Flowering Stage of Corn is Vulnerable to Armyworm

Baudron et *al.* (2019) found a range of other parameters that influence the incidence and severity of CLA on maize crop among which, cultural practices, varieties and chemical use, are important parameters. It is shown in this study that the flowering stage is the most attacked by CLA. These results are explained by the climatic variability observed in recent times, causing disruptions in the agricultural calendar in the study area. In view of this situation, early and late planting of maize is carried out. This leads to overlaps in the CLA cycle and the damage becomes significant. In contrast, Baudron et al. (2019) found no effect of sowing date on CLA damage. Considering the CLA severity rating scale proposed by

Davis et al. (1992), It is possible to determine the losses caused by CLA in terms of management and production (Abrahams et al., 2017; Baudron et al., 2019).

As for the question of judging the abundance of CLA individuals harvested, the average of 38 caterpillars confirms differences between the two seasons in case of attacks. However, the average number of adults harvested decreases with time. This is due to the climatic conditions of the environment and also to the growth of maize. According to Mitchell (1979), the number of CLA adults present in an area is influenced by many factors such as the time of year, abundance and distribution of its wild and cultivated hosts, cropping pattern, climate and dispersal in the area.

IV. Conclusion

The present work contributed to study the influence of season on armyworm attacks on three new biofortified maize varieties being introduced in Kisangani. The objective was to select varieties with a high capacity of adaptation to CLA attacks for a large-scale diffusion.

As a result of this study, the overall average incidence was significantly similar to that of the control. It was found that the biofortified maize tested in Kisangani showed a higher vegetative growth than the growth observed in the high-altitude areas. Climatic factors are believed to be the basis for this growth performance. These introduced maize varieties show potential for adaptation to climate change. Also, the infestation level of the armyworm decreases with precipitation and varies with the cropping season. The flowering stage of maize is the most vulnerable stage for CLA infestation. Our study indicates that in view of the climatic changes observed in the last decades, the A season is the most favorable for maize cultivation in the Kisangani region.

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