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Simulation of Fall Armyworm (*Spodoptera frugiperda*) Attacks and the Compensative Response of Quality Protein Maize (*Zea mays*, var. Mudishi-1 and Mudishi-3) in Southwestern DR Congo

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Abstract

In this paper, to assess the varietal ability to compensate defoliation damage caused by the fall armyworm, a trial was carried out at the INERA Mvuazi research center. The aim of this study was to determine the limit threshold of damage that could cause the significant loss of the harvest of the quality protein maize distributed in the Democratic Republic of the Congo. To do this, three factors including two varieties (Mudishi-1 and Mudishi-3) of quality protein maize, four rating damage and two growth stages were used into a factorial design with 3 replications. Simulation of damage caused by FAW consisted of cutting of blades for all visible leaves of plants. Damage rates simulating leaf destroying were 0%, 25%, 50%, 75% and 100%, occurring at two growth stages: stage V3 (2 to 4 weeks after emergence) and stage V7 (flowering stage). Results showed that damage factor combined with growth stage factor significantly influenced ($p < 0.05$) the yield component variables including yield losses, harvest rate, ear sizes, number of ears harvested and yield as well as the market quality of the ears, based on appearance quotation. Damage rate more than 50%, at all growth stages studied, caused grain losses upper than 50% regardless of variety. However, damage less than 50% at V3 stage resulted in grain losses under 10%. At the end of this study, we showed that the varieties of maize QPM (Mudishi-1 and Mudishi-3) would be able to compensate the damage caused by the FAW and achieve its yield, if the attacks damaging 25% of the leaves occur during V3.

Subject Areas

Agricultural Science

Keywords

QPM, Yield Losses, Growth Stage, FAW, Rate Damage

1. Introduction

Fall armyworm (FAW) *Spodoptera frugiperda*, is a lepidopteran pest native to the tropical and subtropical regions of the Americas [1] [2].

FAW larval stage can completely defoliate seedling and early-vegetative stage of maize plants, stunt plant growth, or kill seedlings [3] [4] giving them a shredded appearance [5] when it is not properly managed. FAW prefers maize, but can feed on more than 80 additional plant species, including rice, sorghum, millet, sugarcane, vegetables such as cabbage, salad, eggplant, pepper and cotton [5] [6]. The pest feeds inside whorls and can destroy silks, panicles and developing grains reducing yields through direct losses, exposure of ears to infections and loss of quality and quantity of grain [5]. But the foliar damage caused by FAW in many cases does not result in dramatic yield reduction [7]. A quantification of the potential yield losses is still speculative, as many variables come into play between FAW infestation and yield reduction [6].

Different levels of damages have been reported from different countries [8] [9] [10]. But rarely, those damages levels are related to the yield losses except some scanty studies [7] [11] [12]. Yield loss could be lower due to climatic factors, the constitution of natural enemies or improved management [13].

Fall armyworm (FAW) *Spodoptera frugiperda* (J.E. Smith) invaded Africa in 2016 [14] [15]. Native to tropical and subtropical regions of the Americas [16], FAW presence is now confirmed in 45 African countries [13]. It is causing significant damage to maize crops, threatening therefore, the livelihood of farmers who rely on maize production [17].

[18] estimated the impact of FAW between 22% and 67% of the yield respectively in Ghana and Zambia, resulting in losses in millions of US dollars. Similarly, [19] estimated the impact of FAW at 32% of yields in Ethiopia and 47% in Kenya. These estimations, however, are based on socio-economic surveys focused on farmers' perceptions, but not on rigorous field scouting methods [11]. Average loss of maize reported by farmers in Ghana was 26.6% and 35% in Zambia. This is much less than what was reported in 2017.

According to an unpublished survey report from the Ministry of Agriculture, Fisheries and Livestock (MINAGRI), 800,000 ha of maize fields had been devastated by this pest in 87 of 150 territories in 2017. Based on a rough estimate of around 500 hectares affected by territory, the DRC could see up to 25,000 hectares of maize affected, representing more than US$20 million in losses for local populations [6]. Following the financial statistics, these losses represent a significant risk in terms of food and nutritional insecurity because they also represent 250 million meals [6].

The response of maize yield to damage caused by FAW has been studied in the field several times on the American continent. A review of the study on the response of maize yield to damage caused by FAW has shown that, although cause for concern, the damage of FAW in maize is not devastating. Despite FAW attacks, damaged maize plants are able to compensate for leaf damage, especially if nutrition and moisture soil conditions are good [20]. Although some studies have shown yield reductions of more than 50% due to FAW, the majority of trials have shown yield reductions of less than 20%, even with a high FAW infestation, up to 100% of infested plants [21].

The aim of the present study is to assess the ability to compensate for leaf damage caused by FAW at two growth stages of quality protein maize under growing conditions in south-west DRC.

2. Materials and Method

2.1. Experimental Site, Analyzes and Characteristics of Soils

Trial was conducted during the 2018-2019 growing season, from October 25, 2018 to March 14, 2019 at Mvuazi research center of the National Institute for Agronomic Study. Mvuazi is located at 14˚54' East longitude and 5˚21' South latitude, at 470 m of altitude (**Figure 1**).

The soil of Mvuazi belongs to the Sudano-Guinean climatic zone of AW4 type [23]. This soil is characterized by a low organic matter content and a low water retention capacity, resulting to a low availability of nitrogen [24] and the orthic soil type [25] (**Table 1**). The climatic data recorded during the experimental period are presented in **Table 2**.

2.2. Plant Material

Varieties Mudishi-1 (M1) and Mudishi-3 (M3) selected by the National Maize

Table 1. Selected chemical and physical parameters for soils of experimental site.

Parameters (u[10]Nit)	*Soil pH*	*P*1 (*ppm*)	*K* (*ppm*)	*Ca* (*ppm*)	*Mg* (*ppm*)	*Mn* (*ppm*)	*S* (*ppm*)	*Cu* (*ppm*)	*B* (*ppm*)
Results	5.76	14	105	1505	229	55	23	12.30	0.21
Guide Low	6.00	30	268	1651	165	100	20	2.00	1.00
Guide high	7.00	100	537	2064	264	250	200	10.00	2.00
Parameters (u[10]Nit)	*Zn* (*ppm*)	*Na* (*ppm*)	*Fe* (*ppm*)	*CEC* (*meq*/100 g)	*OC* (*meq*/100 g)	*Silt* (%)	*Sand* (%)	*Clay* (%)	*N* (%)
Results	7.98	47	194	13.76	4.07	13	49	39	0.21
Guide Low	4.00	0	150	15.00		30	30	20	0.20
Guide high	20.00	158	350	30.00		50	55	55	0.50

Table 2. Climatic data recorded during the experimental period.

Year	2018	2018	2018	2019	2019	2019
Month	*October*	*November*	*December*	*January*	*February*	*March*
TMax (˚C)	30.76	30.95	29.63	21.68	30.95	31.98
TMin (˚C)	20.3	21.55	21.46	28.10	21.33	21.23
Rain (*mm*)	179.1	252.90	197.70	100.90	435.30	60.50
Nber. of rain [18] *Days*	9	10.00	7.00	6.00	16.00	3.00
Rel. hum (%)	74.85	79.96	82.41	80.32	81.99	74.24
T.mean (˚C)	25.52	26.23	32.56	26.05	26.11	26.36

Tmax = Temperature maximal, Tmin = Temperature mi[10]Nimal, Rain = Rainfall, Rel.Hum = Relative humidity, T.mean = Temperature mean.

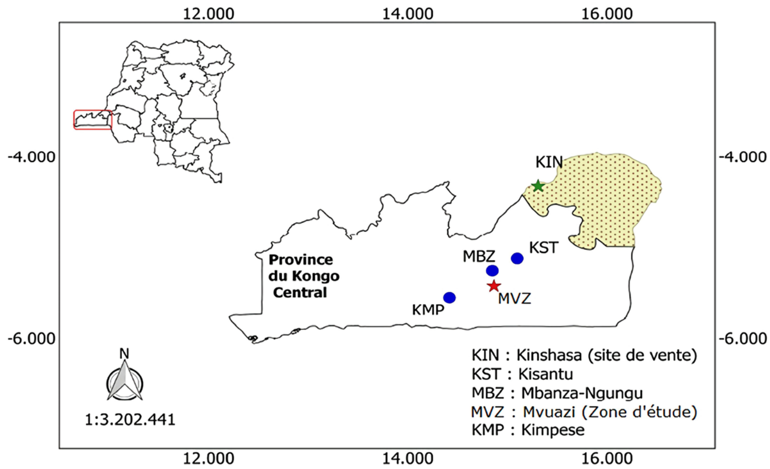

Figure 1. Geographic location of the INERA Mvuazi Research Center (source: [22]).

Program of INERA, are cultivated in the most of agro-ecological zones of the DRC. They are preferred for their resistance to leaf diseases, to root and stem lodging, their yield potential of 4 to 6 t/ha [26] and their high rate in lysine and tryptophan [27].

2.3. Experimental Design and Treatments

The factorial experimental design with 3 replications and 3 factors was used (**Figure 2**). The first factor (percentage of damage by cutting the blade of leaves) consisted of five levels, namely 0% (no damage, which corresponds to the controls), 25% (leaves having lost the 25% of the blade), 50% (leaves having lost the half of the blade), 75% (leaves having lost 75% of the blade) and 100% (leaves having lost all of the blade). The second factor (growth stage) consisted of two levels: V3 and VT as defined by McWilliams *et al.* (1999), V3 which corresponds to defoliation at the 2 - 4 week after emergence and VT which corresponds to defoliation at the stage of flowering. The third factor (variety) was made up of two levels: M1 and M3. The maize plants have been sown at 0.75 m × 0.50 m spacing with 2 seeds per hill in the 1.50 m × 2 m plots.

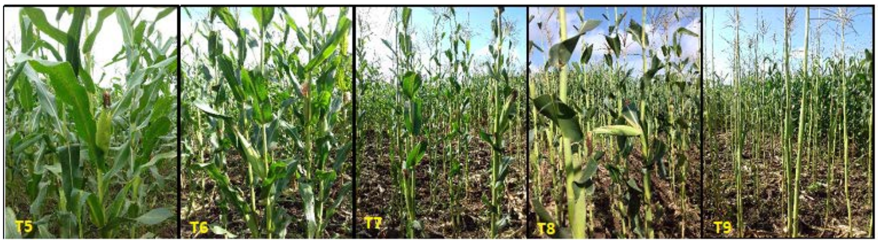

Figure 2. Simulation of defoliation by cutting the blade at 0%, 25%, 50%, 75% and 100% at stage VT.

The combination of percentage of damage (factor in sub-sub-plot), stages of growth (factor in sub-plot) and variety (factor in plot) allowed a total of twenty (20) treatments:

T0.1 (M1:0%:V3), **T0.2** (M3:0%:V3), **T1.1** (M1:25%:V3), **T1.2** (M3:25%:V3), **T2.1** (M1:50%:V3), **T2.2** (M3:50%:V3), **T3.1** (M1:75%:V3), **T3.2** (M3:75%:V3), **T4.1** (M1:100%:V3), **T4.2** (M3:100%:V3), **T5.1** (M1:0%:VT), **T5.2** (M3:0%:VT), **T6.1** (M1:25%:VT), **T6.2** (M3:25%:VT), **T7.1** (M1:50%:VT), **T7.2** (M3:50%:VT), **T8.1** (M1:75%:VT), **T8.2** (M3:75%:VT, **T9.1** (M1:100%:VT), **T9.2** (M3:100%:VT).

2.4. Data Collection

Data collected concerned observations made on some parameters relating to yield performance were:

- Number of plants per useful plot (without borders)
- Number of ears harvested per useful plot
- Percentage of harvest: Number of ears of corn harvested from number of plants per plot multiplied by one hundred
- Percentage of marketable ears based on quotation of appearance: number of healthy ears (not attacked) on number of ears harvested multiplied by one hundred, the quotation scale of appearance of ear is from 1 to 5 where 1 = excellent, 2 = good, 3 = fairly good, 4 = not good and 5 = poor) [26]
- Ear diameter (mm)
- Ear length (cm)
- Yield: was measured in kilogram/m^2 following the formula here beyond.

$$\text{Yield} = (\text{FW} * (100 - \text{FGM}/100 - \text{DGM}) * (\text{GW}/\text{EW}) * (1/\text{UA})) \quad (1)$$

where:

FW: Field Weigh
FGM: Field Grain Moisture
DGM: Dry Grain Moisture
GW: Grain Weigh
EW: Ear Weigh
UA: Useful Area

- Grain loss (%): weight of the grains of a treatment with damage on weight of grains of the control without damage multiplied by a hundred.

Statistical analyzes:

The collected data were analyzed using packages agricolae and FactomineR of R3.1.3 software to determine difference among treatments by analysis of variance following the linear model $(aov(y \sim Trait3 * Trait2 * \ Trait1 + error\ (replication / Trait\ princ))$ with respect to various growing and yield parameters. The means of treatment that exhibited significant differences were separated using the least significant difference (LSD) post-hoc test. A principal component analysis (PCA) to detect the correlations between the variables studied.

3. Results and Discussion

3.1. Analysis of Variance of Study Parameters

Table 3 shows the effects of factors and their interaction on characteristics parameters observed during plant growth and yield parameters.

With regard to Table 3, it can be seen that the damage caused by defoliation, the growth stage and their combined effect influenced significantly ($p < 0.05$) the number of ears harvested, the ear sizes (diameter and length), the harvest rate, the percentage of marketable ears, the yield and the yield losses. No significant difference ($p > 0.05$) was observed between treatments for the number of plants per plot. However, the variety factor and most of its effects interacting with the other factors did not directly influence ($p > 0.1$) the yield as well as the components of the yield (loss, harvest rate, marketable ears, size of ears).

3.2. Principal Component Analysis (PCA)

PCA was performed on 8 active variables characterizing the treatments based on the data of the combination of factors. More than 87% of variability are represented on the plane formed by two exes Dim1 and Dim2 (Figure 3(A)). Dim1 is characterized by strong correlations between variables. This dimension benefits from the strong contributions of variables linked to productivity, including loss, yield, harvest rate, ear size, number of ears harvested. Losses are greatest when yields are low, however the other variables correlate positively with each other variables. Dim2 is characterized only by the number of plants

Table 3. Analysis of variance.

Factors	*Nber of Plant*	*Nber of Ear Harvested*	*Ear Diameter (mm)*	*Ear Lenght (cm)*	*Ear Market %*	*Harvest %*	*Yield (kg/m^2)*	*Loss %*
Var	0.108	0.004835**	0.41	0.772865	0.85085	0.0160*	0.157555	0.1931
Dmg	0.112	1.14e−07***	1.21e−08***	7.18e−07***	0.00125**	1.54e−15***	0.000187***	1.12e−07***
Gstp	0.831	0.000534***	0.000154***	0.000282***	0.00884**	5.89e−10***	0.000953***	0.0124*
*Var * Dmg*	0.500	0.593354	0.512405	0.513076	0.31872	0.6571	0.631025**	0.6244.
*Var * Gstp*	0.943	0.277669	0.615947	0.285471	0.84882	0.0969.	0.978240	0.1523
*Dmg * Gstp*	0.631	5.53e−06***	8.67e−08***	3.03e−07***	0.00846**	1.35e−13***	0.000456***	0.0441*
*Var * Dmg * Gstp*	0.732	0.545530	0.279982	0.701105	0.48768	0.6835	0.807966	0.4680

Sig[10]Nif. codes: 0 "***" 0.001 "**" 0.01 "*" 0.05 "." 0.1 " " 1, Var = Variety; Dmg = Damage; Gstp = Growht stape; V3: 3 to 4 weeks after sowing; VT: Flowering stage.

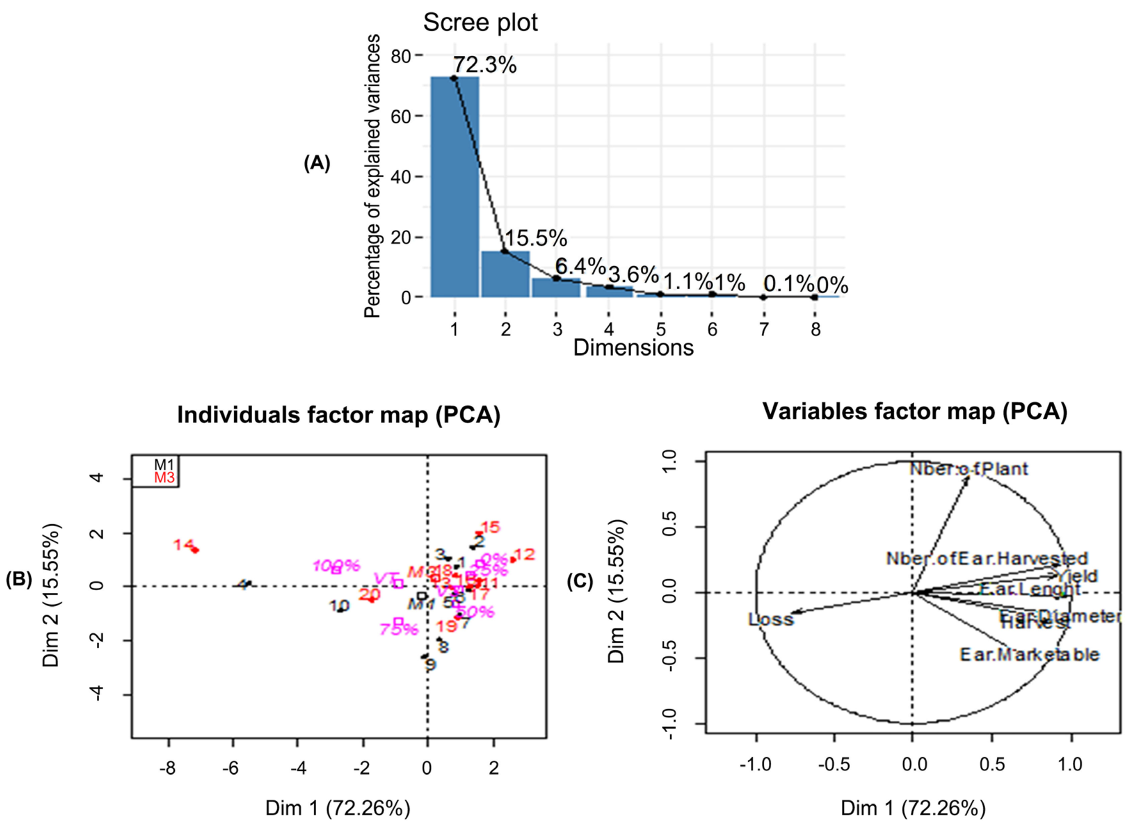

Figure 3. A. Scree plot, B. Individuals factor map and C. variable factor map according to PCA.

per plot (Figure 3(C)). Less dispersion of varieties was observed around two axes (Figure 3(B)). However, there was a large dispersion of the damage rate factor compared to two axes. Based on the contributions of the factors on Dim1 (Figure 3(B)), it seems that the two varieties M1 and M3 combine similar values of the variables studied. However, there is a wide dispersion in damage rates.

3.3. Number of Plants per Plot

For all factors taken individually and in interaction of factors, the number of plants per plot varied from 5.33 to 9.66 plants respectively for T3.1 and T1.2 (Table 4). The results of analysis of variance showed non-significant effects ($p > 0.05$) of factors and interactions between factors on the number of plant per plot. However, there were noticeable variations between the factors resulting in a large coefficient of variation. These variations should be linked to variety effects ($p = 0.1$) by looking at Table 3.

3.4. Number of Ears Harvested

Regardless of variety, the number of ears harvested per plot varied significantly between the factors and interactions studied. The highest number, 9.66 ears per m^2, was recorded at T1.1 and the lowest number, 0 ears per m^2, was recorded at T9.2. In general, the low numbers of ears harvested were recorded for two varieties subjected to 100% of defoliation at flowering stage (VT). High numbers of

Table 4. Comparative study of growing, yield and yield losing variables.

Treatment	*Nber of Plant/plot*	*Nber of Ear Harv/plot*	*Ear Diameter (mm)*	*Ear Lenght (cm)*	*Ear Marketable* (%)	*Harvest* (%)	*Yield* (*kg*/*m*²)	*Loss* (%)
*T*0.1	7.66abcd	7.00abcdef	46.82a	15.79a	40.52cde	92.50bcd	0.24ab	0.00g
*T*0.2	7.33abcd	8.33abc	44.66a	15.53a	55.92abcde	114.28a	0.27ab	0.00g
*T*1.1	7.33abcd	6.33bcdef	48.07a	14.29ab	72.22abcd	86.90bcde	0.22ab	8.44fg
*T*1.2	9.66a	**9.66a**	44.47a	15.37a	61.85abcde	100.00abc	0.28ab	43.31cdef
*T*2.1	6.66bcd	6.66bcdef	46.06a	13.45abc	84.12ab	100.00abc	0.22ab	8.00fg
*T*2.2	8.00abcd	8.00abcd	46.52a	14.65ab	84.12ab	100.00abc	0.27ab	49.83cdef
*T*3.1	5.33d	4.66ef	46.50a	13.39abc	90.47a	92.59bcd	0.20bc	55.33bcde
*T*3.2	7.00abcd	7.00abcdef	47.16a	15.81a	90.47a	100.00abc	0.27ab	75.88abcd
*T*4.1	8.33abc	7.00abcdef	43.69a	15.12a	50.99bcde	85.00cde	0.28ab	38.30cdefg
*T*4.2	7.33abcd	7.33abcde	45.33a	15.70a	57.61abcde	100.00abc	0.22ab	34.17defg
*T*5.1	8.66ab	8.33abc	48.69a	16.49a	45.50bcde	95.83bcd	0.22ab	0.00g
*T*5.2	8.66ab	9.00ab	48.61a	**17.29a**	76.38abc	100.33ab	0.35a	0.00g
*T*6.1	7.66abcd	7.33abcde	48.41a	16.35a	73.33abc	95.23bcd	0.29ab	50.53cdef
*T*6.2	7.66abcd	7.33abcde	48.63a	16.39a	73.14abc	94.44bcd	0.30ab	21.70efg
*T*7.1	5.66cd	5.66cdef	46.15a	14.59ab	77.77abc	100.00abc	0.18bcd	25.26efg
*T*7.2	8.00abcd	8.33abc	46.46a	14.48ab	60.33abcde	100.33ab	0.20bc	41.62cdefg
***T*8.1**	**6.00bcd**	**4.33f**	**37.06a**	**8.95cd**	**30.00ef**	**74.60e**	**0.05de**	**76.91g**
***T*8.2**	**7.00abcd**	**5.33def**	**41.21a**	**10.33bc**	**50.00bcde**	**79.36de**	**0.07cde**	**78.73abc**
***T*9.1**	**7.00abcd**	**0.33g**	**16.90b**	**5.00b**	**33.33def**	**3.70f**	**0.01e**	**93.89ab**
***T*9.2**	**7.33abcd**	**0.00g**	**0.00c**	**0.00e**	**0.00f**	**0.00f**	**0.00e**	**100.00a**
CV	24.3	25.65	16.95	21.10	39.20	12.22	41.41	64.60
LSD	2.9	2.7	11.77	4.68	39.10	17.36	0.14	42.78

ears harvested were associated with low damage rates at three weeks after sowing (V3). No damage (0%) to flowering resulted in the maintenance of a high number of ears harvested per plot. Decrease in number of grain on the ear (cob) was probably the result of floral primordial or a slight pollination of the dichogamy [28]. Both varieties had a high yield in treatments without defoliation. This situation can be explained by the fact that in maize, the grain yield is determined by the quantity of silk and by the length of the period during which the sensitivity is very high [29] [30] [31].

3.5. Diameter and Length of the Ear (Cob)

The averages of diameters of the ears were appreciably affected by the factors caused damage, stage of growth and their interaction. These averages varied between 0 mm and 47.1 mm respectively for T4.2 and T3.2. Low values of ear diameter were recorded for high damage rates during the flowering stage (VT). Similarly to the ear diameter, the ear length was significantly influenced by the same factors. Length values varied between 0 and 17.29 cm respectively for T9.2 and T5.2. [32] [33] observed that defoliation decreases the size of the ears and it seems that the weight of the grains is more dependent on the genetic factor than on the environmental factor. Following [33], ear length and weight had a positive and significant correlation with all treatment. However, [34] observed that defoliation had non-significant effect on ear length.

Based on results, length ear decreased by 12% to 100% in VT treatments, where as other treatments do not have significant effect on ear length (**Table 4**). These results are in agreement with the finding of [35]. It is indicated that ear length is most affect by some factor such as defoliation time, intensity of defoliation and position of leaves on the plant [36] [37].

3.6. Marketable Ear Rate

Marketable ear rates varied between 0% and 90.47% respectively for T9.2 and T3.1, T3.2. Most of the healthy ears were harvested under V3. **Figure 4** shows the appearance quotations of the ears rated from 1 to 5 compared to the treatment corresponding to flowering stage. The ears of the plants that did not loosed leaves (0%) had a quote = 1, which is marketable. Plants treated with 25% damage produced ears with a quote score of 1.5 to 2. Plants treated with 50% damage showed ears quoted 2.5 to 3.5. As for the plants treated at 75% of damage, the quotation was 3.5 to 4, while the full defoliated plants (100%), ears had a quotation greater than 4.5, reducing significantly the rate of ear marketable.

3.7. Harvest Rate

Regarding **Table 4**, is appears that the best harvest rates were recorded after treatments before flowering stage or at V3. The damage caused at stage V3 had no negative effects ($p > 0.05$) on the production of grain. Low harvest rates (0.00% and 3.70%) were recorded respectively in treatments T9.2 and T9. [35] also reported damage to the silk of maize at 50% until 10 days later, which reduced yield by reducing the number of ears after 20 days or more, the yield was reduced by reducing the weight of a thousand grains. Various reports also indicated that a partial defoliation of about 25% to 33% did not change the weight of the seeds at any stage of seed development.

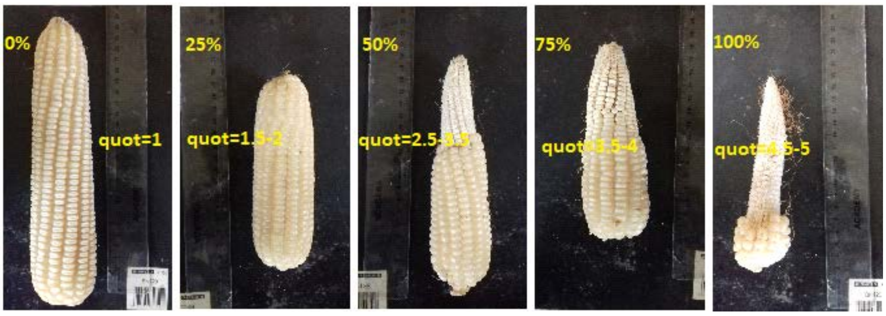

Figure 4. Damage rate (0%, 25%, 50%, 75%, 100%) and ear quotation (quot = 1 to 5).

3.8. Grain Yield

Estimated per m^2, this yield varied between 0.00 kg/m^2 and 0.35 kg/m^2 respectively for T9.2 and T5.2 (**Table 4**). The best productivity was recorded at the control treatment corresponding to 0% damage at V3 and VT. Productivity per m^2 was significantly affected ($p < 0.05$) by damage rate and growth stage. Varieties used did not influenced the yield after two periods of simulated attack.

Several biotics and abiotics stresses affect the yield of maize through defoliation. [38] reported that the critical rate of defoliation in maize was 50%; this rate did not affect grain yield and its components.

In accordance with the study made by [39] on sunflowers (*Helianthus annuus* L.), the yield has been greatly reduced by defoliation at the pre-flowering stage. This is similar to complete defoliation was more detrimental and caused yield loss of 6.4% to 82% compared to partial defoliation with loss of yield of 1.5% to 32.7%. These losses varied with the time of application of the treatment.

Still according to [35], the yield component most affected by leaf loss, for the entire treatment period, was the grain weight decrease from 12.7% to 53%. However, the number of grains was considerably reduced by 62.3% when all the leaves were removed 10 days after the appearance of the silk. Thus, the partial leaf removal affected the number of grains much less, approximate decline, 20%. According to [33], the maize plant in complete defoliation had the lowest grain yield, ear weight, number of rows per ear, ear weight and 100 grain weight, but had a percentage, higher grain germination rate and high vigor.

According to [40], the reduction in grain yield was associated with the number of defoliated leaves and this reduction was linked to the decrease in grain number. Based on the results of the trial, early defoliation in the reproductive phase causes yield losses by reducing the number of grains [41].

3.9. Grain Yield Losses

The average of grain yield losses (loss) varied between 0% and 100% regardless to varieties. These values corresponded respectively for 0% of damage and 100% of damage occurring at two growth stages. The losses observed were associated with the high damage rates and they are more accentuated with the damage caused during the flowering stage (VT).

According to [42], percentage yield loss is depending on factors such as on the amount of removed leaves, leaf position on plant and also defoliation time. This hypothesis can be explain by [43], who suggested that the near leaves to ear are main factor of increasing dry matters and growth rate during the development.

This study showed that a significant loss of leaves at the beginning of silk and up to at least 10 days after 50% of silk had resulted in a reduction in grain yield due to the reduction in the number of grains and regardless of the severity, defoliation in the days after the appearance of the silk considerably reduced the accumulated dry matter [35]. However, the yield declines associated with less severe leaf loss or leaf loss at least 20 days after 50% silk were largely related to a decrease in grain weight. In addition to providing a better understanding of the patterns of dry matter accumulation, these data can be useful for individuals who are required to estimate grain yield after significant loss, due to natural causes, of the leaf area of the plant [35].

4. Conclusion

Results of this study showed that cutting of leaves decreases yield because of diminishing of number of grains. In addition, some variables including ear (cob) sizes, percentage of harvest and rate of ear harvested, are decreased at upper than 25% of defoliation. According to stage of growth imposed on plant, (V3) or (VT), the most change caused by defoliation seen on traits related to yield such as rate of ear harvested, rate of ear marketable and this cause to decrease in yield. This indicates the early reproductive phase specially flowering and pollination is more sensible to any harmful factor to leaves. Concerning the simulation of FAW attacks, the defoliation around 75% or total defoliation at 100% at stage V3 and VT would be the critical threshold, because they induce negative effects on the yield causing losses of more than 50%. Full defoliation severely reduced the grain yield and affected its marketability. However, simulations of less than 50% of damage, occurring at growth stage V3, caused losses of less than 10%. Varieties Mudishi-1 and Mudishi-3 would be able to compensate for losses due to damage up to 25%, occurring at stage V3.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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