Journal of Experimental Agriculture International

40(6): 1-12, 2019; Article no.JEAI.51285
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Evaluation of Susceptibility of Some Sorghum (*Sorghum bicolor* L. Moench) to Stem Borers in Far North Region of Cameroon: A Case of Off Season Local Varieties

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Authors' contributions

This work was carried out in collaboration among all authors. Author JD designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors PN and ENN managed the analyses of the study. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2019/v40i630382
Editor(s):
(1) Dr. Sławomir Borek, Professor, Department of Plant Physiology, Adam Mickiewicz University, Ul. Umultowska 89, 61-614 Poznań, Poland.
Reviewers:
(1) Suprakash Pal, Uttar Banga Krishi Viswavidyalaya, India.
(2) Taiye Hussein Aliyu, University of Ilorin, Nigeria.
Complete Peer review History: https://sdiarticle4.com/review-history/51285

Original Research Article

Received 12 June 2019
Accepted 07 September 2019
Published 19 September 2019

ABSTRACT

Introduction: Among cereals, Sorghum is the most consumed as food in the Far North of Cameroon. *Muskuwari*, which is an off season sorghum, plays a key role in the regulation of its availability. On the other hand, stem borers (*Sesamia cretica* Lederer) constitute a major constraint, compromise its yield and reduce cereal supply. Despite this fact, ecological control measures to reduce losses are still little known.

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Objective: The present research aimed at evaluating the susceptibility of ten local varieties of *Muskuwari* against Lepidoptera stem borers in natural conditions.
Place and Duration of Study: The study was conducted during the 2012 and 2013 agricultural campaign at Ngassa, a locality of Maroua.
Methodology: Experimentation was carried out in a Completely Randomized Block design with tree replications. Ten local varieties were then under natural infestations. Degrees of infestation were estimated by visual observation and destructive methods. Each year, Seed losses in term of percentage of total harvest loosed, were estimated from 30 ears per variety randomly selected from infested and uninfected plants.
Results: The results showed a large variation in agronomic performance depending on the parameters considered. *Mandouéri*, *Bourgouri*, *Tchangalari* and *Soukatari* with infestation rates ranging from 4% to 11% and seed losses ranging from 0.96% to 23.42% are more tolerant or less susceptible than other varieties while *Safra's* varieties are always the most susceptible to stem borers with over to 40% seed loss.
Conclusion: The study showed there are resistant or tolerant varieties of *Muskuwari* able to cope with the attacks of stem borers not exploited to mitigate damages. Degree of infestation, seed loss, number of caterpillars and gallery length per plant are suitable parameters for varietal screening of stem borer resistance. Since varietal resistance is an ecological and easily adoptable option, investigations that could lead to *Muskuwari* varietal improvement could boost cereal supplly in the Far North Region of Cameroon.

Keywords: Muskuwari; infestation parameters; Sesamia cretica Lederer; Diamaré-Maroua.

1. INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) is 5th cereal after wheat (*Triticum aestivum*), rice (*Oryza sativa*), maize (*Zea mays*) and barley (*Hordeum vulgare*). It forms with corn and millet (*Pennisetum glaucum* L.) the first dry cereal in the semi-arid tropics. It is produced in 86 countries over an area of 38 million hectares [1]. It is produced throughout the world for its seeds, sugar content and foraging qualities [2,3]. In the Far North of Cameroon, where sorghum (Muskuwari) is also produced in off-season without irrigation, it is the first cereal consumed as food. Muskuwari is therefore complementary to rainy season production of sorghum to regulate its availability. With the growing demand for cereals, a corollary of the fast growing population of African countries, considerable efforts are needed to increase production and conservation [4,5] around the world. *Muskuwari*, despite it is being produced in the dry season, is subject to attack by Lepidoptera stem borers, the main pests in the Sudano-Sahelian zone [6,7]. Without chemical measures, which is not always within the reach of African producers, the damage, which varies according to the agricultural season and cultural practices (date of transplanting, variety of sorghum, transplanting technique and climatic factors such as temperature and relative humidity), can go as far as the loss of more than 60% of production [8]. And yet alternative measures for the mitigation of damages are still poorly known. The use of resistant varieties is therefore a good option because of its practicality for farmers and its compatibility with other methods of pest control. This option is all the more effective as the selection is made among traditional varieties that have the advantage of being pre-adapted. Our main objective is to detect among the traditional varieties of Muskuwari the variety or varieties that can give good yield under natural infestations by Lepidoptera stem borers by the simple fact of presence of the natural defense mechanisms of the plant and to contribute effectively to establish an integrated pest management plan based on the varietal component.

2. MATERIALS AND METHODS

2.1 Experimentation and Data Collection

The experiment was carried out during the 2012 and 2013 crop years in a locality of the Diamaré Division. It consisted of transplantation in a Completely Randomized Block (BCR) with three replications of 10 local varieties of *Muskuwari*. These varieties, are *Mandouéri*, *Bourgouri*, *Soukatari*, *Madjérinon-crossé*, *Safranon-crossé*, *Soulkéri*, *Adjagamari*, *Safracrossé*, *TchangalariandMadjéricrossé* were selected for their dominance among the productive populations of North-Cameroon and could represent more than 90% of production. Each variety was represented in block by three rows of 45m long. The blocks were separated from each other by a distance of 2 meters. Plants of 40 days old, transplanted in pairs into holes about 8 cm deep previously filled with water, were eparated on the line by a distance of 90 cm and a meter between the lines. Weeding was done manually at two weeks and four weeks after transplanting. For each survey, data collection took place three months after transplanting, at the ripening or plant harvesting stage, Varietals infestation were evaluated as the proportion of plants infested per variety for each block. Thirty (30) ears were then randomly selected per variety and group (infested, uninfested) in each block. Holes on the stems of infested plants were counted, the length of the tunnels per plant measured and the juveniles of the present drillers collected and identified at species level. The ears were also beaten individually and the seeds weighed for the estimation of seed losses (SL) using by the following Walker [9,10].

$$SL\,(\%) = \frac{\text{Harvest in kg/ha of non infested plants} - \text{Harvest in kg/ha of infested plants}}{\text{Harvest in kg/ha of non infested plants}} \times 100$$

2.2 Data Processing and Analysis

The data was entered and ranked first using the Excel spreadsheet and analyzed using XLSTAT Software (Version 2013.5.08). After logarithmic (logn) transformations of non-normal distribution data, multi-factor Variance Analysis tests (varieties, bocs and years) followed by a Post hoc tests were performed at a 95% significance level. Multiple comparisons of averages using the Turkey (HD) test were then required to identify pairs of values that differed significantly at a 95% significance level. Principal Component Analysis (PCA) was required to verify the degree of potential interaction between the parameters.

3. RESULTS AND DISCUSSION

3.1 Degree of Severity of Infestation

The trial in Diamare, the main production area of *Muskuwari*, at a site chosen for its strong borer pressure, highlights the Safracrossé variety as the most infested with a 17% and 16% infestation rate respectively in 2012 and 2013. The *Mandoueri* and *Bourgouri* varieties showed the lowest levels of infestation with respectively 4% and 7% in 2012 and 5% for both varieties in 2013. The varieties *Madjeri non crossé* and *Soulkeri* record the same degree of infestation (8%) for both years (Fig. 1).

In conflicting plant-insect relationships several factors come into play for an inclination of the balance in favor of one or the other. Chemical factors such as the presence of secondary metabolites [11,12] and the physical characteristics of plants [13,14], which vary according to variety, lead to variability of performance according to the agro-climatic context. Varietal infestation levels could be explained by poor farming practices, such as single-crop production that promotes pest infestation as it is the case of off season sorghum. In a sugarcane field under natural infestation by the driller *Eldana saccharina*, Pené et al. Highlighted in 2016 [15] variable levels of infestation according to the nitrogen inputs to the eight commercial varieties, the highest level of infestation being observed with a high intake of nitrogen. Sorghum is of the same botanical family as sugar cane, the mineral content of the soil is rarely homogeneous from one point to another and the mobilization capacity of the minerals also varies according to the genotypes in the presence, it results on varying levels of infestation. These varietal behaviors would reflect levels of resistance of the different locla varieties of transplanted sorghum. Cheng et al. [16] evaluating the behavior of twelve varieties of rainfed sorghum for resistance to phytophagous *Diatraeagrandiosella* and *Spodoptera frugiperda*, showed a strong correlation between the level of resistance of the different sorghum lines and the soluble sugar content. anddhurrin in the leaves. The resistance of the lines was justified by the proportions of dhurrin and jasmonic acid of the different varieties. Thus, chemical and physical arrangements of the different varieties would also have induced varying levels of infestation. The resistance of a transplanted sorghum plant can be assessed at different levels of development and through several parameters (number of holes on the stems, number of caterpillars per plant, gallery length per plant),a plant resistant to a stage of its development may be susceptible to another.

3.2 Percentage of Dead Hearts

The larvae of the drillers, after hatching, feed on the young leaves of their host plants sometimes leading to the destruction of the terminal bud known as the dead heart. This phenomenon is at the origin of a decrease in the density of plants. The following table gives us the different average values.

This shows that the DH and SL levels varied and, depending on the year, the *Mandouéri* and

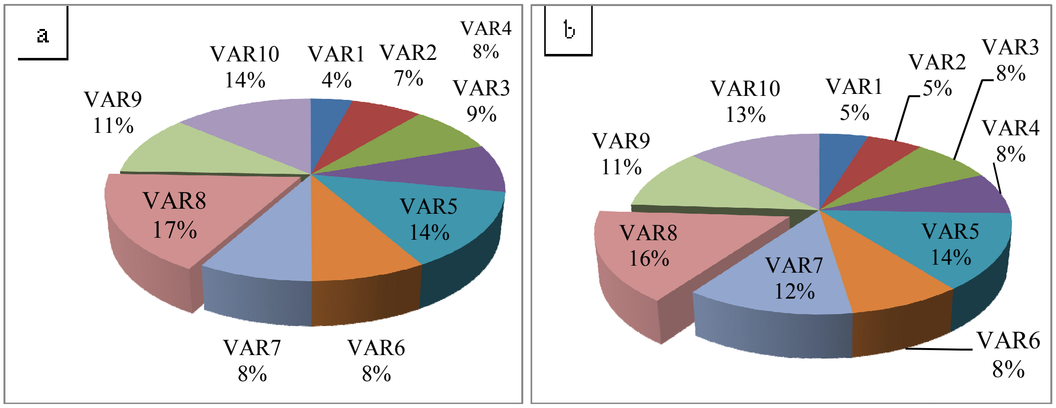

Fig. 1. Severity of the ten local varieties of transplanted sorghums (a in 2012 and b in 2013)
Legend: VAR1-Mandouéri; VAR2- Bourgouri; VAR3- Soukatari; VAR4- Madjérinon-crossé ; VAR5- Saf40 non-crossé; VAR6- Soulkéri; VAR7- Adjagamari; VAR 8- Saf40 crossé; VAR9- Tchangalari; VAR10- Madjéricrossé

Table 1. Percentage of dead hearts (DH) and seed losses (SL)

Sorghum varieties	% de DH 2013 /2012	% de SL 2013/2012
V1 - *Mandouéri*	4,58/6,21	3,49/10,94
V2 - *Bourgouri*	9,80/12,09	2,44/2,87
V3 - *Soukatari*	9,37/8,28	9,29/10,67
V4 -*Madjéri non-rossé*	10,68/9,80	10,23/12,29
V5 - *Saf40 non-crossé*	12,85/10,68	40,76/38,64
V6 - *Soulkéri*	10,35/10,78	18,62/23,42
V7-*Adjagamari*	22,33/21,02	13,16/18,53
V8- *Saf40 crossé*	10,24/15,90	37,89/39,06
V9-*Tchangalari*	13,51/14,16	7,25/0,96
V10- *Madjérirossé*	17,32/17,21	10,95/18,40

Bourgouri varieties with respective DH rates of 4.58% and 9.37% in 2013, 6.61% and 8.28% respectively in 2012, record the lowest rates of apical meristem destruction; on the other hand, the *Adjagamari* variety, which recorded 22.33% and 21.02% respectively in 2013 and 2012, stands out with the highest rates of destruction of apical buds. *Tchangalari*, despite an average rate of destruction of apical buds, has the lowest rate of seed loss (0.96 in 2012 and 7.25 in 2015). Renburg and Berg in 1992 [17] investigating on the types of damage ofborers on sorghum after emergence, also revealed a variation in the proportion of DHdepending on the varieties and the species of borers involved; *Muskuwari* begins its cycle as therainfed sorghum matures, thus ensuring host availability to the latest generation of drillers developed on rainfedthem. The production of *Muskuwari* involves transplanting the nursery to the production area, which would accentuate the development of DH because the plant at recovery is weakened physiologically. A strong correlation with the total number of larvae per plant has been demonstrated. Taneja and Leuchner [18] also demonstrated a strong negative correlation of this parameter with the yield and density of plants per unit area. For a varietal selection for driller resistance this criterion should primarily be put on the front line.

3.3 Number of Holes per Plant

In a multi-species infestation under natural conditions, multiple stem holes can result which can vary from one variety to another depending on the level of resistance of the plant. The following (Tables 2 and 3) respectively represent the results of analysis of variances of the mean values of the holes per plant in experimental station and the result of Post-Hoc analysis of these same mean values.

The mean values of the holes per plant have variances all statistically difference, p-value (<0.0001) being less than α = 0.05 (see Table 2). This reflects a disparity in the resistance levels of different varieties of transplanted sorghum. The Post-Hoc analysis shows that only the cross

Table 2. ANOVA analysis of average holes values per plant at a 95% confidence interval

Source	DDL	Sum of square	Average of square	F	Pr> F
Modèle	41	10543,381	257,156	5,648	< 0,0001
Erreur	1758	80036,019	45,527		
Total corrected	1799	90579,399			

Calculated against the model Y = Mean (Y)

Table 3. Post-hoc analysis of average values of the number of holes per plant at 5% degree of signification

Source	DDL	Sum of square	Average of square	F	Pr> F
Year	1	266,805	266,805	5,860	0,016
Block	2	171,148	85,574	1,880	0,153
Varieties	9	7846,605	871,845	19,150	< 0,0001
Year*Block	2	181,303	90,652	1,991	0,137
Year*Varieties	9	260,156	28,906	0,635	0,768
Block*Varieties	18	1817,363	100,965	2,218	0,002

effect of the experimental year and the block showed statistically significant differences at 95% significance level (p-values = 0.002). These results highlight, on the one hand, the various levels of antibiosis of the different varieties and, on the other hand, the influence of climatic factors on the agronomic and biological performances of plants and their pests. Since each biological species has an ecological preference for an optimum expression of each of its life traits, depending on the climatic variations and the levels of resistance of the plants to pest attacks, the damage will also be significant. The graph of variations in the mean values of the holes above allows us to identify the varieties *Tchangalari* and *Safranoncrossé* as the varieties having a lower mean hole value ranging from 9.88 to 11.06 during the two years whereas, the *Soukatari* variety has always had the highest average value over the two years (16.62 in 2013 and 17.2 in 2012). These values were also very close statistically to those recorded over the two years by the non-crossbred *Madjeri* varieties (10.19 in 2013 and 11.03 in 2012) and *Adagamari* (12.34 in 2013 and 12.10 in 2012).

The paired comparison of the average hole values recorded in 2013 and 2012 for the different traditional varieties of transplanted sorghum, using the Tukey test (HSD) and a 95% confidence level (Table 4) allows us to start the ten local varieties in three groups whose differences in the average values of the categories are statistically insignificant within the same group. These groups consist of varieties *Tchangalari*, *Safra non crossé*, *Madjérinon*croissé and *Madjéricrossé* (averages between 9,156 and 11,489) for the first; the group of *Adjagamari*, *Bourgouri* and *Mandouéri* varieties (average values between 12,344 and 12,500) for the second and the group consisting of varieties *Soulkéri*, *Safracrossé* and *Soukatari* (averages between 13,300 and 16,622) for the third in 2013. The average values of the varieties in the third group were all significantly different from those of the varieties in the second group except for the variety *Soulkeri*. The average values recorded in 2012 for this parameter also allow us, following this comparison, to distinguish three groups: the first consisting of the varieties *Tchangalari*, *Madjéricrossé*, *Adjagamari*, *Soulkéri*, *Safranon crossé* and *Madjérinoncrossé* with average values between 11.011 and 12.59; the second consists of *Mandouéri* and *Bourgouri* varieties with average values of 13,478 and 13,744 respectively; the third group consisting of the *Soukatari* and *Safracrossé* varieties with respective average values of 17,289 and 16,067; the average values of the varieties in the third group are all of a statistically significant difference from the varieties in the second group.It is it also appears that *Tchangalari*, *Safranoncrossé* and *Madjérinoncrossé* have mechanical defense arrangements that may reduce the penetration of borer larvae into the stems. According to Bessinet et al. [19] Van den Berg [20], the lower the number of holes, the lower will be the "moth production index"; which contributes for a lot in the reduction of damage levels. This observation gives credits to the existence of different level of antibiosis of the various varieties and calls for the understanding of the roles of the chemical constituents in the mechanical resistance of the plants of the transplanted sorghum. Several previous works have highlighted the role of silica in the defense mechanisms of the plant; Silica would act directly or indirectly to reduce insect damage [21,22,23,24,25,26]. In the socio-economic context of the Far-North Region where forage demand is high, this parameter allows a judicious choice of the variety or varieties of sorghum transplanted for use of by-products as fodder.

3.4 Number of Caterpillars per Plant and Varieties of Sorghum

Previous work [27,28] has demonstrated the predominance of *Sesamiacretica* (Lederer) coexisting with the species *Sesamiacalamistis* and *Sesamiapoaphaga* on sorghum transplanted in the Sudano-Sahelian zone in general and in the Far-North in particular. In our experimentation for varietal resistance of transplanted sorghum, only the numbers of caterpillars of *Sesamia cretica* (Lederer) taken alone and the total number of caterpillars (all species combined) recorded by variety and year were submitted to analysis, *Sesamia calamistis* (average = 0.07 and mean = 0.05 respectively in 2012 and 2013) and *Sesamia poaphaga* (mean = 0.11 in 2012 and 2013) yet reported, with annual average numbers almost all lower than the tenth of the unit, have not been taken into account.

An analysis of the variances of these two parameters demonstrates differences all statistically significant at the 5% significance level; the p-values (<0.0001) are all less than α = 0.05 (see Tables 5 and 6). This would reflect a disparity in the resistance levels of different varieties of transplanted sorghum. The Post-Hoc analysis reveals differences that are all statistically significant at the significance level α (p-values <α = 0.05) for the number of caterpillars of the species *S. cretica* (Lederer) (Table 7) or for the total numbers of the ankles (Table 8).

The development of caterpillar populations on the different traditional varieties of transplanted sorghum is dependent on the cross-effects of climatic factors and the varietal resistance itself dependent on genetic predispositions; to these factors are added the mechanisms for circumventing the defense of plants developed by pests in this coevolutionary and conflictual relationship. It then follows that the levels of populations of the caterpillars can vary according to the levels of varietal influence of the transplanted sorghum and the conditions of the environment.

In addition, the variety *Madjéri non-crossé* still housed the largest number of caterpillars. The average values of *S. cretica* (Lederer) caterpillars recorded per plant of this variety were 1.92 and 2.89 respectively in 2013 and 2012; those of all driller's caterpillars per plant of this variety were 2.044 and 3.044 respectively in 2013 and 2012. On the other hand, the varieties *Madjéricrossé* and *Bourgouri* are those which always shelter the smallest number of caterpillars per plant whether is for *S. cretica* (Lederer) or for all caterpillars of stem borers. These values (average numbers of caterpillars of the drillers and of the *S. cretica* species (Lederer)), which arweree still minimal, are close to those recorded for the *Soukatari* and *Safranon crossé* varieties, and it also shows that the *Soukatari* variety, having presented an high average number of holes, statistically different

Table 4. Paired comparisons of mean values of the number of holes on different varieties

Year	Year 2013		Year 2012	
	Variance (n)	Mean ± Standard deviation (n)	Variance (n)	Mean ± Standard deviation (n)
Tchangalari	18,754	9,156±4,331^{a}	14,119	11,056±3,758^{a}
Safra non-crossé	20,263	9,878±4,501^{ab}	26,211	11,011±5,120^{a}
Madjéri non-crossé	25,487	10,189±5,048^{ab}	34,899	11,033±5,908^{a}
Madjéricrossé	41,628	11,489±6,452^{ab}	52,687	12,589±7,259^{a}
Adjagamari	33,470	12,344^{a}±5,785^{abc}	33,090	12,100±5,752^{a}
Bourgouri	23,825	12,444^{a}±4,881^{abc}	26,279	13,744±5,126^{ab}
Mandouéri	40,428	12,500^{a}±6,358^{abc}	45,672	13,478±6,758^{ab}
Soulkéri	235,854	13,300±15,358^{bcd}	32,146	12,378±5,670^{a}
Safracrossé	51,952	15,122±7,208^{cd}	56,196	16,067±7,496^{bc}
Soukatari	49,324	16,622±7,023^{d}	51,117	17,289±7,150^{c}

NB: in a column, numbers with the same letters are not statistically significantly different in the 95% confidence interval

Table 5. Anova analysis of mean values of caterpillars of *Sesamia cretica* (lederer) at a significance level of 5%

Source	DDL	Sum of squares	Average of squares	F	Pr> F
Modèle	41	918,371	22,399	6,868	< 0,0001
Error	1758	5733,762	3,262		
Total corrected	1799	6652,133			

Calculated against the model Y = Mean (Y)

Table 6. ANOVA analysis of mean values of caterpillars (all species combined) at a significance level of 5%

Source	DDL	Sum of square	Average of squres	F	Pr> F
Modèle	41	984,128	24,003	6,546	< 0,0001
Error	1753	6427,547	3,667		
Total corrigé	1794	7411,675			

Calculated against the model Y = Mean (Y)

Table 7. Post-hoc analysis table for the cross-effect of the variety, year and block effect on the number of *S. cretica* (lederer) caterpillars at the 5% significance level

Source	DDL	Sum of square	Average of squares	F	Pr> F
Year	1	97,534	97,534	29,904	< 0,0001
Block	2	43,471	21,736	6,664	0,001
Variety	9	548,227	60,914	18,677	< 0,0001
Year*Block	2	40,938	20,469	6,276	0,002
Year*Variety	9	74,716	8,302	2,545	0,007
Block*Variety	18	113,484	6,305	1,933	0,011

Table 8. Post-Hoc table for the cross effect of variety, year and block effect on total numbers of caterpillars at 5% significance level

Source	DDL	Sum of square	Average of squares	F	Pr> F
Year	1	105,439	105,439	28,757	< 0,0001
Block	2	59,453	29,727	8,107	0,000
Variety	9	581,388	64,599	17,618	< 0,0001
Year*Block	2	41,070	20,535	5,601	0,004
Year*Variety	9	77,625	8,625	2,352	0,012
Block*Variety	18	119,153	6,620	1,805	0,020

from the average values of the other varieties in 2013 and 2012, shows average numbers of driller and caterpillars of *S. cretica* (Lederer) almost constant and always statistically lower, predicting the existence of a chemical defense of these varieties: *Bourgouri*, *Soukatari* and *Safranon crossé.* It resulted in high mortality of the larvae having penetrated the stems. A two-to-two comparison of the average number of caterpillars of the species *Sesamia cretica* (Lederer) or all borer larvae recorded in 2013 and 2012, at a 95% confidence interval, allows us to distinguish between pairs of values or groups of mean values statistically not significantly different (see Tables 9 and 10).

On the other hand, the *Safracrossé* variety, with a high degree of infestation, a high mean number of holes and a similar average number of caterpillars, is a variety susceptible to Lepidoptera stem-borers attacks. Perrot et al. [29] also found this traditional variety very susceptible to stem borer's attacks although it is appreciated by farmers.

The Table 10 show that the traditional varieties of transplanted sorghum can be grouped into four categories according to their agronomic performance (ability to influence the development of larvae of stem borers): the first category comprises the varieties *Madjéricrossé, Soukatari, Mandouéri*, *Safrauncrossed* and *Mandouéri* variety. The second includes *Mandoueri* and *Tchangalari* varieties. The third included the varieties *Adjagamari*, *Soulkéri* and *Safracrossé*. The fourth includes the *Safra* varieties and the *Madjéri noncrossé* variety.

These groups of varieties with closely average values of related caterpillars would thus have almost the same levels of tolerance.

3.5 Gallery Length per Plant

The caterpillars after having penetrated the stem, feed there by realizing galleries. These galleries hinder the good distribution which leads to the reductions of yield. This infestation parameter, negatively correlated (r = 0.062 and 0.034 respectively for *S. cretica* and total caterpillar) to the grain yield of plants under infestation and which reflects the level of resistance and/ortolerance of the plants, would have variable average values according to the varieties. Theresults show that the *Bourgouri*, *Soukatari* and *Tchangalari* varieties, which nevertheless recorded average values of drillers of statistically non-different, either in 2013 or in 2012 and always lower, have the highest average tunnel length per plant for the same years, while the variety 4 having a number of caterpillars. per plant always high has the lowest average lengths of galleries per plant. These results could indicate inter specific and/or intra specific interaction in the populations of borers infesting the transplanted sorghum and which would be responsible for the variations in the modalities of the various infestation parameters such as the length of the tunnels. An analysis of variance of the average values of gallery lengths and a post hoc analysis are presented in Tables 11 and 12.

Table 9. Comparison table of mean values of caterpillar of *Sesamia cretica* (lederer) on different varieties of transplanted sorghum

	2013		2012	
Varieties	**Variance (n=90)**	**Mean± standard deviation n=90)**	**Variance (n=90)**	**Mean±standard deviation n=90)**
Bourgouri	1,228	0,711±1,108^{a}	2,237	1,089±1,496^{ab}
Madjéricrossé	1,201	0,767±1,096^{ab}	1,099	0,700±1,048^{a}
Saf40 non-crossé	2,217	0,778±1,489^{ab}	4,041	1,122±2,010^{abc}
Soukatari	1,835	0,856±1,355^{ab}	2,432	0,889±1,560^{ab}
Mandouéri	2,731	1,189±1,653^{abc}	2,512	1,233±1,585^{abc}
Soulkéri	2,517	1,289±1,586^{abc}	4,200	2,578±2,049^{de}
Tchangalari	3,454	1,300±1,859^{abc}	5,029	1,756±2,243^{bcd}
Adjagamari	3,693	1,533±1,922^{bc}	4,054	2,033±2,014^{cde}
Saf40 crossé	4,533	1,667±2,129^{c}	6,591	2,378±2,567^{de}
Madjéri non-crossé	4,516	1,922±2,125^{c}	5,788	2,889±2,406^{e}

NB: in a column, numbers with the same letters are not statistically significantly different in the 95% confidence interval

Table 10. Table of two-by-two comparisons of average numbers of caterpillars recorded in 2013 and 2012 (all species) on the different local varieties of transplanted sorghum

	Year 2013		Year 2012	
Varieties	**Variance (n=90)**	**Mean±standard deviation n=90)**	**Variance (n=90)**	**Mean±standard deviation n=90)**
Mandouéri	3,191	1,378±1,786^{abc}	3,091	1,444±1,758^{abc}
Madjéricrossé	1,351	0,933±1,162^{a}	1,361	0,833±1,167^{a}
Bourgouri	1,293	0,800±1,137^{a}	2,391	1,178±1,546^{ab}
Soukatari	2,254	1,033±1,501^{ab}	2,956	1,094±1,719^{ab}
Madjéri non-crossé	4,665	2,044±2,160^{c}	6,087	3,044±2,467^{e}
Saf40 non-crossé	2,475	0,944±1,573^{ab}	4,312	1,278±2,076^{ab}
Soulkéri	2,668	1,433±1,633^{abc}	4,451	2,756±2,110^{de}
Adjagamari	4,595	1,778±2,144^{bc}	4,790	2,256±2,189^{cde}
Saf40 crossé	5,176	1,956±2,275^{c}	6,940	2,644±2,634^{de}
Tchangalari	4,032	1,367±2,008^{abc}	5,919	1,944±2,433^{bcd}

NB: in a column, numbers with the same letters are not statistically significantly different in the 95% confidence interval

It emerged that, cross effects two by two of factors block, year and variety, showed no significant difference for the cross effect Year*Block and the cross effect Year*Variety, the p-values (0.672 and 0.664 respectively) being all greater than α = 0.05. On the other hand, the crossed effect Bloc*Variety highlights a statistically significant difference, p-value (<0.0001) being lower than α = 0.05. These results confirm the existence of variations in the defense responses of each variety of transplanted sorghum plant according to prevailing agroclimatic conditions. The two-by-two comparison of the average values of this parameter for the different varieties is given in the following table (Table 13).

It appeared that the *Soukatari*, *Bourgouri*, *Safra non crossé* and *Madjéricrossé* varieties present in 2013 average values all statistically not different at a 95% confidence level. This first group made up of these four varieties above also had average values all statistically of a significant difference at the same degree of confidence with the average values recorded during the same year by the varieties *Mandouéri*, *Soulkéri* and *Tchangalari* constituting a second group in which the average values are all statistically insignificant. The third group consisting of *Adjagamari*, *Madjérinoncrossé* and *Safracrossé* varieties also show average values recorded in 2013 all statistically not significantly different within a 95% confidence interval. On the other hand, some varieties in this group had have average values that are statistically not significantly different from the average values recorded in 2013 by certain varieties in the first two groups. It is the *Adjagamari* variety whose mean value of the length of galleries is statistically not significantly different from those recorded by the *Safranon crossé* and *Madjéricrossé* varieties of the first group and that of the *Mandouéri* and *Soulkéri* varieties of the second group. The average values of the lengths of galleries recorded by the different varieties in 2012 also allow us to form groups of varieties *Mandouéri*, *Soulkéri*, *Madjéri non crossé* and *Adjagamari* for the first; *Bourgouri*, *Soukatari* and *Tchangalari* for the second with higher average values. The third group includes *Safracrossé*, *Safra non crossé* and *Madjéricrossé* varieties. The Soukatari variety, which had previously exhibited a high average number of holes and a mean number of caterpillars statistically insignificant with the smallest mean value, had ever-increasing mean gallery lengths and no statistically significant differences between years.

In addition, the Mandouéri variety has the smallest average gallery lengths and is always statistically close over the two years, but significantly different from the average values recorded by the other varieties. *Mandouéri* would therefore present antibiosis type defense mechanisms that would influence the pest both in its development and in its intake of food. These groups of traditional varieties of transplanted sorghum thus have the same level of antibiosis that would act on the trophic behavior of the caterpillars, which results in the lengths of the galleries showing the voracity of the caterpillars having succeeded in the penetration of the stems. On cultivated grasses, the nitrogen content of the plant appears to be of particular importance in the stem-borers interaction with a tendency for growth in infestation levels as a result of increased nitrogen in the plant [30]. Since the plant's ability to mobilize soil nitrogen is a varietal, there will be different levels of infestation. In addition, the choice of borer nesting sites is conditioned by certain agro-morphological parameters of the plants.

Varietal selection of (rainfed) sorghum for stem borers (*Chilopartellus* for example) is based on several infestation parameters such as the extent of leaf damage, the number of dead hearts, the holes on them stems, gallery length and plant tolerance resulting in its ability to produce secondary tillers after destruction of the main meristem [31]. On the basis of the selection parameters retained above,the *Mandoueri* local variety characterized by average yields, light orange seeds, a straight and loose panicle, very popular in the Region for making porridge and the variety *Soukatari* characterized high yields, orange seeds, a tasseled and very compact panicle but a poor taste quality [32] are

Table 11. Analysis of Variance of average values of gallery lengths per plant at a 5% significance level

Source	DL	Sum of squares	Mean of squares	F	Pr> F
Modèle	41	159606,975	3892,853	11,033	< 0,0001
Erreur	1758	620313,746	352,852		
Total Corrected	1799	779920,721			

Calculated against the model Y = mean (Y); DL = Degree of freedom

Table 12. Post-Hoc analysis of mean values of gallery lengths per plant for the cross-effects of the various factors at a significance level of 5%

Source	DDL	Sum of squares	Mean of squares	F	Pr> F
Year	1	1485,307	1485,307	4,209	0,040
Block	2	281,001	140,501	0,398	0,672
Variety	9	120482,774	13386,975	37,939	< 0,0001
Year*Block	2	289,171	144,585	0,410	0,664
Year*Variety	9	3938,628	437,625	1,240	0,266
Block*Variety	18	33130,094	1840,561	5,216	< 0,0001

Table 13. Table of pairwise comparisons of average gallery lengths for the ten varieties recorded in 2013 and 2012

Variety	Year 2013		Year 2012	
	Variance (n=90)	Mean±standard deviation n=90)	Variance (n=90)	Mean±standard deviation n=90)
Mandouéri	90,251	15,439±9,500^{abc}	92,269	16,289±9,606^{a}
Madjéricrossé	289,724	28,616±17,021^{ab}	316,005	30,210±17,777^{bc}
Bourgouri	414,682	38,422±20,364^{a}	488,002	40,466±22,091^{de}
Soukatari	671,718	38,891±25,918^{ab}	671,646	43,303±25,916^{c}
Madjéri non-crossé	310,117	22,107±17,610^{c}	347,394	22,919±18,639^{ab}
Saf40 non-crossé	380,423	28,138±19,504^{ab}	454,591	29,958±21,321^{bc}
Soulkéri	120,887	19,807±10,995^{abc}	262,630	20,081±16,206^{a}
Adjagamari	234,536	25,416±15,315^{bc}	279,915	24,142±16,731^{abc}
Saf40 crossé	575,930	34,450±23,999^{c}	565,502	32,844±23,780^{cd}
Tchangalari	397,348	33,269±19,934^{abc}	303,254	42,509±17,414^{e}

more resistant to stem borers compared to other varieties evaluated under the same conditions. They also had low percentages of seed losses (Table 1). These varieties once transplanted on small areas for specific needs could experience a boom because of the constraints at the origin of the fall of productions of the popular local varieties such as the variety *Safra* with always a higher percentage of seed loss (Table 1) and accounted for about 85% of the transplanted areas in northern Cameroon in 2002 [33]. However, it is difficult to select on the basis of a single index or a single parameter, a variety resistant to some form of damage that may be susceptible to another form of injury [34,35]. To be effective, varietal selection for driller resistance should be made on the basis of several criteria.

4. CONCLUSION

This work highlighted the existence of traditional *Muskuwari* tolerant or less susceptible to stem borers in North Cameroon. It also highlighted the role of Lepidoptera stem borers (such as *Sesamia cretica* Lederer on transplanted sorghum) which adds to local socio-cultural contingencies to cause varietal drift as a result of abandonment of more sensitive varieties or poor food quality. It also gives more tools to people in charge of agricultural policies and seed industry technicians to reduce losses due to stem drillers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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