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Full Length Research Paper

Severity and prevalence of the destructive fall armyworm on maize in Uganda: A case of Bulambuli District

Buteme Sharon[1], Masanza Michael[2] and Masika Fred Bwayo[3]*

[1]Department of Agriculture, Faculty of Vocational Studies, Kyambogo University P. O. Box 1 Kampala, Uganda,
[2]Department of Agricultural and Biological Sciences, Faculty of Science, Uganda Christian University, P. O. Box 4 Mukono, Uganda.
[3]Department of Biology, Faculty of Science, Muni University, P.O Box 725 ARUA, Uganda.

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Maize kernel contains a large quantity of carbohydrates, proteins, vitamins, oils, fats and competes favorably with root and tuber crops as a rich energy source. In Uganda, the per capita consumption ranges from 28 to 125 kg per annum. However, the yields remain low, fluctuating around 1.5 tons per hectare. Although some losses to maize production occur through the post-harvest period, pre-harvest factors such as biotic and abiotic constraints significantly affect its production. The most important biotic constraints include pests and diseases. Among the pests, Lepidopterans such as the fall armyworm (FAW) (*Spodoptera frugiperda* JE Smith) has become an important pest of maize during the early growing stages of the crop. Yet there is no information on the destructive levels of this pest in maize fields and this hinders management options for this pest. To determine the incidence, severity and prevalence of the FAW which may be responsible for low yields and poor maize quality, a survey was carried out in Bulambuli district in Uganda. Forty fields were sampled in Bwinkhonge Sub County to determine the level of damage caused by this pest. The severity of damage on leaves (df = 9, $\chi 2$ = 87.66, P = 0.000*) ears (df = 9, $\chi 2$ = 299.2, P = 0.000*) and kernels (df = 7, $\chi 2$ = 19.9, P = 0.005*) was high and significantly different in two parishes surveyed.

Key words: Larvae, incidence, pests, damage.

INTRODUCTION

Maize (*Zea mays* L.) also known as corn, zea, silk maize, makka, barajovar (Kumar and Jhariya, 2013) belongs to the class Liliopsida. Maize is believed to have originated from central Mexico about 7000 years ago from a wild grass, and was transformed by Native Americans into a better source of food. Maize is one of the three most widely cultivated crops in the world (Abdel-rhman, 2015). The USA, China and Brazil contribute 63% of the global maize production. Other major producing countries include; Mexico, Argentina, India, Ukraine, Indonesia,

*Corresponding author. Email: masikafred2012@gmail.com.

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France, Canada and South Africa (http://www.fao.org/3/BS183E/bs183e.pdf). In Uganda, an an average of 1.5 tons per hectare is produced annually making it the third most important cereal crop after sorghum and millet in terms of area under cultivation, production and human consumption (Daly et al., 2016).

Maize kernel contains a large quantity of carbohydrates, proteins, vitamins, oils and fats and competes favorably with root and tuber crops as a rich energy source (Rouf Shah et al., 2016). Maize is used in the local brewery industry, and is eaten when still fresh on cobs either as cooked or roasted. The flour is used to prepare a local paste called 'porridge' and 'posho' whose demand is on the increase in hotels and restaurants in several urban centers including Kampala City (Agona et al., 1999). Maize is also used in the manufacture of feeds for livestock and is now a key export to surrounding countries like Kenya, Sudan (Rouf Shah et al., 2016).

Per capita maize consumption ranges from 28 to 125 kg per annum in Uganda. However, the yields remain low, fluctuating around 1.5 tons per hectare (Daly et al., 2016). Improving the productivity of maize-based farming could significantly reduce hunger and enhance food security (Stevens and Madani, 2016).

Although losses to maize production occur throughout the post-harvest period, pre-harvest factors of maize production such as biotic and abiotic constraints affect maize production (Pandey et al., 2017). Among abiotic factors, soil nutrients and moisture are the most important while key biotic constraints include pests and diseases. Among the pests, stem borers such as (African maize stalk borer), American grasshoppers *(Schistocerca americana*), and lepidopterans are important pests of cereals including maize (Masika et al., 2017a). Lepidopterans like the fall armyworm (FAW) (*Spodoptera frugiperda* JE Smith) are important pest of maize during the early growing stages of the crop (Otim et al., 2018).

Invasion of the FAW was first reported in Africa in September 2016. Since then, it has become resident in most Sub Saharan countries where severe damage in maize fields is observed (Goergen et al., 2016). By the end of 2017, about 38 countries in Africa were infested with the FAW. The suitable climate in Africa favors the growth of main and alternative hosts of the FAW; therefore, they do not need to migrate within the continent (Hailu et al., 2018). Furthermore, according to Hailu et al. (2018), the rapid spread of FAW poses unprecedented threat to food security, incomes and livelihoods in the country, most especially among smallholder farmers grappling with the parasitic weed Striga. The FAW was first detected in Uganda in 2016 and caused serious devastation to the crop (http://www.fao.org/uganda/news/detail-events/en/c/1149243/). Towards the end of 2018, the pest sprung and farmers do not have a solution on how to manage them (http://www.fao.org/uganda/news/detail-events/en/c/1149243/). The eastern region particularly Bugisu and Sebei sub-regions are key maize producing areas in Uganda (FAO, 2014); where about 75 to 95% of the household production is sold to earn money. Towards the end of 2018, we inadvertently observed in various farms in Bwikhonge Sub County, Bulambuli District in eastern Uganda sporadic incidences of the FAW. Consequently, we followed up with systematic studies to assess the incidence, prevalence and severity of FAW damage in maize fields in Bwikhonge Sub County at the onset of the rain season which also coincides with the main maize growing season in the area. There is currently no information on incidence, severity and prevalence of this pest in maize fields in Uganda, let alone in Bwikhonge Sub County which may be hindering any management options for this pest.

MATERIALS AND METHODS

Study area

The study was carried out in Bwikhonge Sub County, Bulambuli District located in the Mt Elgon region. It is bordered by Nakapiripirit district in the north, Kapchorwa district to the east, Sironko district to the south and Katakwi district to the west. Bulambuli is located approximately 32 km (20 miles) by road, north east of Mbale at coordinates (0122N, 3409E) consisting of nine sub counties, 35 parishes and 455 villages with a total land area of 651.8 km^2 and an approximate population of 125,400 people. The Sub County has parishes such as Buwenkanda Parish, Buwabwala, Buwekanda and Buyaka parish. The major economic activity is agriculture including animal husbandry and crop farming. The crops grown include; millet, sorghum, bananas, beans with maize being the major crop (https://www.ugandainvest.go.ug/wp-content/uploads/2019/06/Elgon-Investment-Profile.pdf).

The study area is located in the Mt Elgon region and receives approximately a bimodal rainfall pattern with the periods between March/April and October/November being the wettest. The dry period is from December to February while the period between July to August receives less intense rainfall. The mean annual rainfall varies from 1200 at low altitudes to 1400 and 1800 mm at mid altitudes and at high altitudes respectively (Liebig, 2016). The mean annual temperatures also range from 23 to 21°C and 18°C in the low, mid and high altitudes (Hijmans et al., 2005).

Sampling and data collections

The survey was carried out in two parishes in the Bwikhonge Sub County namely; Buwabwala and Buwekanda parishes as these are the ones where extensive maize cultivation is being carried out. Data was collected on prevalence, incidence and severity of FAW damage on the maize shoot, ears, and kernels. During the survey, we collected data from a total of forty farmers, twenty from every parish. From each farmer, we collected data from one field measuring at least one acre and we skipped at least two fields before sampling the next field.

Incidence of FAW damage on maize in Bulambuli

FAW incidence, defined as the extent of infestation on maize plants in the field was calculated by expressing the number of infested plants as a percentage of the total number of plants in the field. It was recorded and estimated as percentage infection, whereby 1-20% = low incidence; 21-49% = moderate incidence; and 50 - 100% = high incidence (Nono-Womdim et al., 1996).

Table 1. Incidence of FAW damage on maize in Bwikhonge Sub County.

Incidence category	Number of fields in Buwabwala parish	Number of fields in Buwekanda Parish	Total number of fields in the Sub county
No incidence	1 (5.0%)	7 (35.0%)	8 (20.0%)
Low (1-20%)	3 (15.0%)	3 (15.0%)	6 (15.0%)
Moderate (21-49%)	4 (20.0%)	5 (25.0%)	9 (22.5%)
High (50-100%)	12 (60.0%	5 (25.0%)	17 (42.5)
Total	20	20	40

Numbers (and percentages in the parentheses) of maize farms showing the level of damage of the FAW in the study parishes.

Prevalence of FAW on maize in Bulamuli

Prevalence of the FAW was determined at parish level according to Masika et al. (2017b). In this case, twenty farmers' fields were surveyed and the fields which were observed to have maize plants damaged by the fall armyworm were expressed as a percentage of all farms sampled in that parish. Afterwards, prevalence was determined for the whole Sub County. Assessment for the presence of FAW larva was done by counting the number of larva on the infested plant including on the kernels and ears. This was done by careful observation and opening of the plants with leaf damage caused by FAW larvae and also those plants with FAW frass in the whorl and on the ears (Baudron et al., 2019).

Severity of infestation of FAW on maize in Bulambuli

In the field, sampling for severity of leaf damage was visually rated on 20 randomly selected plants from 5 different locations in the field on a scale of (0-9) representing the different levels of damage, according to Davis and Walliams (1992). Similarly, sampling severity of ear damage was visually rated at the same time that 10 randomly selected ears from 20 randomly selected plants from 5 different locations in the field were inspected.

Data analysis

Data were analyzed using Stata Corp, 4905 Lakeway Drive to output frequencies, tables and pie charts for descriptive statistics while categorical data (severity data) were analyzed using non parametric chi-square analysis.

RESULTS

Incidence of FAW on maize

Generally, for all the forty fields sampled in the Sub County, FAW incidence was high, where more fields showed a high incidence, followed by those with moderate incidence, those which showed no FAW damage and then those with low incidence. In individual parishes, Buwabwala had more fields with a high FAW incidence as compared to those from Buwekanda (Table 1 and Figure 1).

Prevalence of the FAW larvae on maize

In Bwikhonge Sub County, FAW larvae were so prevalent when infested plants were carefully inspected. Buwabwala parish had the highest percentage prevalence of FAW larvae as compared to Buwekanda parish. Three hundred and fifty-four FAW larvae were collected from the twenty fields surveyed in Buwabwala parish. In Buwekanda parish, 196 FAW larvae were collected from plants which were inspected in the twenty fields surveyed. The inspection and collection of the FAW larvae was done together with the farmers of the fields as one of the methods of managing the destructive FAW pest most especially in maize fields with young and still growing maize plants.

Severity of FAW damage on maize in Bwikhonge Sub County

A total of 800 maize plants were analyzed for severity of FAW damage on leaves in the Sub County, where 400 plants were from Buwabwala parish and 400 also from Buwekanda parish. Generally there was a high FAW damage on maize leaves in the Sub County. Of the total number of plants inspected for FAW damage on leaves in Buwabwala parish, only 160 (40.0%) plants had leaves with no FAW damage while in Buwekanda parish, a total of 272 (68.0%) maize plants had no FAW damage on the leaves. The remaining plants had leaves damaged at different severity levels according to Davis and Walliams (1992). The differences in severity of FAW damage on the leaves in Buwabwala and Buwekanda parishes were statistically significantly ($df = 9$, $\chi 2 = 87.66$, $P = 0.000^*$) (Table 2 and Figure 2).

A total of 800 maize plants were selected and their ears were inspected for FAW damage in the Sub County. Fifty per cent (400) maize plants were from Buwabwala and 50% (400) were from Buwekanda parish. A total of 223 (55.8%) maize plants from Buwabwala had ears which did not have FAW damage and frass while from Buwekanda Parish, 380 (95.0%) maize plants did not have FAW damage and frass on their ears. Only twenty

Figure 1. A-Inspecting FAW damage on maize plant, B-Field infested with FAW, C- Maize tassel destroyed by FAW and D- Plant leaves drying because of extensive FAW damage.

maize plants from Buwekanda parish had ears damaged by the FAW and 177 plants from Buwabwala had ears damaged by the FAW. The damage on the ears had different severity scores as described by Davis and Walliams (1992). The severity of FAW damage on the ears in the two parishes were different and these differences were statistically significant (df = 9, $\chi 2$ = 299.2, P = 0.000*) (Table 2 and Figure 2).

A total of 800 maize plants were selected and their ears inspected for FAW damage on their kernels in Bwikhonge Sub County. 400 maize plants were from Buwabwala and 400 also from Buwekanda. Of the total number of maize ears analyzed, 383 (97.8%) plants did not have any FAW damage on their kernels in Buwabwala parish while 398 (99.5%) plants from Buwekanda did not have kernels damaged by the FAW. The severity of FAW damage on the kernels was also scored according to Davis and Walliams (1992). The damaged kernels showed different severity scores and the differences in severity of FAW damage on the kernels were statistically significant (df = 7, $\chi 2$ = 19.9, P = 0.005*) (Figure 3 and Table 2).

DISCUSSION

Incidence of fall armyworm damage in maize fields

There was a high incidence of FAW in Bwikhonge Sub County. The Sub County is located next to River Sipi that never dries even in the dry season and also next to a permanent swamp in Buryalo. These features provide constant humid conditions coupled with cultivation of maize, the primary host of the FAW all year round, and facilitate proliferation of the pest throughout the year as the pest life cycle is never broken (Prasanna et al., 2018).

Prevalence of fall armyworm in maize farms in Bwikhonge Sub-county

Prevalence of falls armyworm larvae

There was a high prevalence of the FAW with over 198 larvae collected on 800 maize plants during the survey.

Table 2. Chi square analysis for severity of FAW damage on plant leaves, ears and kernels in Bwikhonge Sub County.

Severity	Severity on plant leaves			Severity	Severity on plant ears			Severity	Severity on kernels		
	Buwekanda	Buwabwala	Total		Buwekanda	Buwabwala	Total		Buwabwala	Buwekanda	Total
0	68.0 (272)	40.0 (160)	54.0 (432)	1	95.0 (380)	55.8 (223)	75.4 (603)	0	97.8 (383)	99.5 (398)	97.6 (781)
1	8.8 (35)	14.5 (58)	11.6 (93)	2	0.3 (1)	25.8 (103)	1.3 (104)	1	0.3 (1)	0.0 (0)	0.1 (1)
2	2.5 (10)	11.3 (45)	6.9 (55)	3	1.3 (5)	5.0 (20)	3.1 (25)	2	1.0 (4)	0.0 (0)	0.5 (4)
3	1.3 (5)	7.3 (29)	4.3 (34)	4	0.3 (1)	6.8 (27)	3.5 (28)	3	0.8 (3)	0.5 (2)	0.6 (5)
4	5.3 (21)	5.5 (22)	5.4 (43)	5	0.5 (2)	1.8 (7)	1.1 (9)	4	1 (4)	0.0 (0)	0.5 (4)
5	3.8 (15)	3.3 (13)	3.5 (28)	6	0.3 (1)	1.3 (5)	0.8 (6)	5	0.5 (2)	0.0 (0)	0.3 (2)
6	3.0 (12)	4.8 (19)	3.9 (31)	7	0.8 (3)	3.0 (12)	2.1 (15)	6	0.3 (1)	0.0 (0)	0.1 (1)
7	1.3 (5)	3.5 (14)	2.4 (19)	8	0.3 (1)	0.5 (2)	0.4 (3)	7	0.5 (2)	0.0 (0)	0.3 (2)
8	2.3 (9)	3.8 (15)	3.0 (24)	9	0.5 (2)	0.3 (1)	0.4 (3)	Total	400	400	800
9	4.0 (16)	6.3 (25)	5.1 (41)	Total	400	400	800	**df = 7, χ2 = 19.9, P = 0.005***			
Total	400	400	800	**df = 9, χ2 = 299.2, P = 0.000***							
df = 9, χ2 = 87.66, P = 0.000*											

Percentages (and numbers in the parentheses) of plant leaves, ears and kernels surveyed for severity of FAW damage in Bulambuli District. *Statistically significant.

The FAW was also present throughout the growth stages of maize in the two surveyed parishes. This may be attributed to presence of maize plant residues in the swamps of River Sipi which result in no breakage of pest life cycle, hence high prevalence of FAW which is supported by what has been reported by Prasanna et al. (2018). Furthermore, the high prevalence may be mainly due to lack of proper management strategies of the pest because it is a new invader in the region and proper integrated pest management options are yet to be designed (Thierfelder et al., 2018). Moreover, the cultural methods which have been reported to reduce FAW infestation (Midega et al., 2018; Hailu et al., 2018) are not yet known by the local farmers. Similarly, there is little empirical evidence to guide farmers on how to effectively control the FAW through agronomic management practices in Africa (Baudron et al., 2019).

Infestation by the larvae showed that at the time of the survey, the larvae incidence of 0.88 was not too high to cause economic loss which occurs at a mean infestation of 3 or more fall armyworms per plant in 20 damaged plants/100 (Davis and Walliams, 1992). However, any increase in infestation would lead to economic loss. Since the survey was carried out early in the season when most of the maize in the fields was silking, a follow up survey after one month would result in a higher mean infestation since the FAW takes 30 days to complete its life cycle (FAO and CABI, 2019) and according to the biology of FAW, it does not diapause, meaning that there was a continuous population buildup and several generations can overlap within a single crop cycle when suitable conditions prevail, hence, there may be no need for the pest to migrate from Bulamuli to other areas since it enjoys favourable conditions throughout the year (FAO and CABI, 2019).

Although efforts have been made by the farmers to apply pesticides to manage the FAW, potential health issues to the environment and the population arising from hazardous chemicals and long term exposure to pesticide crop residues in consumed produce and in the environment raises unresolved issues (Harrison et al., 2019). Furthermore, some of the pesticides being used may not be the right ones, their doses and concentrations may not be optimal and may be applied at a wrong age of plant growth which was frequently observed in farmers' fields. This renders the chemicals ineffective, inconsistent and unsatisfactory to control the pests in a given local context (Midega et al., 2018). Most chemicals used are broad spectrum chemicals which may end up killing what would be the natural enemies that control the FAW population (Harrison et al., 2019). Integrated pest management options including CABI`S plant-wise advice to small scale farmers to use hand picking and destroying egg masses and larvae and putting sand mixed with lime or ash in the leaf funnels to kill the FAW larvae may help to reduce its prevalence. This is one of the

Figure *2.* A-FAW larvae on one of the plants surveyed in Buwekanda, B- Larva on one of the plants surveyed for FAW damage in Buwabwala, C- Maize plant ear destroyed by FAW larva in Buwekanda and D-Maize plant ear damaged by FAW larva in Buwabwala.

methods we employed as we surveyed the farmers' fields and collected the larvae in determination of the incidence. This is supported by Grzywacz et al. (2014), who asserts that low-cost options of pest control which build on indigenous knowledge and ecological options are more relevant to smallholder farmers.

Severity of fall armyworm larva in maize farms in Bwikhonge Sub County

Generally, there was a high severity level of FAW damage on maize leaves and ears which where statistically significant between the two parishes (Table 2). The high levels of damage caused by the FAW of 32% in Buwekanda and 60% in Buwabwala is almost in the same range with what has been reported by previous studies in Ethiopia, Kenya and Zimbabwe (Baudron et al*.,* 2019; Kumela et al., 2018). The severity of FAW damage on maize kernels was low (Table 2) which could be attributed to the early silking stage at which most of the maize in the fields were during the survey. During this time, most of the maize fields had not yet reached milking stage for the kernels to be damaged. However, the significant damage caused by the FAW on maize leaves and ears has great potential to further spread and damage the kernels which may lead to economic loss as the FAW has been reported to be the second most dangerous pest in agriculture causing $39 to $297 million every year (Sparks, 1986). The high severity of the FAW are similar to what has been reported by Aguirre et al. (2016). Continuous cultivation throughout the year and warm humid conditions which promote population buildup allowing several generations to overlap within a single

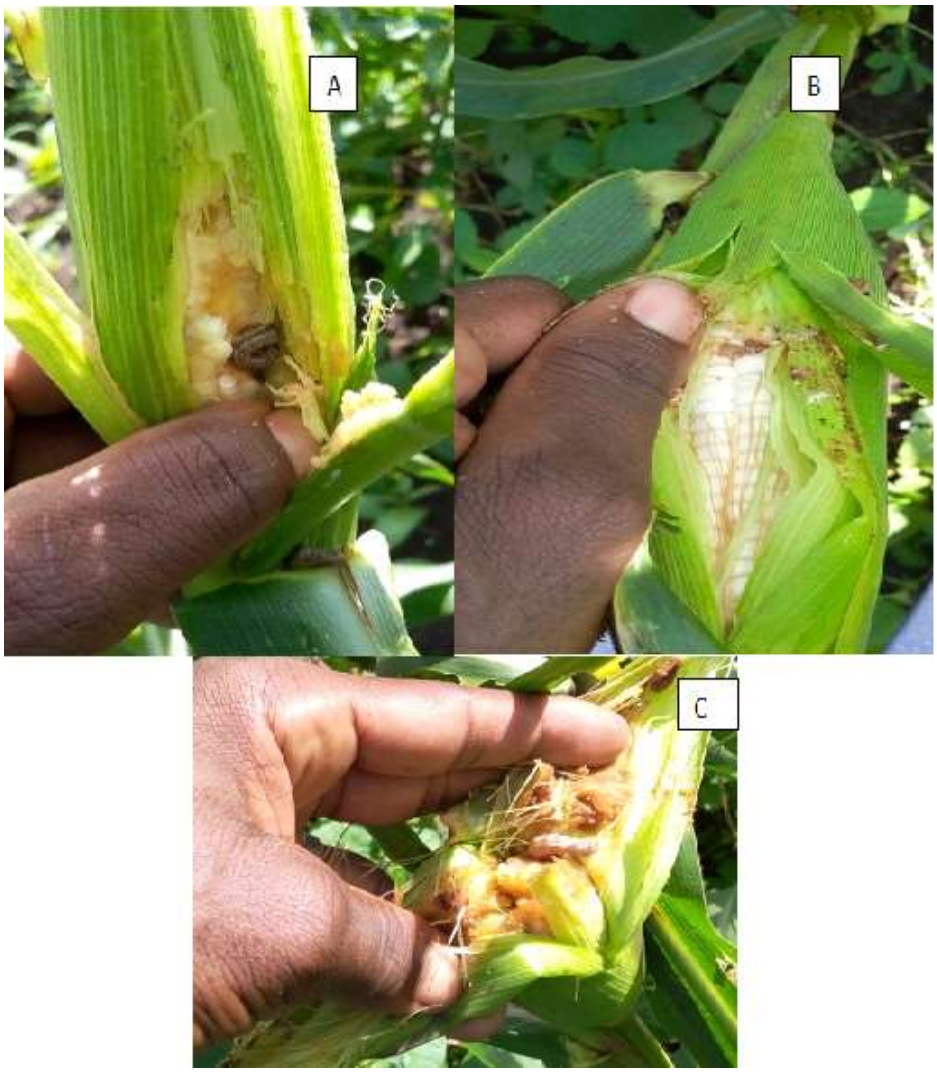

Figure 3. A, B-Maize kernels destroyed by FAW in Buwabwala and C-maize kernels destroyed by FAW in Buwekanda.

crop cycle with suitable prevailing conditions should be responsible for the high severity observed in maize farms in Bulambuli (FAO and CABI, 2019).

CONCLUSION AND RECOMMENDATIONS

The study showed that there was a high incidence of FAW in Bwikhonge Sub County which was attributed to the humid conditions that are provided by the surrounding water bodies and facilitate FAW buildup and overlap within a single crop cycle. High population buildup will lead to economic loss when proper management options are not designed. Therefore, there is need to design collaborative research incorporating indigenous knowledge of pest control, biological control and plant breeding options to develop integrated pest management strategies for the pest.

Surveying the FAW severity in all the agro-ecologies in Uganda across the different generations and growth stages of the plant is important to give an idea of the level of damage and economic losses that the pest is inflicting on the smallholder farmers.

There is need to model weather conditions with the population dynamics of FAW and desert locust to give an idea of the factors perpetuating the proliferation of insect pests in Africa. For example, the looming invasion of the Eastern part of Africa with the desert locust is attributed to the extreme weather conditions where 2019 started with a dry spell and ended with an extremely wet season ever which is just speculative.

There is need to evaluate the chemical being used to control the FAW as most of the broad spectrum chemicals being used may be dangerous to the natural

enemies of these pests or may leave residues in the food and cause damage to the environment and human life.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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