

Early Harvesting of Rainfed Plant Cane to Prevent Heavy Infestations of *Eldana saccharina* (Lepidoptera, Pyralidae) in Ferké Sugarcane plantations, Ivory Coast

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Abstract— The African stalk borer *Eldana saccharina* is an endemic pest of high economic importance in sub-Saharan Africa which often causes heavy infestations in rainfed plant cane subjected to a cycle of 15-17 months. The present study aimed to reduce overall damage due to this borer by early harvesting of sugarcane at three different periods. It involved two experiments carried out in Ferké 1 and Ferké 2 sugar estates over 17 months in rainfed plant cane, following a randomized complete block design (RCBD) with four different treatments. Treatments were composed of three harvesting periods (T1: November 15, T2: December 15, and T3: January 15), and a control (T0, no harvest), all in 4 replicates. The Ferké 1 experiment was planted with the variety N21 on 25/07/2017 and harvested on 23/06/2019. That of Ferké 2 was planted on 15/06/2017 with the variety M2592/93 and harvested on 05/12/2018. The study showed that variety N21 with high fiber content was more tolerant to stem borer than variety M2593/92 credited with a moderate fiber content. Stem borer infestations were significantly reduced across crop cycle following early harvesting on M2593/92, as opposed to N21. Without early harvesting, M2593/92 was much more infested than N21, with respectively 24 and 10% of internodes bored. Borer infestations recorded were strongly dependent on crop cycle duration and the intensity of crop water stress. Data showed that early harvesting in rainfed plant cane could be beneficial in the prevention of heavy infestations by *E. saccharina*.

Keywords— Crop Cycle, Pest Tolerance, Water Stress, Cane Variety, Natural Enemy, Cropping Practice.

1. Introduction

The Stem borer *Eldana saccharina* Walker (Lepidoptera: Pyralidae) is an endemic pest of economic importance in sub-Saharan Africa which often causes heavy infestations in rainfed sugarcane mainly due to its longer growth cycle. In case of heavy infestations in sugarcane plantations, significant yield losses varying from 5 to 10% were reported depending on varieties cultivated, nitrogen fertilizer rates, crop water stress, and biodiversity with respect to *E. saccharina* natural enemies (Do Thi Khanh et al, 2012). Sugar losses due to high infestations observed in Ferké sugarcane plantations of northern Ivory Coast in 2016-17 and 2017-18 harvesting seasons, were estimated to about 5,000 and 2,200 t i.e. 5 and 2% of total sugar production, respectively (Péné et al, 2018). It was reported that among numerous agronomic factors which could be responsible for borer infestations, water stress and crop cycle duration in plant cane seemed to be specific to rainfed sugarcane. This cropping system which covers around 2,000 ha of industrial plantations (13%) and 3,500 ha of village plantations (22%) in Ferké sugarcane areas, needs to be addressed specifically in terms of crop protection strategy against the stem borer (Konan et al, 2017a et b). Early harvesting of rainfed sugarcane plantation for the purpose of reducing borer infestations used to be considered as a nice control strategy but hardly applicable by farmers because of the threat of severe cane yield reduction.

Several species of lepidopteran moth borers causing such damage belong to the genus *Chilo*, *Sesamia*, *Diatraea* and *Eldana*. *E. saccharina* is known as a major pest in sugarcane which larva cause galleries into cane stalks (Dick, 1945; Leslie, 2009), especially on their lower parts (Mazodze and Conlong, 2003). These damage levels on stem tissues being afterwards infected by fungus species (*Fusarium* spp.) are characterized by a dark-red coloring of surrounding tissues of galleries (McFarlane et al, 2009). *E. saccharina* damage

levels affect young and mature cane stalks (as opposed to that of other stem borer species like *S. calamistis*, *Chilo partellus* and *C. sacchariphagus* on young tillers) increase with crop age, especially over 12 to 16 months of vegetation (Leslie, 1994). Insecticides were recently used in South Africa to control *E. saccharina* on reported sugarcane crops as a result of the closing of sugar mills during the summer (Berry *et al*, 2009). Nevertheless, this practice was not unanimously adopted by growers because of the negative impact of pesticides on natural enemies of the borer. According to Betbeder-Matibet (1983), 95% of *E. saccharina* generations are eliminated by ants, trichogramma, and arachnids. Despite this and the long list of useful biological agents tested (Conlong, 1994), the biological control showed its limits in the decrease of stem borer populations to an acceptable economic level. Despite a good knowledge of the insect biology (Atkinson, 1981; Atkinson *et al*, 1989; Atkinson and Nuss, 1989; Keeping, 2006), much less is known on its behavior in the field over time, on the way it colonizes a newly planted area or the following sugarcane ratoons. Number of research studies carried out over the last 25 years focused on biological control and varietal resistance regarding two major stem borer species, namely *E. saccharina* *et* *C. sacchariphagus*. If varietal resistance became more successful, it was not the case of biological control which was more difficult to implement, especially on *E. saccharina* (Conlong, 1994 cited par Goebel *et al*, 1992). The importance of some farming practices such as nitrogen and silicon fertilizer applications in the control of borer populations was reported by several authors (Paxton, 1982; Way *et al*, 2003; Lopez *et al*, 1983; Goebel *et al*, 2005; Kvedaras *et al*, 2007; Kouamé *et al*, 2010; Péné *et al*, 2016).

The study aimed to reduce *E. saccharina* infestations in rainfed sugarcane plantations by early harvesting at different periods.

2. Materials and methods

2.1. Site characteristics

The study was carried out on two sugarcane plantations L1-005 and P7-014, at Ferké 1 and Ferké 2 sugar mills, in northern Ivory Coast (9°20' – 9°60' N, 5°22' – 5°40' O, 325 m a.s.l.). The prevailing climate is tropical dry with two seasons: one, starting from November to April, is dry and the second, from May to October, is wet. The dry season is marked by the northern trade wind which blows over mid-November to late January. The rainfall pattern is unimodal and centered on August and September which total amount of rainfall reaches almost half of the average annual rainfall (1200 mm) with an average daily temperature of 27 °C. Average maximum and minimum daily air temperatures are 32.5 and 21 °C, respectively. To meet sugarcane crop water requirements, the total amount of irrigation water required reaches 700 mm/year [11-13]. Both Ferké sugar mill plantations cover around 15 500 ha with 10 000 ha under irrigation and 3500 ha of rainfed village plantations, lie mainly on shallow or moderately deep soils built up on granites. Main soil units encountered are ferralsols and temporally waterlogged soils in valley bottoms of Bandama and Lokpoho river basins with a sandy-clay texture.

2.2. Experimental design

Both experiments were carried out over 17 months on plant cane following a randomized complete block design (RCBD) with four different treatments comprising three early harvesting dates (T1: November 15, T2: December 15, and T3: January 15), and a control (T0, no harvest), all in 4 replicates. Each sugar mill plantation was equipped with a weather station where parameters required to determine crop ET₀ like solar radiation, average daily air temperature, relative air moisture, and wind speed were measured. Rainfall data were recorded from rain gauges L1-003 and P7-021 located close to Ferké 1 and Ferké 2 experiments, respectively. The experiment in Ferké 1 was planted on 25/07/2017 with the variety N21 and harvested on 23/01/2019. The experiment in Ferké 2 was planted on 15/06/2017 with the variety M2592/93 and harvested on 05/12/2018. Each plot was composed of 10 rows of 10 m long with 1.50 m of row spacing. Doses of fertilizer and herbicide were applied according to usual practices in commercial plantations. NKP fertilizer (16-8.5-23) was applied mechanically at the routine rates of 500 kg/ha in rainfed plant cane. Pre-emergence herbicide based on pendimethalin combined with clorimuron-ethyl (3.5 l/ha) was achieved mechanically two days after planting.

2.3. Agronomic traits

Data were collected at harvest from eight central rows for the number of millable stalk number per ha, cane yield, juice quality traits (sucrose, purity, and recoverable sucrose), fiber content, and internodes bored by *E.*

saccharina.

At harvest, the cane production of the eight central rows of each plot was weighed separately to determine crop yield. Moreover, 50 millable stalks were randomly chosen within every plot and split longitudinally with a machete to determine the percentage of internodes bored (%INB) or cane damaged (% SD).

Thirty millable cane stalks were sampled per plot for sucrose analyses in the laboratory. Prior to sample crushing operations in the laboratory for sucrose analyses, every stalk was cut into 3 pieces of almost equal length while separating them in basal, median and top parts. This allowed to randomly reconstitute 3 batches of 10 stalks for a better homogenization of the initial field sample by permutation of the pieces so that each reconstituted stalk was composed of parts coming from 3 different cane stalks. Eventually, only one batch of 10 reconstituted stalks over 30 (1/3 of initial sample) were crushed for a series of sucrose analyses to determine the sucrose content (Pol%C), fiber content (Fiber %C), juice purity (Purity %C) and recoverable sucrose (SE%C). Equipment used comprised a Jefco cutter grinder, a hydraulic press (Pinette Emideceau), a digital refractometer BS-RFM742 and a digital polari-meter SH-M100. Methods used in the determination of required technological parameters were reported by Hoarau (1970). The recoverable sucrose was calculated as follows (Péné et al, 2016; Hugot, 1999):

$SE \%C = [(0.84 \times Pol\%C) (1.6 - 60/Purity) - (0.05 \times Fib \%C)]$ with:
 $Purity \%C = (Pol\ juice/Brix) \times 100$ and $Pol\ juice = Pol\ factor \times Pol\ read$.
 $Pol\%C = Factor\ n \times Pol\ juice$

The Pol Factor depending on Brix value (amount of soluble dry matter in juice measured with a refractometer) is provided by the Schmidt table relative to a polarimeter for 26 g of glucose. The fiber content and the factor n were provided by a table depending on the weight of the fiber cake obtained after pressing 500 g of cane pulp resulting from the crushing operation of every sample of cane stalks.

2.4 Statistical analyses

The quantitative data recorded in this study were subjected to the analysis of variance using statistical procedures described by Gomez and Gomez (1984) and reported by Shitahum et al (2018) using R software package version 3.5.1. Differences between means of treatments were determined from Duncan's test.

3. Results and discussion

3.1 Climatic conditions over plant crop

As expected, both experiment sites presented a similar rainfall patterns with a per-humid season taking place from June to September where weather conditions used to be favorable for planting of rainfed sugarcane or its main growth stage. The dry season taking place two or three months after planting of rainfed sugarcane tends to be suitable for borer infestations due to crop water stress. In contrast, the later dry season was beneficial for crop ripening before harvest.

In Ferké 1 experiment, total rainfall and reference evapotranspiration (ET_o) recorded across crop cycle gave 1912 and 2188 mm, respectively. Total rainfall deficit over crop growing season from November 2017 to May 2018 was 764 mm and the average daily temperature across crop cycle varied from 25.2 to 34.5 °C.

In Ferké 2 experiment, total precipitation and reference evapotranspiration (ET_o) recorded across crop cycle gave 2071 and 2197 mm, respectively. Total rainfall deficit obtained over crop growing season from October 2017 to May 2018 was 613 mm whereas the average daily temperature across crop cycle varied from 25.3 to 30.1 °C.

As reported by several authors (Conlong, 1994; Goebel et al, 2008; Parra et al, 2010), climate is one the most important factors determining spatio-temporal variations of stem borer infestations in sugarcane. An average temperature of 27°C with an air moisture content of about 80 % is required for the breeding of *E.sacharina* (Conlong, 1994). Therefore, climatic conditions of both sites investigated, particularly during the rainy season which lasts more than 6 months, were quite favorable for completion of the biological cycle of several borer generations. Nevertheless, the period of heavy rainfall occurred from June to August 2018 might have been

harmful to pest population dynamics because of the high percentage of eggs and larva being flushed away by the rainwater.

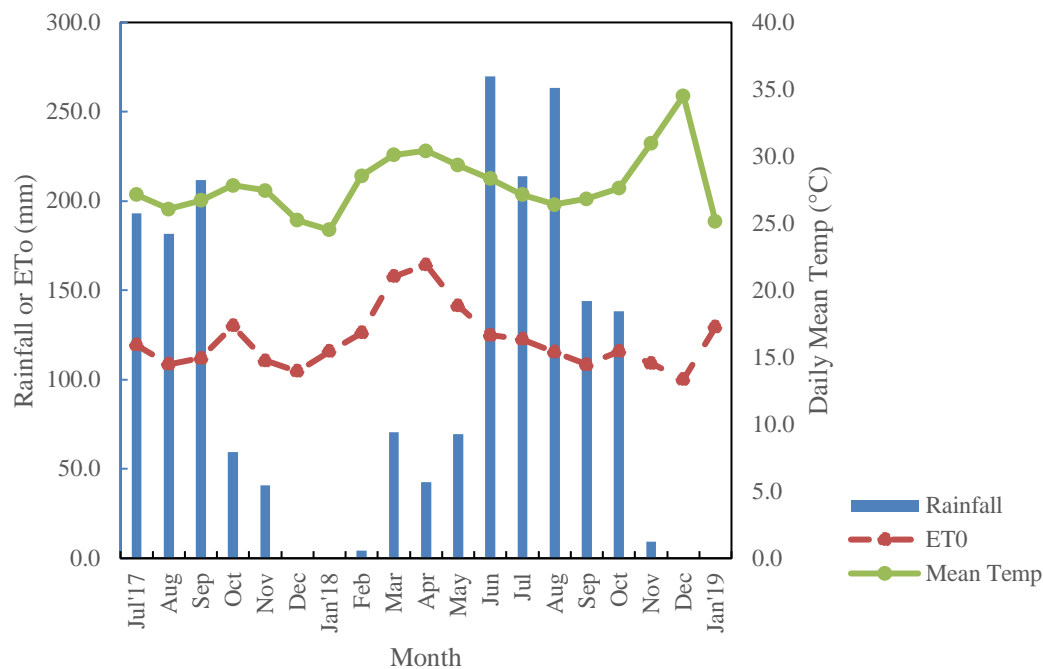


Figure 1. Prevailing climate in the Ferké 1 experiment (field L1-005), Ivory Coast.

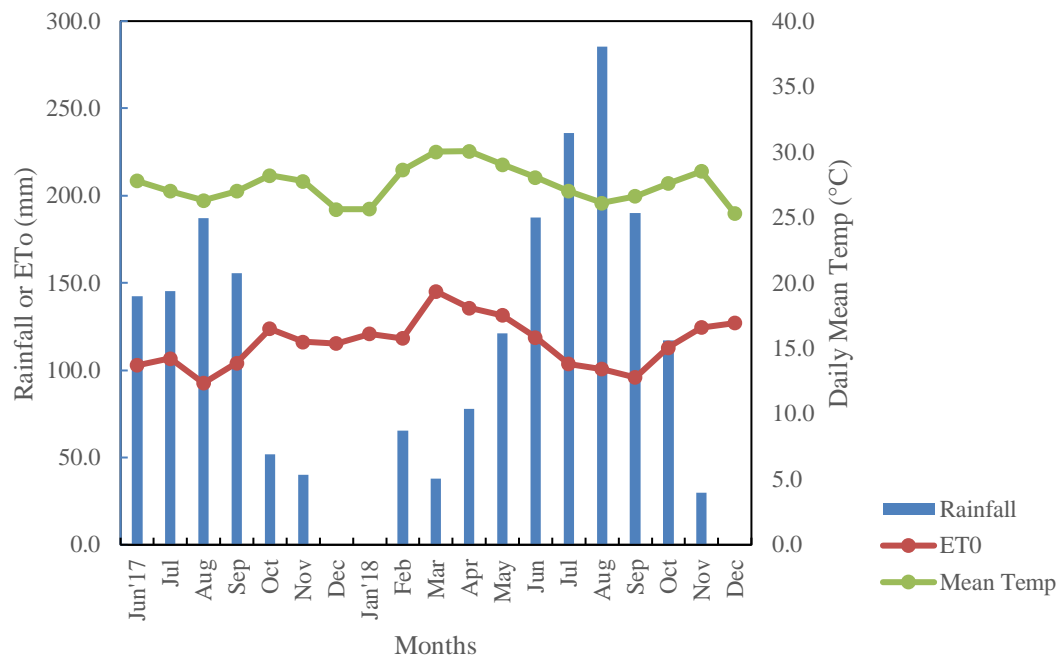


Figure 2. Prevailing climate in the Ferké 2 experiment (field P7-014), Ivory Coast.

3.2. Stem borer infestations as influenced by early harvesting

In Ferké 1 experiment, early harvesting of rainfed sugarcane plant crop did not reduce significantly borer infestations ($P=5\%$), although a higher damage level of about 10% INB was obtained on the control treatment plots (T0) compared to 8% for the average of early harvest treatment plots (Table 1). In contrast, these infestations were significantly reduced by 64% ($P<5\%$) compared to the average of early harvest treatment plots (Table 2). Although not significantly ($P=5\%$), December and January early harvestings seemed to be beneficial in controlling infestations over the following crop cycle. Higher infestations rates occurred in Ferké

2 experiment with 12.6% INB on average compared to that of Ferké 1 (8.3%INB), in relation to varietal susceptibility to stem borer. On the control treatment of Ferké 2 experiment, without early harvesting, infestations observed reached as much as 24% INB compared to 10% for that of Ferké 1. Variety N21 cultivated in Ferké 1 experiment with its high fiber content (15.5%) seemed much tolerant to *E. saccharina* than M2593/92 used in Ferké 2 experiment with a moderate fiber content (13.6%) in line of findings reported by several investigators (keeping, 2006; Konan et al, 2010, Péné et al, 2016). In rainfed plant crop, regardless the sugarcane variety, , stem borer infestations were strongly dependent on the crop cycle duration and the intensity of crop water stress, as reported by different authors (Sharma et al, 2005; Kvedaras et al, 2007; McFarlane et al, 2009). That's why early harvesting in rainfed plant cane could be beneficial in the prevention of heavy borer infestations. It was also reported by several authors that sugarcane crop was more susceptible to borer infestations than ratoons, especially in the presence of nitrogen rates higher or equal to 100 kg/ha (Lopez et al, 1983; Way et al, 2003; Goebel et al, 2005; Péné et Coulibaly-Ouattara, 2019). Higher damage levels observed particularly in the control treatment plots of Ferké 2 experiment (24% INB) did not significantly affect cane and sugar yields in contrast of findings reported by different authors (Leslie, 2009; Goebel et al, 2010; Péné et al, 2016; Péné et al, 2019, Péné and Coulibaly-Ouattara, 2019). Similarly, they did not significantly affect fiber content of sugarcane in contrast of observations reported by Goebel et al (2000). Nitrogen fertilizer application at planting could be an additional factor of stem borer infestations from *Sesamia calamistis* (African pink specie) at tillering stage as well as *E. saccharina* at early boom stage, as N rates used to be high in order to compensate lower fertilizer use efficiency over the three months of sugarcane growth under heavy rainfall conditions. That is why fertilizer application in rainfed sugarcane could be preferable at the beginning of the rainy season in March or April, at least 6 months after planting. Similar finding was reported by different authors (Bikila et al, 2014; Forestieri, 2017; Otto et al, 2019).

Treatments	Purity %	Pol%C	Fiber %C	CYield (t/ha)	RSucrose %C	SYield (t/ha)	SNbx103 (/ha)	INB (%)
T0	78.5	12.7	16.2	68.4	8.1	5.5	73.4	9.7
T1	81.9	13.8	15.4	65.9	9.3	6.2	68.3	7.8
T2	82.1	13.1	15.6	81.2	8.8	7.1	63.7	8.1
T3	81.9	13.4	15.0	77.8	9.0	7.1	64.6	7.5
Mean	81.1	13.3	15.5	73.3	8.8	6.5	67.5	8.3
CV (%)	3.0	6.3	6.5	16.3	9.9	20.9	18.4	34.6
SD	2.4	0.8	1.0	12.0	0.9	1.4	12.4	2.9
Replications	0.26 ns	0.31 ns	0.44 ns	0.29 ns	0.29 ns	0.25 ns	0.38 ns	0.70 ns
Treatments	0.19 ns	0.33 ns	0.44 ns	0.28 ns	0.32 ns	0.33 ns	0.69 ns	0.70 ns

Table 1. Mean values of agronomic traits investigated in plant crop of rainfed sugarcane regarding Ferké 1 experiment.

3.3. Cane and sugar yields as influenced by early harvesting

In both experiments, sugar yields were not significantly affected by early cane harvesting ($P=5\%$) although cane yields were significantly reduced by 21% ($P<5\%$) with the harvesting of Ferké 2 experiment in November (Table 2). Similarly, in Ferké 1 experiment, cane yields regarding the November harvesting were reduced by 3.6% although not significantly ($P=5\%$). Moreover, in this experiment, cane yields obtained on December and January early harvestings increased surprisingly by 19 and 14%, respectively, although not significantly ($P=5\%$). December and January early harvestings might have enhanced cane stalk elongation of the following crop cycle, as lower millable stalk numbers/ha were observed (63 700 and 64 600/ha) although not significantly compared to that of the control treatment T0 without early harvesting (73 400/ha). This finding looks contradictory to the general belief about early harvesting in rainfed plant cane which was supposed to be harmful to cane and sugar yields although seen as beneficial to crop protection against stem borer infestations by reducing significantly crop cycle as well as the number of borer generations as reported by Goebel et al (2012).

Treatments	Purity %	Pol%C	Fiber %C	CYield (t/ha)	RSucrose %C	SYield (t/ha)	SNbx103 (/ha)	INB (%)
T0	78.9	10.7	13.6	80.1 a	6.8	5.5	92.2	24.2 a
T1	80.5	11.3	13.6	63.2 b	7.4	4.7	80.4	11.2 b
T2	81.6	11.7	13.7	75.2 ab	7.8	6.0	90.3	7.2 b
T3	79.5	11.0	13.5	74.2 ab	7.1	5.3	88.5	7.8 b
Mean	80.1	11.2	13.6	73.4	7.3	5.3	87.9	12.6
CV (%)	1.6	4.3	4.3	9.3	5.9	12.8	13.4	33.7
SD	1.3	0.5	0.6	6.8	0.4	0.7	11.8	4.2
Replications	0.06 ns	0.40 ns	0.82 ns	0.15 ns	0.25 ns	0.35 ns	0.53 ns	0.06 ns
Treatments	0.06 ns	0.70 ns	0.96 ns	0.05*	0.06 ns	0.20 ns	0.54 ns	0.01**

Table 2. Mean values of agronomic traits investigated in plant crop of rainfed sugarcane regarding Ferké 2 experiment.

3.4. Integrated management of *E. saccharina*

The intensity of *E. saccharina* infestations is highly variable from one field to another and from one year to another depending on numerous factors among which the most important are climate, natural enemies, and cropping conditions (Goebel et al, 2008; Nikpay et al, 2015). Stem borer populations used to be stable under natural conditions due to their regulation by the parasitoids through an equilibrium. For example, *Trichogramma evanescens* W. (Hymenoptera: Trichogrammatidae) is a well-known species which parasitizes eggs of *E. saccharina* as well as *S. calamistis* (Lepidoptera: Noctuidae), (Parra et al, 2010). This equilibrium used to be disrupted under certain cropping conditions such as high nitrogen fertilizer rates for better yields, excessive applications of insecticides. It was reported that a sudden increase of borer infestations in sugarcane was explained by high nitrogen fertilizer rates (Goebel et al, 2010; Péné et al, 2019). Some cane varieties with prominent growth cracks and lower or moderate fiber content which are often susceptible to infestations must be avoided despite their high performance as reported by several authors (Hensley et al, 1977; Goebel et al, 2000; Kouamé et al, 2010; Péné et al, 2016). As stated by many investigators (Kvedaras et al, 2007; Goebel et al, 2010; Saljoqi and Walayati, 2013; Nikpay et al, 2014; Gobel and Nikpay, 2017; Goebel et al, 2018), an effective control of stem borer in sugarcane lies in an integrated approach based on well managed cropping practices in combination with a good knowledge of the biology of pest, a selective application of insecticides, the use of leguminous plants providing ecosystem services to build up natural enemies, the breeding of key parasitoids like *Trichogramma* species followed by their release in the field, as well as the installation of light traps to catch *E. saccharina* adults across sugarcane fields.

4. Conclusions

The study showed that in rainfed sugarcane, the variety N21 with high fiber content was more tolerant to stem borer than the variety M2593/92 credited with a moderate fiber content. Stem borer infestations of rainfed plant cane were significantly reduced across crop cycle following early harvesting of M2593/92, in contrast to N21. Without early harvesting, M2593/92 would have been much more infested by *E. saccharina* than N21, with respectively 24 and 10% of internodes bored. Regardless the variety used, sugar yields were not significantly affected by early harvesting. However, cane yields could be significantly reduced, with respect to the November harvesting, depending on type of variety, nitrogen application rate, soil type, crop cycle duration, and weather data. In rainfed plant cane, regardless the variety, stem borer infestations were strongly dependent on crop cycle duration and the intensity of water stress. That's why early harvesting in plant cane seems to be beneficial in rainfed conditions for preventing heavy infestations of stem borer.

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