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Effectiveness of *Calotropis procera* (Ait. R. Br.) and *Cassia siamea* (Lamk.) Leave Powders in the Control of *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae)

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ABSTRACT

Sitophilus zeamais (Coleoptera: Curculionidae) is a major pest of maize grains. The objective of this study was to evaluate the efficiency of *Calotropis procera* and *Cassia siamea* leaves powders against *Sitophilus zeamais* as possible stored maize grain protectants under laboratory conditions (25 ± 3°C, 75 ± 5 % rh). *Calotropis procera* and *Cassia siamea* leave powders were tested at three rates of 3.00 g, 5.00 g and 8.00 g, and chemical application Actellic 2% DP® respectively that were mixed with the 50 g maize grains sterilized in translucent plastic containers and the control (untreated). Three pairs of *Sitophilus zeamais* were put in each translucent plastic containers. Three replicates were performed for each treatment including the control. *Calotropis procera* and *Cassia siamea* leaves powders tested at 8.00 g per 50 g of maize grains inflicted highest adult mortality of *Sitophilus zeamais* and it recorded the lowest seed damage and reduced maize seeds weight losses as a pesticide Actellic. *Calotropis procera* leaves powders at the rates (8.00 g and 5.00 g) recorded highest reproductive deterrence than the pesticide Actellic 2% DP® and had similar viability index with the pesticide Actellic. The lowest WPI was recorded in *Calotropis procera* leaves powders at the rate 8.00 g and was 9.722 % followed by the pesticide Actellic 2% DP®. However, *Cassia siamea* leaves powders (8.00 g) had a similar reproductive deterrence, similar viability index with a pesticide Actellic and had a positive protectant. *Calotropis procera* and *Cassia siamea* leaves powders can be used to maize stored protection against a maize weevil *Sitophilus zeamais*.

Key words: *Cassia siamea*, *Calotropis procera*, *Sitophilus zeamais*, Reproductive deterrence, Adult mortality, Weevil Perforation Index.

INTRODUCTION

Maize (*Zea mays* L.) is an important cereal in the world that have a great importance in people nutrition (Mulungu *et al.*, 2007; Akowuah *et al.*, 2018). It is an excellent source of macronutrients and micronutrients (Chaudhary *et al.*, 2014). It is usually stored to provide food reserves and their grains were also used for planting (Mulungu *et al.*, 2007; Akowuah *et al.*, 2018; Paneru *et al.*, 2018). In Côte d'Ivoire, maize production was estimate at 654 738 tons (Anader, 2014). The pests of stored-product are economically important because they attack the agricultural product such as maize grains (Danga *et al.*, 2015). The maize weevil (*Sitophilus zeamais*) is a major pest of stored maize, responsible for serious economic damage and having a negative impact on food security (Danga *et al.*, 2015; Paneru *et al.*, 2018; Patiño-Bayona *et al.*, 2021). *Sitophilus zemais* Motschulsky, 1855 (Coleoptera: Curculionidae) are found in all tropical and sub-tropical parts of the world (Throne, 1994). It reduce both the quality and the yield of maize sored. It cause an estimated 24.5% to 80% loss of maize stored and damaged grains have reduced nutritional value and weight, low frequency of germination, and low market value (Ukeh *et al.*, 2008; Yuya *et al.*, 2009; Napaleao *et al.*, 2013; Danga *et al.*, 2015; Paneru *et al.*, 2018). Thus, this pest is a major obstacle to achieving food security (Asawalam *et al.*, 2008; Paneru *et al.*, 2018; Ehisianya *et al.*, 2019). In terms of

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protection of natural resources or from economic considerations, it is more reasonable to protect harvested produce against loss than to invest in further increases in agricultural production (Diabaté *et al*., 2014; Paneru *et al*., 2018). Previously, the control of storage insects like *S. zeamais* has centered mainly on the use of chemical insecticides that are hampered by many attendant problems such as toxicity to humans that consume the product, development of insect resistant strains and the cost of procurement (Paneru *et al*., 2018; Ehisianya *et al*., 2019). Chemical control of the maize weevil (*S. zeamais*) has been ineffective and presents serious collateral damage (Patiño-Bayona *et al*., 2021). Alternative methods such as the use of plant material powders and plant extracts have good results than the use of synthetic pesticides (Asawalam *et al*., 2007; Udo, 2011; Danga *et al*., 2015; Ileke *et al*., 2020). Pure compounds, solvent extracts or essential oils of plants products such as dried materials and powdered form were used against different stored-product pests (Paul *et al*., 2009; Nukenine *et al*., 2013; Paneru *et al*., 2018). *Piper guineense* seed powders used at smaller rates against *S. zeamais* on maize have similar efficacy with Pirimiphos Methyl (Asawalam and Emosaire, 2006; Paneru *et al*., 2018). *Jatropha curcas* seed recorded the lowest adult emergence (0.67- 2.67) and reduced grain damage with a weevil perforation index and it also inflicted adult mortality of *S. zeamais* (Ojiako *et al*., 2014; Paneru *et al*., 2018). The use of natural methods such as biopesticides that can offer compatible control efficiency plus the benefit to environment is most favoured (Diabaté *et al*., 2014; Paneru *et al*., 2018). However, few studies have been carried out on the efficacies of Côte d'Ivoire plants materials in the control of stored-products. Then, these studies were carried out to evaluate the efficacies of two plants leaves powders (*Calotropis procera* and *Cassia siamea*) against *Sitophilus zeamais* as possible stored maize seed protectants. In fact, the efficacies of these two plants material were evaluated on the reproductive deterrence, the adult mortality, the weight loss of maize seeds, the grains damage with the Weevil Perforation Index and on the viability index, respectively.

MATERIALS AND METHODS

Rearing of Insects

Sitophilus zeamais Motschulsky, 1855 (Coleoptera: Curculionidae) used in this study were reared at Man University on maize seeds infested.

Plant Materials and Pesticide

*Calotrop*is *procera* (Aiton, 1811) (Asclepiadaceae) and *Cassia siamea* (Lamk., 1783) (Fabaceae) were identified by the botanists of Man University (west of Côte d'Ivoire). Then, *Calotrop*is *procera* and and *Cassia siamea* leaves were collected in Man University during daytime. These leaves were cleaned, washed with water and were air-dried for four weeks at room temperature (30 ± 2°C) and a relative humidity of 72 ± 5%. Then, *Calotrop*is *procera* (T1) and *Cassia siamea* (T2) were grounded to fine powders using a sieve of 500 ųm (Figure 1).

The maize grains used in this study come from the maize farm of Man University. Insecticides used in this study were Actellic 2% (Dusting Powder (DP)®, Syngenta AG, Switzerland). Actellic 2% DP® (T3) is an organophosphate insecticide-acaricide used for the protection of stored cereals such as maize grains.

Bioessays

Laboratory bioassays were conducted to evaluate the reproductive deterrence, the adult mortality, the weight loss of maize grains, the grains damage with the Weevil Perforation Index and on the viability index, respectively.

C. procera and *C. siamea* leaves powders at the rates 3.00, 5.00 g and 8.00 g were tested and compared to the conventional Actellic 2% DP® (Pyrimiphos-methyl, 50 mg for 50 g of maize grains) (T3) against *S. zeamais* (Motsch.) under laboratory conditions (25 ± 3°C, 75 ± 5 % rh), in the Central Laboratory of University of Man (Côte d'Ivoire). Fifty grams (50 g) of uninfested maize grains were weighted into thirty-three translucent plastic containers which were covered and sterilized with deep freezer at 0°C. Thus, *C. procera* and *C. siamea* leaves powders were measured out in rates of 3.00, 5.00 g and 8.00 g, and chemical application respectively, were mixed with the 50 g maize grains sterilized in translucent plastic containers. Each treatment was replicated three times including the control (no chemical and no plants powders application). The translucent plastic containers were labelled according the treatments. Three pairs (3 males and 3 females) of newly emerged *Sitophilus zeamais* were introduced into translucent plastic containers and covered (Figure 2).

Observations were made in each treatment at fifty days and for every other week for two weeks. Both the number of dead and living weevils, reproductive deterrence, the weight loss of maize seeds, the seeds damage with the Weevil Perforation Index in each treatment and the viability index was recorded, respectively.

Mortality Rate

Mortality rate was calculated using the following formula used by Asawalam *et al*. (2007):

$$M\ (\%) = \frac{d * 100}{T} \qquad (1)$$

With:
M= Mortality rate,
T=Total number of *S. zeamais*,
d= Number of dead *S. zeamais*.

Damage Rate and Weight Loss

The damage rate (Dr) were calculated using the following formula used by Asawalam *et al.* (2007):

$$Dr\ (\%) = \frac{dg * 100}{tg} \qquad (2)$$

with:
Dr= Damage rate,
dg= Number of damage grains,
tg= Number of total grains.
Initial weight of the three repetitions (150 g) and the final weight in each treatment and in the control were recorded. The weight loss was calculated using the following formula:

$$WL(\%) = \frac{(Wi - Wf) * 100}{Wi} \qquad (3)$$

Whith:
WL= Weight loss,
Wi= Initial weight (g),
Wf = Final weight (g).

Effect of *Calotropis procera* and *Cassia siamea* leave powders and pesticide Actellic 2% DP® on weevil adults emergence.

The fecundities (emerging adults) during the 50 days of bioessay and at the end of the bioassay were evaluated. The reproductive deterrence was determined using the formula used by Ehisianya *et al*. (2019) and Su (1989):

$$Rd\ (\%) = \frac{(Nc - Nt) * 100}{Nc} \qquad (4)$$

with:
Rd= Reproductive deterrence of the treatment,
Nc= Number of newly emerged adults of *S. zeamais* in control,
Nc= Number of newly emerged adults of *S. zeamais* in treated.

Weevil Perforation Index

The Weevil Perforation Index (WPI) (Fatope *et al*. 1995), was calculate by using the formula:

$$WPI(\%) = \frac{Npt * 100}{Npc} \qquad (5)$$

with:
Npt= Number of perforated seeds in the treatment,
Npc = Number of perforated seeds in the control.
If WPI < 50%: positive protectant of the treatment and WPI > 50%: negative protectant of the treatment.

Viability Test

The effect of the two plants (*C. procera* and *C. siamea)* leave powders on maize grains germination was evaluated by using 10 undamaged grains selected from each replicate. Each batch of 10 grains selected were placed separately in petri dishes (9 cm) which base was lined with Whatman's paper disc (9 cm diameter) and moistened with water. The petri dishes were labelled and covered according the treatment. These petri dishes were kept in the laboratory for seven days and moistened with water every 3 days. Observations were made at 7 days after sowing and the numbers of emerged seedlings per Petri dish were recorded in all the treatments. Germination of maize grains were assessed and the viability index was calculated using the formula of Zibokere (1994):

$$VI(\%) = \frac{NG * 100}{TG} \qquad (6)$$

with:
VI= Viability index,
NG= Number of germinated grains,
TG: Total number of maize grains tested.

Data Analysis

Data on reproductive deterrence, adult mortality, weight loss of maize grains, grains damage and Weevil Perforation Index and on the viability index were subjected to Microsoft SPSS Software version 22.0 (IBM, New York, USA). The means were discriminated with the Fisher test (LSD) with a significance level of 5% using XLSTAT 2016.

RESULTS

Effect of *Calotropis procera*, *Cassia siamea* leaves powders and the pesticide Actellic 2% DP® on *Sitophilus zeamais* adult mortality, the weight loss of maize seeds and their damage

C. procera leaves powders tested at the highest rate (8.00 g) caused highest adults' mortality (41.111%) and it recorded the lowest grains damage (7.778 %) and grains weight loss (6.00%). Comparatively, however, the pesticide recorded the highest mortality of *S. zeamais* than the highest rate (8.00 g) of *C. procera* leaves powders. The pesticide Actellic 2% DP® (50 mg for 50 g of maize grains) (T3) recorded similar grains damage (13.889 %) and grains weight loss (8.667%) with *C. procera* leaves powders tested at the highest rate (8.00 g).

C. procera leaves powders affected the survival of *S. zeamais* adults with a mortality ranging from 11.991 to 41.111% and the *Cassia siamea* leaves powders with a mortality rate ranging from 3.759 to 7.731 %. Higher mortality of 74.088 % was recorded on maize treated with the pesticide Actellic 2% DP® followed by *C. procera* leaves powders at the highest rate (8.00 g) (41.111 %). *C. procera* leaves powders (3 g and 5 g) and *C. siamea* leaves powders (3 g, 5 g and 8 g) recorded similar mortality. These mortality rates were between 3 % and 17%. The lowest mortality rates of S. zeamais was recorded in the untreated seeds and were 1.3783% (F= 26.092, ddl= 23, p= 0.001) (Table 1).

The lowest grains damage was recorded in the highest rate (8.00 g) of *C. procera* (7.778 %) and *C. siamea* (17.2222 %) leaves powders and in the pesticide Actellic 2% DP® (13.889 %). These damage rates were respectively followed by those of the lowest rates (3 g) of *C. procera* (37.222 %) and *C. siamea* (46.667 %) leaves powders. The highest grains damage was recorded in untreated seeds of maize (80.000 %) (F= 20.124, ddl= 23, <0.001) (Table 1).

Higher grains weight loss of 42 % was recorded in untreated maize seeds followed by *C. siamea* leaves powders 3 g. The weight losses rate was 32.00 % and respectively followed by *C. siamea* leaves powders at the rates 5 g (24.000 %) and 8 g (21.333%). All trials of *C. procera* leaves powders (3 g, 5 g, 8 g) and the pesticide Actellic 2% DP® were reduced maize seeds weight losses (F= 29.564, ddl= 23, <0.001) (Table 1).

Effect of *Calotropis procera* and *Cassia siamea* Leave Powders on *Sitophilus seamais* Adults' Emergence

C. procera leaves powders at the highest rates (8.00 g and 5.00 g) recorded highest reproductive deterrence (81.85 % and 75.82% respectively) than the pesticide Actellic 2% DP® (70.67%). *C. siamea* leaves powders (8.00 g) have a similar reproductive deterrence as the pesticide Actellic 2%. However, the lowest rate of *C. procera* leaves powders (3.00 g) and *C. siamea* leaves powders at the rates 5.00 g and 3.00 g had a lowest reproductive deterrence than the pesticide Actellic 2% DP® (50 mg for 50 g of maize seeds) (F=11.445; ddl= 20; <0.001) (Figure 3).

Effect of the Plants Leaves Powders on the Weevil Perforation Index (WPI) and on the Viability index

All rate of *C. procera* leaves powders (3 g, 5 g and 8 g) tested and the highest rates of *C. siamea* leaves powders (8 g and 5 g) had a WPI which not exceeding 50.0 %. Only the lowest rate of *C. siamea* leaves powders (3 g) had a WPI of 58.33% and is regarded as negative protectant.

Fig. 1: T1: *Calotropis procera* (a) and T2: *Cassia siamea* (b) leave powders

Fig. 2: Plant powders (*Calotropis procera* and *Cassia siamea*) and pesticide Actellic 2% DP® mixed with the 50 g maize seeds

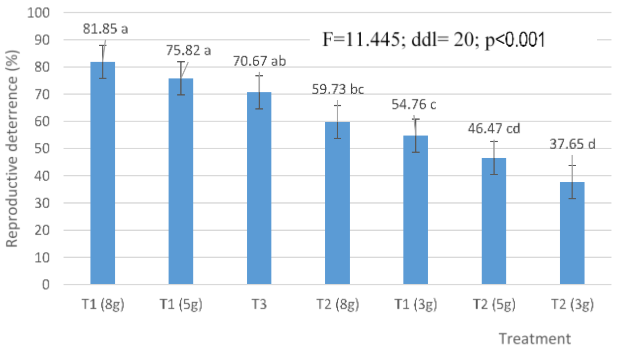

Fig. 3: Reproductive deterrence of *Calotropis procera* (T1) and *Cassia siamea* (T2) leaves powders and the pesticide Actellic 2% DP® on *Sitophilus zeamais* in maize seeds: *The means assigned to the same letter are not significantly different (Fisher test (LSD), P < 5%):* T0= Control ; T1 : *Calotropis procera* Leaves powder, T2: *Cassia siamea* Leaves powder, T3: Pesticides Actellic 2% DP®

The lowest WPI was recorded in *C. procera* leaves powders at the highest rates (8.00 g) and were 9.7222 % followed by the pesticide Actellic 2% DP® (17.3611%) (F = 6.252, ddl = 23, p = 0.02) (Table 2). The highest rates of *C. procera* leaves powders tested and those of *C. siamea* leaves powders (8 g and 5 g) had similar viability index with the pesticide. However, the lowest rate of *C. procera* (60%) and *C. siamea* (66.67%) leaves powders (3 g) gave moderate viability index. The lowest viability index was recorded in maize untreated seeds (F = 20.974, ddl = 23, p<0.001) (Table 2).

DISCUSSION

Different rates of *C. procera* and *C. siamea* leaves powders tested against against *S. zeamais* showed potential insecticidal, reproductive deterrence and affected the weight loss of maize seeds, the seeds damage with the Weevil Perforation Index (WPI) and the viability index.

Table 1: Damage rate, mortality rate and weight loss on maize seeds by the weevils

Treatment	Mortality rate (%) ± SE	Damage rate (%) ± SD	Weight loss (%) ± SD
T0	1.378 ^{d} ± 0.133	80.000 ^{f} ± 0.000	42.000 ^{d} ± 4.000
T1 (3 g)	11.991 ^{cd} ± 8.883	37.222^{de}± 12.509	12.667 ^{a} ± 1.155
T1 (5 g)	17.672 ^{c} ± 11.792	25.000^{bcd} ± 8.333	8.667 ^{a} ± 2.309
T1 (8 g)	41.111 ^{b} ± 18.359	7.778 ^{a} ± 3.469	6.000 ^{a} ± 2.000
T2 (3 g)	3.759 ^{cd} ± 2.786	46.667 ^{e} ± 11.667	32.000 ^{c} ± 4.000
T2 (5 g)	4.206 ^{cd} ± 1.175	31.111 ^{cd} ± 3.849	24.000 ^{b} ± 6.928
T2 (8 g)	7.731 ^{cd} ± 3.621	17.222^{abc}±14.175	21.333 ^{b} ± 6.110
T3	74.088 ^{a} ± 2.751	13.889 ^{ab} ± 6.736	8.667 ^{a} ± 2.309
ddl	23	23	23
F	26.092	20.124	29.564
P	<0.001	<0.001	<0.001

SD. Standard deviation: *The means assigned to the same letter within the same column are not significantly different (Fisher test (LSD), P < 5%):* T0= Control ; T1 = *Calotropis procera* Leaves powders, T2= *Cassia siamea* Leaves powders, T3: Pesticides Actellic 2% DP®

Table 2: Viability index and weevil Perforation Index on maize seeds by the weevils

Treatment	Weevil Perforation Index ± SD	Viability index ± SD
T0	-	30.000 ^{d} ± 10.000
T1 (3 g)	46.527 ^{de} ± 15.637	60.000^{c} ± 0.000
T1 (5 g)	31.250 ^{bcd} ± 10.417	70.000 ^{abc} ± 5.000
T1 (8 g)	9.722 ^{a} ± 4.337	76.667 ^{abc} ± 5.774
T2 (3 g)	58.333 ^{e} ± 14.583	66.667 ^{bc} ± 5.774
T2 (5 g)	38.888 ^{cde} ± 4.811	76.667 ^{abc} ± 5.774
T2 (8 g)	21.527 ^{abc} ± 17.718	83.33 ^{ab} ± 5.774
T3	17.361^{ab} ± 8.419	86.667 ^{a} ± 5.774
ddl	20	23
F	6.252	20.974
P	0.02	<0.001

SD. Standard deviation: *The means assigned to the same letter within the same column are not significantly different (Fisher test (LSD), P < 5%):* T0= Control ; T1 = *Calotropis procera* Leaves powders, T2= *Cassia siamea* Leaves powders, T3: Pesticides Actellic 2% DP®

The study showed that *C.* and *C. siamea* leaves powders at the rate 8.00 g were the most effective of the treatment used in the control of the maize weevil. *C. procera* and *C. siamea* leaves powders tested at the highest rate (8.00 g) caused the highest mortality of *S. zeamais*. It recorded the lowest seed damage and seed weight loss. Then, it had a similar reproductive deterrence with the pesticide Actellic 2% DP® and had a WPI which not exceeding 50.0 %. These leaves powders of plants had similar viability index with the pesticide Actellic 2% DP. Study was also supported by Kestenholz *et al.* (2007) and Alamuoye (2019) who showed that the leaf of *C. procera* and *C. siamea* contain relative repellency properties that could be used in the control of insects. *C. procera*, have been observed to have very wide effects against wide range of organisms (Awadh *et al.*, 2008). The toxicity of leaves powders of two plants (*C. procera* and *C. siamea*) against *S. zeamais* was led to several compounds that have toxic effects. These toxic compounds have a negative impact on insect biology and would be responsible for the mortality of *S. zeamais* larvae and their adults. A wide range of chemical compounds such as, cardiac glycosides, flavonoids, triterpenes, sterols, phenolic compounds, alkaloids and carbohydrates have been isolated from *C. procera* (Morsy *et al.*, 2001; Mueen *et al.*, 2003;

Rajashekar *et al*., 2012; Srivastava *et al*., 2012). These compounds of *C. procera* reduced the consumption of maize seeds by *S. zeamais*. Study was also supported by Chauhan *et al*. (2016) who tested methanolic extract of *C. procera*. They found that *C. procera* helps in reducing ovipositions and emergence there by controlling seeds loss and increased weight loss of the crop and seed germinations. The phytochemicals of the genus Cassia, such as glycosides, flavonoids, phenolic compounds, diterpenoids, sterol and alcaloids significantly reduced the number of emerging insects (Babu *et al*., 1999; Kestenholz *et al*., 2007).

Conclusion

Different rates of *C. procera* and *C. siamea* leaves powders affected reproductive deterrence, the adult mortality, the weight loss of maize seeds, the grains damage with the Weevil Perforation Index (WPI) and the viability index. The *C. procera* and *C. siamea* leaves powders tested at 8.00 g per 50 g of maize grains inflicted adult mortality and it recorded the lowest grains damage and grains weight loss. It had positive protectant (WPI< 50%). The pesticide Actellic 2% DP® (Pyrimiphos-methyl) recorded similar grains damage (13.88%) and grains weight loss (8.67%) with *C. procera* leaves powders tested at the highest rate (8.00 g). These leaves powders of these plants can be used to proctect stored grains against a maize weevil *Sitophilus zeamais*.

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