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Impacts of intercropping on the major insect pests of *Jatropha curcas* L. in south of Benin

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ABSTRACT

Jatropha curcas is an oleaginous plant whose seed yield is low. The present study aimed at evaluating is pests associated with *J. curcas*. In regards to the densities, *Denticera* near *divisella* density was obtained 0.85 larvae per plant in *J. curcas* in sole farming and 0.70, 0.61, 0.85 larvae respectively when intercropped with casava, maize and cowpea. When *J. curcas* was intercropped with cassava *Stomphastis thraustica* was the most encountered species with a density of 1.28 larvae per plant while 0.61 larvae density was encountered for intercropped with maize and 0.27 larvae density with cowpea against 0.43 larvae in mono culture. For *J. curcas* with maize, *Aulacophora africana* was the most abundant species with a density of 0.47 adult per plant. In the case of *J. curcas* with cowpea. *D.* nr *divisella* had the highest density of 0.85 larvae per plant. It was also shown that the grain yield of *J. curcas* depends of intercrop. The yields were from 591.75 ± 109.25kg / ha; 431.75 ± 92.50kg / ha; 252.50 ± 51.50kg / ha; 89.50 ± 43.00kg/ha respectively in pure farming of *J. curcas*, *Jatropha* intercropped with maize, cowpea or cassava respectively. Therefore, it is important to choose intercropping to reduce the density of pests in *Jatropha* crop.

Keywords: *Jatropha curcas*, pests, *Denticera* near *divisella*, intercropping, biofuel

INTRODUCTION

Many countries have experience in *J. curcas* (E) crop farmingg. Some people refer to it as the "green gold" of the desert due to its oils use as biodiesel. African countries have not remained on the sidelines of the development of biofuels. Biofuels are an approach to solving the problems of fossil fuel depletion. But the use of *Jatropha* oil for biofuel has been perceived as a shortfall for agriculture which could slow down its adoption (Dorin and Gitz, 2008; Belewu et al., 2010). To overcome this difficulty, the agricultural extension services of Benin advise associating jatropha with food crops. In this light, the NGO GERES wasthe first to start to advise the farmers on *Jatropha* crops with food crops in order to contribute to ensuring food security (GERES, 2010). So, it was important to we have to demonstrate its feasibility with the farmers so as to get them to do it (Brittaine and Lutaladio, 2010; Ahoton et al., 2011).

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The the sustainable development of the *J. curcas* sector necessarily needs to go through a thorough knowledge of the agronomic, phytopathological and entomological characteristics of the plant. There are not many experiments with *J. curcas* on pests including predators, parasitoids and plant pests. Perhaps that jatropha-associated crops may be secondary host plants for *Jatropha* pests. In this case, they may be a reservoir for *Jatropha* pests especially if they are grown in associaton. Therefore, it is important to choose the best cultural association in order to alleviate insect pest infestations and diseases.

According to Datinon et al. (2013), *J. curcas* is subject to parasitic constraints. So, it is important to measure the pest pressure exerted by pests of *J. curcas* in association with food crops. This is especially necessary for Benin where food crops occupy only 24.1% of cultivated areas (Agbo and Honkpehedji, 2009). This study is to our knowledge the first in Benin interested in the impact of cultural associations between *J. curcas* and the main food crops for food security in this case maize, cowpea and especially cassava which is a Euphorbiaceae as *J. curcas*. The present study aimed at determining the impact of pests when the association of *J. curcas* with some food crops in southern Benin. Specifically, this involves assessing the damages caused by these insects to the plants, and the effect on *J. curcas* yield.

MATERIALS AND METHODS

Study site

The trials were conducted from 2014 to 2018 in a field at Ouinhi in the region of Zou in southern Benin, located in the intertropical zone in West Africa.

Experimental design

The plant material consisted of *J. curcas* plants installed on the CIRAPIP-IITA project sites. These plants were intended for the inventory of the entomofauna associated with plants of *J. curcas* or associated crops including the main staple crops of Benin such as maize (cereal), cowpea (legume) and cassava (tuber).

Change to experimental design

For this study, four plant species were used for crop associations. These are *Jatropha* and three food crops namely cassava, maize, and cowpea. *Jatropha* is grown pure or associated with one of these three food crops. The experimental design was a complete random block with four treatments or types of association with four repetitions. The four treatments or types of associations were

- Culture (To): single *Jatropha* crops;
- Culture (T1): *Jatropha* curcas intercropped with cassava;
- Culture (T2): *Jatropha curcas* intercropped with maize;
- Culture (T3): *Jatropha curcas* intercropped with cowpea.

Each type of crop association was represented by an experimental plot. Each experimental plot measured 20 x 20 m, an area of 400 m². Two blocks or consecutive repetitions were separated by 4 m inter-row, and within the same block, two consecutives experimental plots were separated by 4 m inter-row. A walking space of 4 m strip was built around the design. The different experimental plots were installed on June 25, 2012, at Ouokon in the District of Ouinhi.

Data collection in the experimental field of *Jatropha curcas* plants

Pest scoring on *J. curcas* plants was done on a weekly basis. As soon as the seeds germinated, special attention was given to the plants by regular monitoring every seven (7) days in order to detect the appearance of harmful insects. For each observation, 30 plants were randomly selected per experimental plot. This operation was repeated 4 times, with a total of 120 plants observed. Insect pests were counted visually on all the plants using the frontal magnifier. This was done with great delicacy to avoid insect pests from escaping. Infested organs were dissected on white paper and insects were counted the

same day. Larvae and adults of the various insect pests collected were reared and identified in the laboratory to adults identified.

Collection of data on the food crops associated with *Jatropha curcas*

Data was also collected on a weekly basis on each of the associated food crops on 30 plants randomly chosen per plot. Some organs were taken to observe insect pests in each crop. 20 flowers or 20 pods per unit plot were randomly picked in envelop bag at each observation of the cowpea. In maize plots, 20 ears were randomly collected per unit plot.
In addition, five (5) density squares were placed diagonally to estimate the yield.

Statistical analysis

Excel software was used to analyze the data is the General Linear Model (GLM) (GLM) and the mean was separated by the student-Newman-Keuls multiple comparison tests (SNK) at the 5% threshold by SAS software (2008).

RESULTS

Impacts of pest on *J. curcas* single culture experimental plot

Concerning the population dynamic of insect pests on *J. curcas* crops, the average population density of insect pest species ranged from 0.17 to 0.85 per plant. The highest density was observed in *Denticera* near *divisella* Duponchel (Lepidoptera: Pyralidae) with 0.85 hoppers per plant. This pest attacked both young leaves, flowers and fruits of *J. curcas* (Figure 1.a) followed by *Calidea dregei* Germar (Hemiptera: Scutelleridae), a fruit pest with 0.17 adults per plant (Figure 1.f). Then, come the defoliator *Aulacophora africana* (Weise) (Coleoptera: Chrysomelidae) with an average density of 0.43 adults per plant (Figure 1.c). It was followed by the leafminer *Stomphastis thraustica* (Meyrick) (Lepidoptera: Gracilariidae) with a density of 0.43 larvae per plant (Figure 1.b). In addition, we observed *Apion* sp. (Coleoptera: Apionidae) with an average density of 0.40 adults per plant (Figure 1.e) followed by the defoliator *Lagria vilosa* (Fabricius) (Coleoptera: Lagriidae) with 0.38 adults per plant (Figure 1.d) and finally the bug *C. dregei* whose average density was 0.17 adults per plant of *J. curcas* (Figure 1.f). Basically, the most important pest species observed in *J. curcas* pure culture were *D.* nr *divisella, A. africana, S. thraustica, Apion sp.* and *C. dregei*.

The population density of insect pests on *Jatropha* intercropped with cassava

The average density of insect pests observed on *Jatropha* associated with cassava ranged from 0.086 to 1.28 per plant with the highest density observed on *S. thraustica* and the lowest on *Clavigralla tomentosicollis* Stäl. (Hemiptera: Coreidae; synonym: *Acanthomia tomentosicollis* Stäl.) (Figure 1). Then the defoliator *A. africana* recorded an average density of 0.73 adults per which plant while its density was 0.47 adults per plant on *Jatropha* crops ($F = 41.65$, $df = 3$, $P < 0.001$) (Figure 1.c). It was followed by *D.* near *divisella* with an average of 0.70 larvae per which cassava plant compared to that of *Jatropha* with an average of 0.85 larvae per plant giving a highly significant difference ($F = 15.38$, $df = 3$ $P < 0.001$) (Figure 1.a). In addition, we have *L. vilosa* pest had an average density of 0.51 adult per which cassava plant while its density was 0.38 adults per plant in *Jatropha* ($F = 43.25$, $df = 3$; 0.001) (Figure 1.d). *C. tomentosicollis* pest was observed only on cassava-associated with *Jatropha* plants with an average density of 0.086 adults per plant (Figure 1) (Figure 1.g).

Ultimately, the most important pest species observed in cassava-associated *Jatropha* crops were: *S. thraustica, D.* nr *divisella, A. africana, Apion sp.* and *L. vilosa* (Figure 1).

The population density of insect pests on *Jatropha* intercropped maize

The average density of insect species observed on *Jatropha* associated with maize varied from 0.37 to 0.73 per plant with the highest density observed on *A. africana* and the

lowest on *C. dregei*. Observations on *Jatropha* associated with maize showed that the defoliator *A. africana* was the most abundant with an average density of 0.73 adults per maize plant (Figure 1.c). In addition, *D.* nr *divisella* showed an average density of 0.61 larvae per plant with a highly significant difference ($F = 15.38$, $df = 3$, $P<0.001$) compared to the average density of 0.85 larvae per plant observed in the pure culture of *J. curcas* (Figure 1.a). It was followed by S. thraustica leafminer with a density of 0.61 larvae per maize plant compared to its density of 0.43 larva per *J. curcas* in plant with a significant difference ($F = 218.81$, $df = 3$; $P<0.001$) (Figure 1.b). In addition, an average population density of *L. vilosa* which is 0.50 adults per plant with a significant difference ($F = 43.25$, $df = 3$, $P<0.001$) (Figure 1.d). When *Jatropha* was associated with maize, *C. dregei* had an average density of 0.36 adults per maize plant compared to its density of 0.17 adults per plant observed on *Jatropha* with a significant difference (F = 33, 07, df = 3, P0.001) (Figure 1.f). So, the most important insect pests recorded with the production of *Jatropha* associated with maize were: *A. africana, D.* nr *divisella, S. thraustica, Apion* sp. *L. vilosa* and *C. dregei* (Figure 1).

The population density of insect pests on *Jatropha* intercropped with cowpea

The average densities of insect pest species observed on *Jatropha* associated with cowpea were highly variable. These varied from 0.052 to 0.80 per plant with the highest density observed in *D.* nr *divisella* and the lowest in *C. tomentosicollis*. When *Jatropha* was associated with cowpea, *D.* nr *divisella* were high in numbers with an average density of 0.85 larvae per *Jatropha* plant (Figure 1.a). Then followed by *S. thraustica* leafminer with a density of 0.27 larva per plant. The defoliator *A. africana* follows with an average density of 0.47 adults per plant with a highly significant difference (Figure 1.c). With regard to the *L. vilosa* defoliator, its density was 0.27 adults per plant with a statistically significant difference ($F = 43.25$, $df = 3$, $P<0.001$) (Figure 1.g). Ultimately, the most important pest species associated with cowpea in *Jatropha* were *A. africana, D.* nr *divisella* and *Apion* sp. (Figure 1).

The insect pests observed on *Jatropha* are depended on the associated crops. Thus, *Jatropha* associated with the cassava and *Jatropha* associated with cowpea was favorable to the development of insect pests.

***A. africana* is an important defoliating pest observed in *Jatropha* crops, in *Jatropha* intercropped with cassava, maize or cowpea**

It has been consistently observed on *J. curcas* plants that *D.* nr *divisella* is the only pest that causes damage to both young leaves, flowers and young fruits observed in pure *Jatropha* crops and in all *Jatropha* intercropping systems. It is, therefore, necessary to follow the changes in numbers of these two major pests according to the intercropping installed.

The infestations of *A. africana* were described by following the phenology of *J. curcas* plants. The infestation of pure *Jatropha* crops was late compared to that of *Jatropha* intercropped with cassava. From 61st day after sowing (DAS) to 117th DAS, *Jatropha* crops experienced 2 peaks, one in 89th DAS with an average density of 1.3 adults per plant, and the second peak at 117th DAS with an average density of 1.2 adults per plant (Figure 2). From 124th to 166th DAS, the infestation rate of *A. africana* averaged 0.70 adults per plant. When *Jatropha* was intercropped with cassava, the attacks were observed precisely on the 40th DAS. From 40th to 166th DAS, we had 3 peaks were determed. The first peak had been observed at 47th DAS was during the vegetative phase of Jatropha. Then, the densities of A. africana went through an instability characterized by peaks followed by minimum between the 131st and 166th DAS. This last period corresponded to the fruiting phase.

When Jatropha was intercropped with maize, the infestation was observed to be same

as that cassava from 54th to 166th DAS. The heavy infestation rate was observed during the period from 54th to 110th DAS with 3 peaks, the first at 61st, the second at 82nd and the third at 103rd DAS with average densities of 1.2, 1.3 and 1.80 respectively of individual per plant (Figure 2). Range from 110th to 166th DAS corresponds to the period of flowering and fruiting. The density of *A. africana* was reduced almost constantly with an average density of 0.70 individual per plant during that time (Figure 2). When *Jatropha* was intercropped with corn, the infestation was observed to be same as observed in the crop of cassava case from 54th DAS to 166th DAS. Heavy infestation was observed during the period from 54th to 110th DAS with 3 peaks. The first at 61st, the second at 82nd and the third at 103rd DAS with an average density of 1.2, 1.3 and 1.80 respectively of individual per plant (Figure 2). 110th to 166th DAS corresponds to the period of flowering and fruiting. The density of *A. africana* was reduced almost constantly with an average density of 0.70 per plant (Figure 2).

When *Jatropha* was intercropped with cowpea, the infestation started late on the 61st DAS and the average densities of *A. africana* were considerably lower than those of pure *Jatropha* crops. The fact that the average densities were low compared to those of the intercropping with either cassava or maize, could be interpreted that cowpea has a repellent effect on *A. africana* (Figure 2).

Fluctuations of populations of *Denticera* nr *divisella* on *Jatropha* crops and *Jatropha* intercropped with cassava, maize or cowpea

The average densities per plant of the population of *D.* nr *divisella*, one major pest of *J. curcas*, helped to illustrate the fluctuations in pest numbers on *Jatropha*.

The attacks of *D.* nr *divisella* were observed in pure *Jatropha* crops at the 75th DAS until the 166th DAS with 3 peaks. The first pick at 110th DAS which corresponded to the vegetative phase of *Jatropha* with a density of 0.75 larvae per plant. This confirms that *D.* nr *divisella* attacks young *Jatropha* plants. Then the second peak was estimed at 131th DAS during the flowering phase with an average density of 0.90 larvae per *J. curcas* plant. Finally, the last peak of infestations were observed at the 159th DAS corresponding to the fruiting phase of *J. curcas* with an average density of 0.70 individuals per plant**.** When *Jatropha* is intercropped with cassava, the infestation started from 54th to 166th DAS with 3 peaks of infestations. The first peek at 75th DAS was observed during the vegetative phase with a density of 0.40 larvae per plant, the second peak at 117th DAS during the flowering phase with a density of 0.65 larvae per plant. It was followed by the last peak at 145th DAS with an average density of 0.72 larvae during the fruiting phase (Figure 3). The infestation rate of *D.* nr *divisella* observed on *Jatropha* intercropped with cassava was low compared to pure *Jatropha* crops.

When *Jatropha* was intercropped with maize the attacks were observed early on the 54th DAS. From 54th to 166th DAS infestations showed 3 peaks. The two (2) peaks during the vegetative phase at 89th and 103rd DAS and the last at 124th DAS at the fruiting stage with the same density of 0.72 larvae per plant (Figure 3). *Jatropha* infestation with maize showed that maize attracts the *D.* nr *divisella* population to *Jatropha* plants during the vegetative phase.

When *Jatropha* intercropped with cowpea, the attacks were observed precisely at 61st DAS. From 75th to 166th DAS, we had 3 peaks were observed. The first at 110th DAS during the vegetative phase, the second at 131th DAS at the flowering phase and the last at the 159th DAS during the fruiting phase with respective densities of 0.75, 0.90 and 0.70 larvae per *J. curcas* plant (Figure 3).

The population density of cassava pest intercropped with *J. curcas*

Cassava crop intercropped to *J. curcas* was infested by only one pest, *Tanajoa mononychellus* (Bondar) (Cassava green mite), whose average was 2.34 ± 0.57. This pest was

observed only on cassava although the two plants intercropped were of the Euphorbiaceae family.

The density of pest population on Maize intercropped with *J. curcas*

The maize intercropped with *J. curcas* was infested with three major pests including *Apion* sp., *L. vilosa* and *Sesamia calamitis* Hampson (Lepidoptera: Noctuidae). The first two pests were observed on *J. curcas* alone while *S. calamitis* remains specific to maize with mean values ranging from 0.24 ± 0.09, 0.28 ± 0.08 and 2.07 ± 0.67 respectively for *Apion* sp., *L. vilosa* and *S. calamitis*.

The density of pest population on cowpea intercropped with *J. curcas*

Cowpea in intercropping to *J. curcas* was infested with five major pests. There were *Aphis craccivora* Koch (Homoptera Aphididae) averaging 5.25 ± 1.78 adults per plant, then *Ootheca mutabilis* (Sahib.) (Coleoptera, Galerucidae) who averaged 1.83 ± 0.67 adults per plant, followed by *Megalurothrips sjostedti* Thrybom (Thysanoptera: Thripidae) that averaged 11.21 ± 2.43 adults per plant, *Maruca vitrata* Fabricius (Lepidoptera: Crambidae) averaging 1.72 ± 0.78 larvae per plant, *Apion sp*. with 0.87 ± 0.23 adults and finally *Clavigralla tomentosicollis* Stal (Hemiptera: Coreidae), whose averaged with 2.98 ± 0.89 adults per plant. *Apion sp.* and *C. tomentosicollis* were accounted on *J. curcas* as pests that attack both cowpea and *J. curcas*.

Effects of intercropping on the growth of *Jatropha curcas* plant

In the case of intercropping of *J. curcas* with the three food crops, we note that the growth of *J. curcas* plants intercropped with cassava or cowpea was noted to be show compared to single *J. curcas* culture and *J. curcas* intercropped to maize (Table 1). The measurement of certain parameters, in particular, the diameter, the height and the span in cm (cm) after 5 months after sowing, showed that the J. curcas plants intercropped with beans slowed considerably the growth of *J. curcas* compare to that of *J. curcas* in intercropping with other food crops.

Effect of crop associations on average grain yields of *Jatropha*

Average yields were expressed in kilograms of *J. curcas* seeds over an area of 400m2 during the first year in pure *Jatropha* fields or in association with food crops. The average yields from the harvest of *J. curcas* cultures per 400 m^2 were 23.67 ± 4.37 kg; 17.27 ± 3.70kg; 10.10 ± 2.06kg and 3.58 ± 1.72kg these yields in hectare (Ha) were as follows 591.75 ± 109.25kg / Ha; 431.75 ± 92.50kg / Ha; 252.50 ± 51.50kg / Ha and 89.50 ± 43.00kg / Ha respectively in single culture of *J. curcas* fields, *J. curcas* intercropped with maize, cowpea and cassava (Figure 4). The analysis of variance (Proc ANOVA) showed that the yields of the different crops had a statistically significant difference ($F = 8.50$, $df = 3$ $P < 0.001$).

Yields of cassava, maize or cowpea intercropped with *Jatropha curcas*

The productivity of food crops in intercropping to *Jatropha* was very low since the plants are not treated to monitor the infestations of each pest in the plots.

- The average yield in tonnes (T) of cassava tubers in fresh weight on *J. curcas* plots intercropped with cassava was 29.92 ± 7.22 T / ha during 12 months.
- The average yields in tonnes (T) of maize intercropped with *J. curcas* was 1.92 ± 0.63 T / ha during the first season and 1.13 ± 0.31 T / ha during the second season.
- The average yield in kilograms (kg) of cowpea seed in cowpea intercropped with *J. curcas* was 298 ± 81.96 kg/ha during the first season and 225 ± 58.35 kg/ha during the second season.

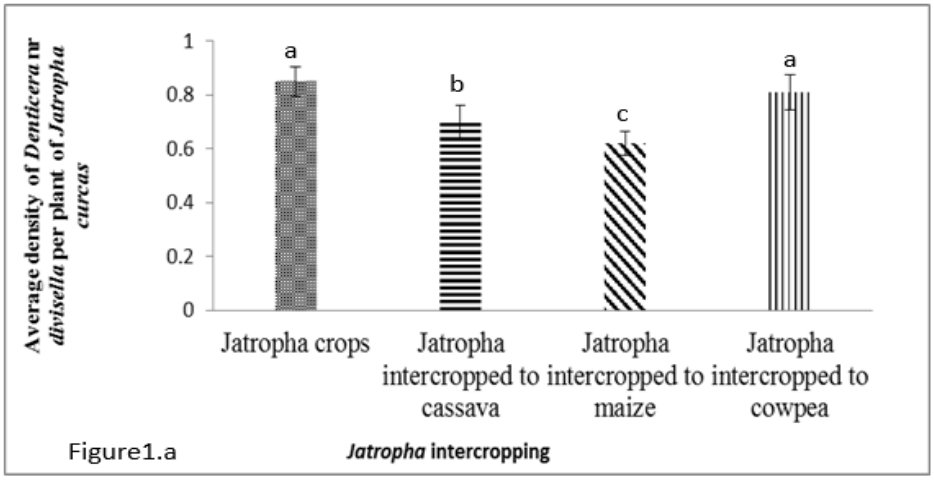
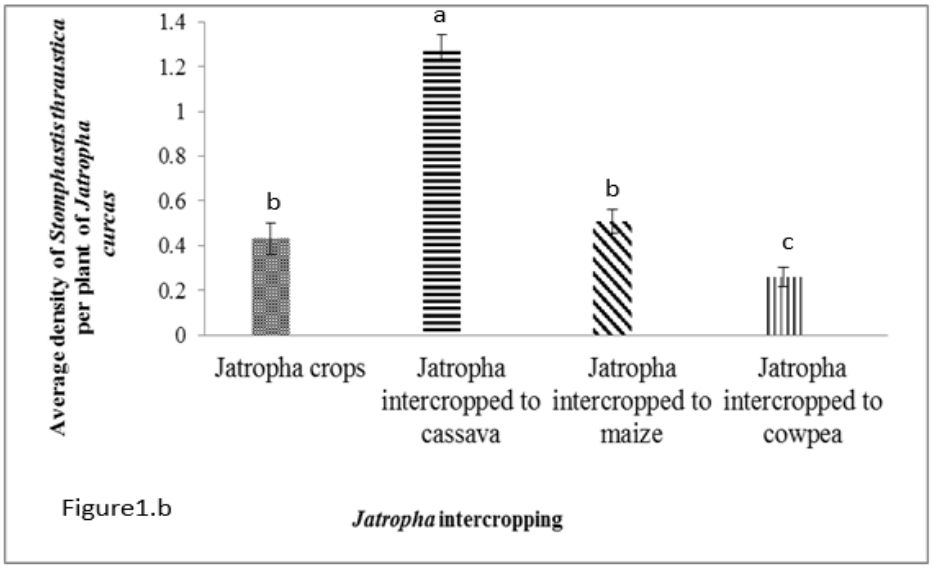


Figure1.a



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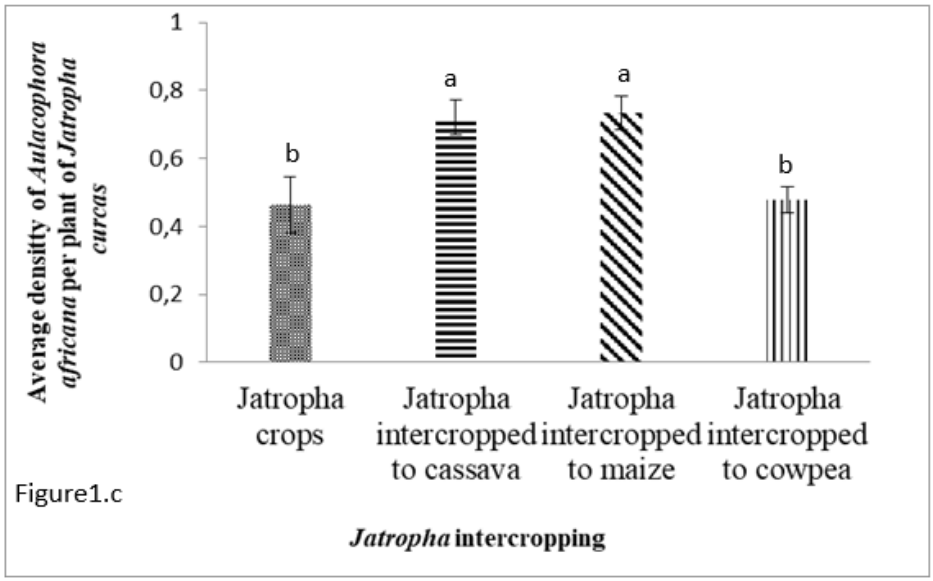

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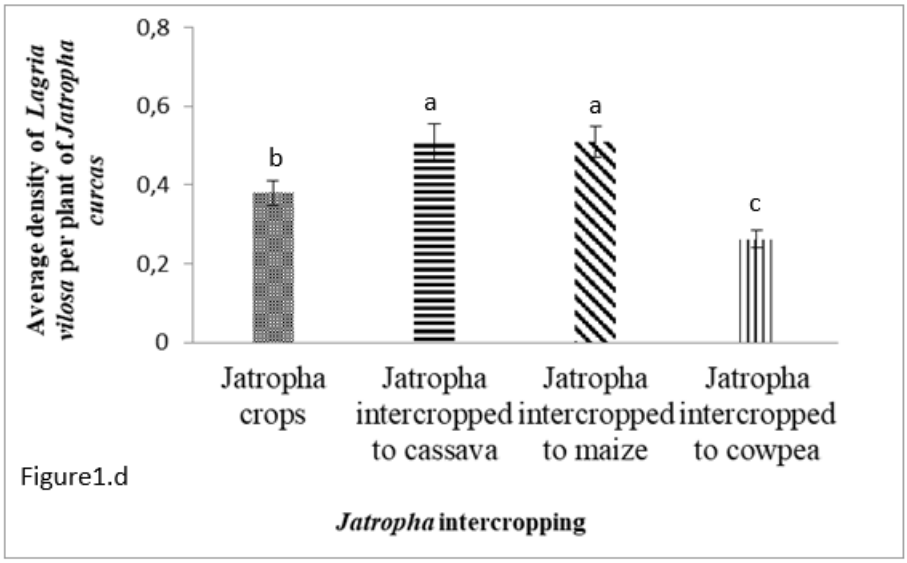

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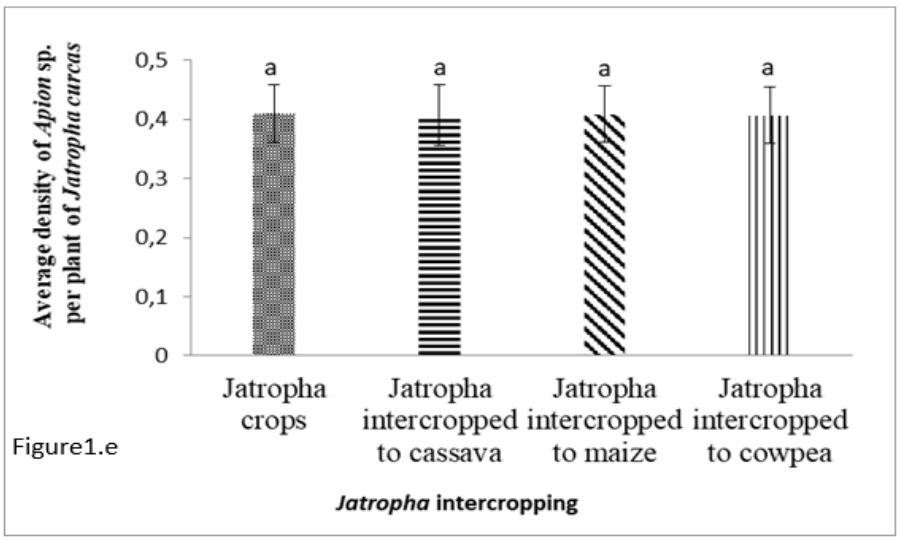
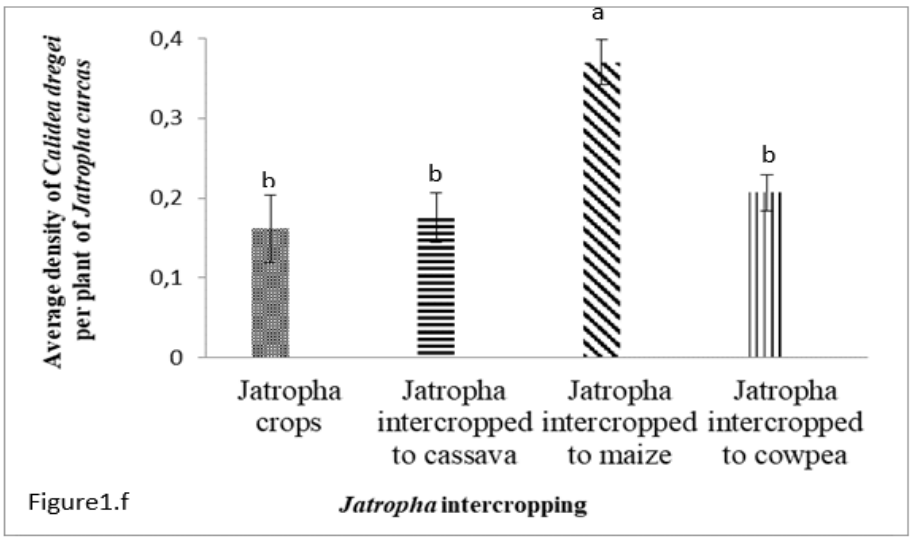


Figure1.e



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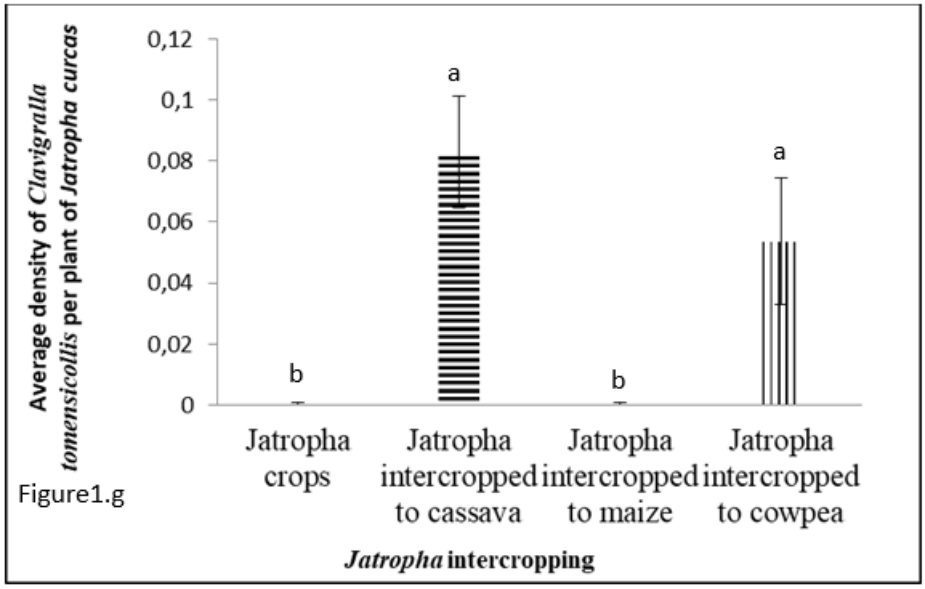

Figure 1: Impact of *Jatropha curcas* intercropping of cassava, maize and cowpea on pests Bars with the same letter are not statistically different at the 5% threshold with ANOVA followed by the SNK test.

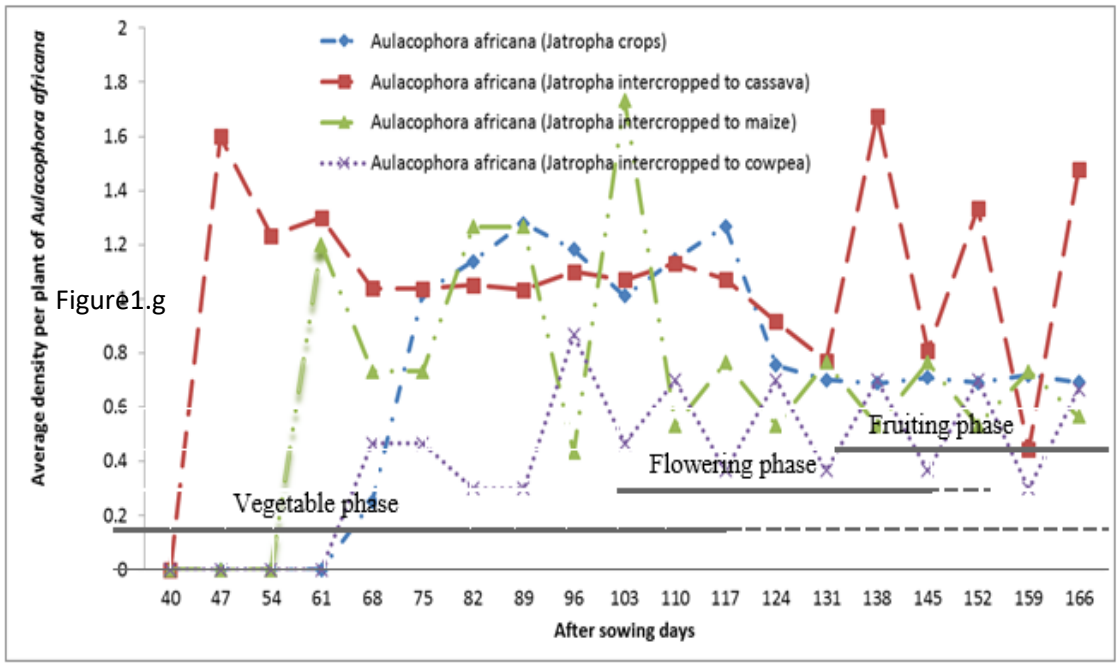

Figure 2: Population dynamics of *Aulacophora africana* on Jatropha crops and Jatropha intercropping of cassava, maize or cowpea.

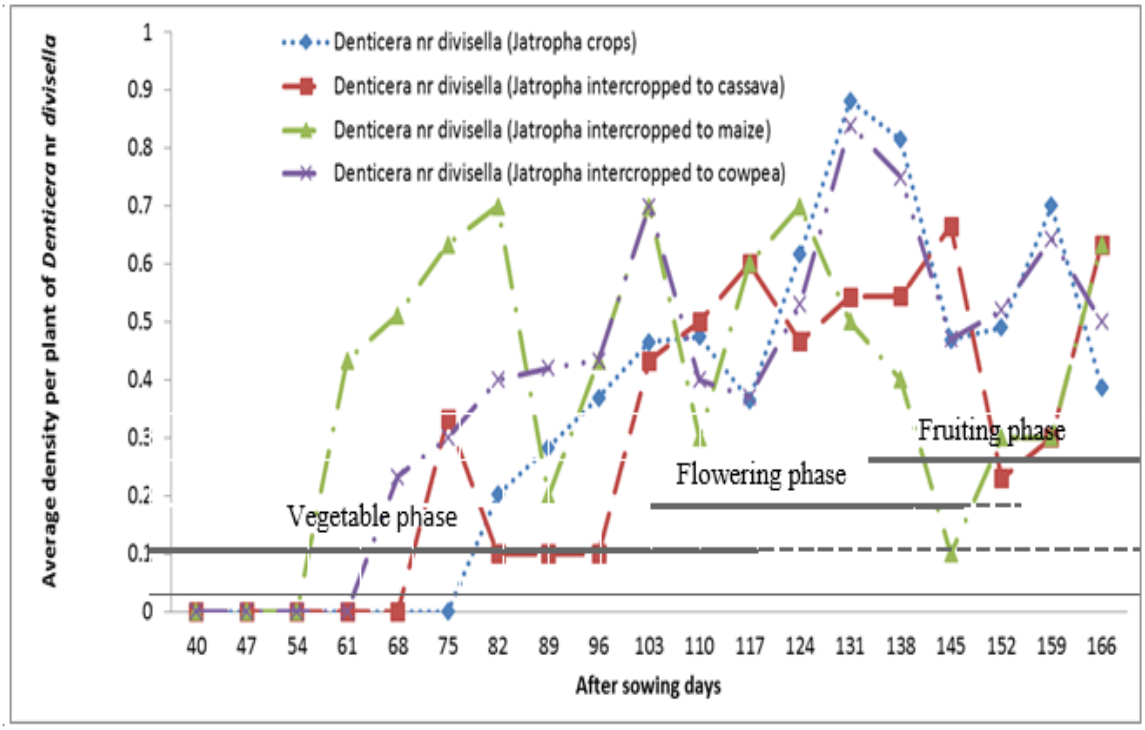

Figure 3: Population dynamics of *Denticera* nr *divisella* on Jatropha crops and Jatropha intercropping of cassava, maize or cowpea.

Table 1: Impact of intercropping on *Jatropha curcas* growth.

Treatment	Plant growth (cm)		
	Height ± SE	**Diameter ± SE**	**Span ± SE**
Pure Jatropha crops	107.77±22.23 a	5.06±1.03 a	95.30±21.72 a
Jatropha intercropped with cassava	96.54±23.94 b	4.63±2.05 b	86.22±22.03 b
Jatropha Intercropped with Maize	102.35±13.71 a	5.30±1.07 a	90.37±23.41 ba
Jatropha intercropped with cowpea	63.94±22.12 c	3.97±1.01 c	50.52±12.23 c

The averages followed by the same in each column are not significantly different at the 5% ANOVA threshold followed by the Student-Newman-Keuls test; SE = Standard Error

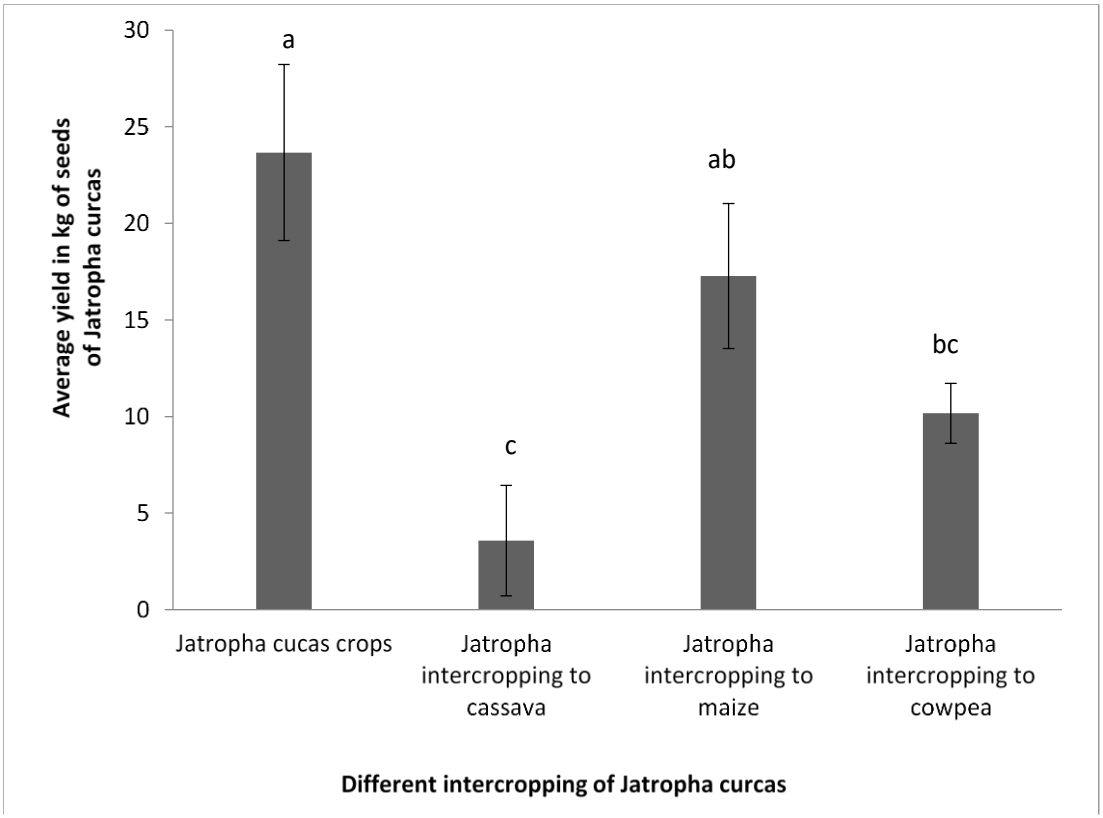

Figure 4: Average grain yields of Jatropha curcas in intercropping with food crops.
Bars with the same letter are not statistically different at the 5% threshold with ANOVA followed by the SNK test.

DISCUSSION

The numerous works carried out, in the past, on *J. curcas* are mainly focused on the valorization of the oil. The collection of seeds was mainly limited to valorizing the presence of plants in their natural state or in hedges. It is only recently that scientists have been studying the technical aspects of the crop's production. It is important to note that the pure culture of *J. curcas* does not favor small farmers. This culture can only be done in intercropping for many producers to adhere. Thus, observations made on the effect of intercropping of *J. curcas* with food crops grown in the study area showed that the pests associated to *J. curcas* vary according to the associated food crop. In Benin, where food crops occupy 24.1% of the cultivated area (Agbo and Honkpehedji, 2009), it is important that the cultivation of *J. curcas* be associated with food crops**.** Thus, this study, being is, the first in Benin focused on the impact of intercropping between *J. curcas* and the main food crops. Cultivated consumed for food security (in this case maize, cowpea and especially cassava which is a Euphorbiaceae like *J. curcas*) on pest activity of the crops involved and the growth of *Jatropha* deserved to be conducted. During this study, the observed pests including *A. africana, S. thraustica, L. vilosa, D. nr divisella, C. dregei* are insect pests associated with *J. curcas*. Studies of the entomofauna associated with *J. curcas* crops have shown that *J. curcas* is subject to numerous insect pests as reported in many countries with some variations. In India, two main species have been reported to cause serious problems to *J. curcas* plants. There we *Pempelia morosalis* Saalm Űller (Lepidoptera: Pyralidae) which attacks the inflorescences, spiderweb and digs hollow at the tender stems

and devours the young capsules, and *Scutellera nobilis* Fabricius (Heteroptera: Scutelleridae) that causes flower drop, fruit abortion, and seed malformation. In Kenya, the following species have been identified: *C. dregei*, *Planococcus* sp. (Homoptera: Pseudococcidae), *Aphtona* sp. (Coleoptera: Chrysomelidae), *Stomphastis rupsen* (Lepidoptera: Gracillariidae) (Otieno and Mwangi, 2009). Other insects such as *Leptoglossus* sp. (Heteroptera: Coreidae), *Achea janata* Linnaeus (Lepidoptera: Noctuidae), *Indarbela quadrinotata* Walker, and *Oxycetonia versicolor* Fabricius (Coleoptera: Cetoniidae) have also been identified as *J. curcas* pests (Brittaine and Lutaladio, 2010). In Benin, according to recent studies done by Fassinou (2009), their results showed that *S. traustica*, *A. africana*, *L. vilosa* and *C. tomentosicollis* were the pests of *J. curcas*. Similarly, the study by Datinon et al. (2013; 2017) showed that *Jatropha* is attacked by major insects including *A. africana*, *L. vilosa*, and *Altica* sp. defoliating beetles and *Zonocerus variegatus* L. (Orthoptera: Pyrgomorphidae) causing damage to the leaves, *S. thraustica*, a leaf miner whose larvae feed on chloroplast, *Paracoccus marginatus* Williams & Granara de Willink (Hemiptera: Pseudococcidae), an invasive scale that gradually destroy the plants. Also, present *D.* nr *divisella*, as a small lepidopteran specific to *J. curcas* plants. The larvae attack the main organs of the plants causing significant damage to both the leaves, especially the apex, inflorescences, flowers and young fruits of *Jatropha*, *C. dregei*, a specific bug *J. curcas* which causes the fall of flowers and the abortion of seeds' formation and termites, *Macrotermes bellicosus* Smeathmann (Isoptera: Termitidae) causing the fall of *J. curcas* plants frequently at the level of the seedlings next to the termite mounds. Of these pests, *D.* nr *divisella* is observed as the most devastating flower and fruit of *J. curcas* in South Benin (Datinon et al., 2013; Datinon, 2014). According to all observations made on *J. curcas*, the strong infestation by the *A. africana* pest occurs during the vegetative phase when the plants have soft leaves and a low rate of infestation during the flowering and fruiting phases. During this phase, the soft leaves begin to be scarce, which does not favor infestation by *A. africana*. This confirms that *A. africana* is a defoliator. Indeed, the study done by Datinon et al. (2013) on the specific pest diversity showed that the presence of this defoliator was very remarkable in the vegetative phase of *J. curcas* plants. In *J. curcas* plots intercropped with to cassava, it was noted that there was a strong infestation by the *A. africana* defoliator during the fruiting phase where the leaves were soft despite the scarcity of rains. This shows that cassava attracts the *A. africana* on *J. curcas*. In the single cropping of *Jatropha*, the average density of *S. thraustica* leafminer was 1.28 larvae per plant compared to 0.43 larvae per cassava plant in mix cropping (Figure 1b). We found that the fluctuation of *A. africana* observed on *J. curcas* associated with cowpeawas low compared to pure *Jatropha* crops. This could signal that cowpea is repelling the population of *A. africana*. In the cropping of maize, the average density of 0.47 adults of A. africana per with maize plant observed compared to Pure *Jatropha* showed a highly significant difference (Figure 1.c). Likewise in the cropping of maize, the average population density of *L. vilosa* was 0.50 adults per with maize plant with a significant difference compared to the average density of 0. 38 adults per with plant observed with single cropping of *Jatropha* (Figure 1.d). When Jatropha was associated with cowpea plant the desnity of pests was significant differences relative to the density of pests in single cropping of *Jatropha.* The high rate of *D.* nr *divisella* infestations was observed during all phenological phases of the plant. The infection rate by *D.* nr *divisella* observed on cassava intercropped with *J. curcas* was low compared to pure *Jatropha* crops. This showed that cassava develops a mechanism that attracted the population of *D.* nr *divisella*. The high infestation rate of *D.* nr *divisella* observed on *J. curcas* in intercropping with maize compared

to *J. curcas* crops during the vegetative phase shows that maize developed a mechanism attracting the population of *D.* nr *divisella*. *Jatropha* intercropped to corn showed low infestation rate during the vegetative phases compared to pure *Jatropha*. The low infestation rate recorded during the fruiting phase showed that corn emits some volatiles which repels *D.* nr *divisella*. The diversity of crops grown on a plot can significantly influence crop pest abundance compared to a single crop (Corre-Hellou et al., 2014; Ebeling et al., 2018). Ultimately, the most important pest species associated with cowpea with *Jatropha* were A. africana, *D.* nr *divisella* and Apion sp. (Figure 1). Finally, *Jatropha* associated with the Cassava and cowpea were favorable to the development of insect pests compared to the densities of pests observed in single Jatropha cropping and *Jatropha* associated with maize. Indeed, mix cropping modifies many factors that can impact on insects and microorganisms depending on their ecological requirements (light radiation, microclimate within the plant community, trophic resources). The complexity of these interactions makes it necessary to have a better understanding of the mechanisms underlying pest control in crop associations. Many biotic interactions are intervened in plant associations. The mechanisms most studied are those involved in the regulation of pests. It appears interesting to highlight the competition that occurs between insect pests and crops in the association. The presence of the cowpea pod weevil, *Piezotrachelus varius* Wagner [syn. *Apion varium* Wagner] (Coleoptera: Curculionidae) and *C. tomentosicollis* on *J. curcas* intercropped with Maize or cowpea showed that these pests have a diverse range of hosts. In general, *P. varius* cause damage to cowpea pods, which may be up to 20% (Annicchiaricoa et al., 2015). *P. varius* species are known to attack many crops Annicchiaricoa et al., 2015). This confirms it presence on *Jatropha* fruits. *C. tomentosicollis* is a pest of cowpea pods (Tamò et al., 2002; Dabire, 2005). However, its presence on other crops had been reported by Onzo et al. (2016) who had classified it into the group of sucking bugs capable of changing host plants throughout the year. These effects of plant association were particularly significant for the high pest density observed on *J. curcas* intercropped with maize or cassava compared to pure *J. curcas* crops. In fact, the high density observed shows that maize and cassava plants seem to attract pests on *J. curcas.* These numerous observed pests attacking Jatropha confirm the observations made by Regupathy and Ayysamy in (2011) and Pirot and Hamel (2012). It could thus be said that *J. curcas* crops are subject to the attacks of many pests impacting its development, especially when it is intercropped. Pests on *J. curcas* should be further investigated in mix cropping with other crops to better understand the intercropping's effects on *J. curcas*. Crop association also had a significant impact on *Jatropha* grain yields. In fact, the grain yields of *J. curcas* intercropped with cassava, maize or cowpea was lower than those of pure *J. curcas* crops. The lowest yields obtained for *J. curcas* intercropped with cassava are thought to be due to the high pest densities observed in this type of association. It should also be emphasized that competition between *J. curcas* and cassava in the use of soil nutrients cannot be ruled out because both plants are from the Euphorbiaceae family (Montenegro et al., 2019). Concerning *Jatropha* intercropped with cowpea, the low average grain yields obtained for *J. curcas* is due to the late growth observed. Indeed, cowpea has the ability to fix atmospheric nitrogen and normally this should accelerate the growth of *J. curcas* plants. The late growth of the associated Jatropha seems to be obvious. A large amount of nitrogen in the soil may affect the development of *J. curcas* plants (Montenegro et al. 2019, Ly et al., 2014). The association of maize to *Jatropha* is not without effects on the average yields of the associated *Jatropha.* The low yields of food crops were due to insect attack since these crops were not treated. This was design to monitor the population dynamics of insect

pests in the associated crops. The variations in yields observed during the second season compared to the first season are due to the damages caused by various pests in each association of crops and the seasons.

Conclusion

This study helps to know the effects of intercropping wish *J. curcas*. The observed effects depend of associations. Thus, attractive or repulsive effects were observed on *J. curcas* intercropped to maize or cassava and pure *Jatropha* crops. However, for *J. curcas* associated with cowpea, *Jatropha* plants were found to be stunted therefore an inhibitory effect was observed on plant growth of *J. curcas* associated with cowpea. All of these pests have an impact on *J. curcas* yields.

Thus, cassava and maize attract pests on *Jatropha* plants while cowpea sown at the same time has an inhibitory effect on *J. curcas* growth. The fluctuations of insect pests on *J. curcas* vary depending on the associated crop. All pests have an impact on *Jatropha* yields. This could be the cause of the low yields observed. All *J. curcas* plants associated with food crops were attacked by insect pests. Significant effects were observed on *J. curcas* yields when Jatropha was associated with maize, cowpea or cassava.

COMPETING INTERESTS

The authors declare that the have no competing interest concerning this article.

AUTHORS' CONTRIBUTIONS

All authors contributed to the realization of the work and to the manuscript preparation.

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