Dynamic of bruchid egg-laying in cowpea-based cropping systems: importance for determining an optimal release period of the oophagous parasitoid *Uscana lariophaga* Steffan (Hymenoptera: Trichogrammatidae)

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Abstract— *In West Africa, the pods of cowpea, Vigna unguiculata (L.) Walp., are often infested with eggs of the main bruchid species, Callosobruchus maculatus Fab. and Bruchidius atrolineatus Pic in the fields resulting in significant post-harvest losses. An experiment was carried out from 2010 to 2011, at Gampela in central Burkina Faso, to identify the optimal period of the oophagous parasitoid (Uscana lariophaga Stef.) releases in cowpea –based intercropping systems, in order to minimize or supress the initial infestation of cowpea pods. During both years of study a relatively low number of bruchid eggs was noticed on the pods (60-130 eggs/100 pods). However, there was significantly a larger number of eggs laid in monocrops in comparison to intercrops. Natural global parasitism of bruchid eggs by Uscana lariophaga ranged 20-45% but was significantly higher in intercrops where parasitism peaks >50% were sometimes reached. Comparative analysis of bruchid egg laying and their parasitism showed that cowpea infestation gradually increased whereas parasitism decreased. Given these results we discuss and suggest that cowpea be produced in millet intercropping systems and combined with releases of U lariophaga in the fields specifically during cowpea pod setting*.

***Keywords*— Bruchid egg laying dynamic; Cowpea, Egg parasitism, Intercropping, Parasitoid releases.**

I. INTRODUCTION

Cowpea, *Vigna unguiculata* (L.) Walpers, is one of the most important leguminous crops in West Africa which is probably the largest area of cowpea production in the world[1]. Cowpea is a major staple food crop in Sub-Saharan Africa, especially in the dry savanna regions of West Africa. The seeds are a major source of plant proteins and vitamins for human [2], and also a significant source of income when the post-harvest constraints are overcome. In Burkina Faso, cowpea is often infested by two bruchid species, *Callosobruchus maculatus* Fab. and *Bruchidius atrolineatus* Pic. [3;4]. These pests oviposit on the ripening pods in the fields. Hatching larvae penetrate the pod and enter the seed, where they develop up to pupation. One of these bruchids, *Callosobruchus maculatus* (F.) (Coleoptera Bruchidae), is well adapted to storage. Emerging females from stored pods coming from the field continue to oviposit on pods or seeds during the storage in the granaries. *C. maculatus* is the only serious storage pest of cowpea, but it is generally very destructive and can result in complete loss of cowpea in individual granaries [5;6]. Many traditional methods, including the use of botanicals focus on prevention or control of *C. maculates* with a relative effectiveness [7;8;9]. Recently, a hermetic storage method using triple bagging proved to be effective for cowpea and several crop storage[10;11] and is currently being largely extended. However, in a view of developing a sustainable control strategy, several options should be considered. One promising option might be biological control since in West Africa, several parasitoid species are associated with *C. maculatus* populations both in the field and in storage systems[12; 13; 4; 14]. Previous investigations carried out in fields show that *C. maculatus* F. and *B. atrolineatus* eggs and larvae were parasitized respectively by *Uscana lariophaga* Stef. [15]and two larval parasitoid species, *Dinarmus basalis* Rond. and *Eupelmus vuilleti* Crw.[16; 4]. These naturally occurring parasitoids are responsible for substantial control of *C. maculatus*[16; 17; 18]. The indigenous egg parasitoid *Uscana lariophaga* Steffan (Hymenoptera:Trichogrammatidae) has been identified as the most important mortality factor for *C. maculatus* eggs in the field [15]and inside granaries where parasitism reached 69-73%[18]. However, the ecology of this egg parasitoid species in cowpea fields in relation with bruchid egg-laying dynamic remains unclear. This study is a contribution to a better knowledge of temporal variations of bruchid egg-laying dynamic in cowpea fields. The results are expected to give insights for determining a suitable period to release *U. lariophaga* and enabled a significant reduction or suppression of initial infestation of cowpea pods at harvest. Moreover, intercropping is supposed to create particular microclimates favourable to pest natural enemies and infestation reduction [19]. Therefore we assessed the effects of intercropping cowpea with millet and sorghum on egg parasitism and initial infestation by bruchids.

II. MATERIAL AND METHODS

2.1 Experiment site and conditions

The study was carried out in the Central region of Burkina Faso, accurately in the village of Gampela (12°25'51''N and 1°22'18''W) located at around 20 Km from Ouagadougou in the North Sudanese agro-ecological zone. The rainy season occurs from June to September with a total annual rainfall of 839 and 689.4 mm respectively in 2010 and 2011. During the study period, mean temperatures and relative humidity were 27°-30.9°C and 48-60% respectively.

2.2 Cowpea and cereal varieties used

The KVX 61.1 cowpea variety was used for all field experiments. This variety has a growing cycle of seventy (70) days in optimal conditions, and has the advantage of early flowering (43 days after sowing (DAS)). In intercropped agrosystems, Gampela local varieties of *Sorghum bicolor* and *Pennisetum typhoides* were used as do farmers in the study area.

2.3 Experimental design

The experimental design was a 3x4 completely randomized Fisher block with three cropping systems as treatments and 4 replications. Each plot was 10x10m with a buffer of 1m between plots. Two consecutive blocks were separated by a 3m space. In intercrops two rows of cowpea were intercropped with two cereal rows. The treatments were i) monocrop of cowpea ii) cowpea associated with millet, and iii) cowpea associated with sorghum. To protect against cowpea flower thrips and pod sucking bugs, the crops were respectively sprayed, at 50% flowering and two weeks later, with Decis® containing 12.5g/kg Deltamethrin.

2.4 Dynamic of bruchid egg-laying and parasitism by *U. lariophaga* as a function of cropping systems

From the 50% pod setting stage at 50 DAS, and each week, at least 150 cowpea pods from second stage [20] were marked by slightly tying them with a colored cord. The color of the cord varied according to the marking date. Pods were then marked on 50, 57, 64 and 71 DAS. As maturity progressively occurred, bruchid egg-laying and parasitism dynamic were monitored on 100-ripped pods samples randomly harvested each week by plot in accordance with their date of marking (i. e. the first marked pods were the first harvested).The cowpea pods were observed under binocular microscope to determine the number of bruchid eggs laid and the number of parasitized eggs. Eggs parasitized by *U lariophaga* were easily distinguishable by rapidly turning black[4].

2.5 Initial infestation of cowpea by bruchids at harvest in different cropping systems

At complete maturity, the cowpea pods were harvested whatever the marking period and 100 pods randomly selected in each plot. Each pod sample was incubated in a Plexiglas box (26x14x8cm) placed in laboratory indoor ambient conditions. The first generation of bruchids and associated parasitoids emerged up to 30days post-incubation. The pods were then shelled and the cowpea seeds observed to count the number of seed bearing at least one bruchid emergence hole. The initial infestation rate was estimated as [the number of seeds with emergence holes/total number of seeds x 100].

2.6 Statistical Analysis

All data were submitted to ANOVA and when the probabilities indicated significant differences, means were separated by the Student Newman-keuls multiple comparison test using SAS software 9.1 version. Calculated percentages were first arcsine transformed prior to ANOVA. In all the cases means were considered as different when the test provided discrimination at the 5% level.

III. RESULTS

3.1 Overall results on bruchid egg laying and parasitism in different cropping systems

As expected, two bruchid species, *C. maculatus* and *B. atrolineatus*, laid eggs on cowpea pods in all of the three cropping systems in 2010 and 2011.The mean total number of eggs laid was significantly higher in cowpea monocrop compared to intercrops (TABLE 1) whatever the year of study. *B. atrolineatus* laid significantly a larger number of eggs than C. *maculatus*. The rates of egg parasitism were significantly higher in intercrops both in 2010 and 2011.

TABLE 1
EFFECT OF CROPPING SYSTEMS ON THE TOTAL MEAN NUMBER (+/- SD) OF BOTH BRUCHID SPECIES EGGS LAID ON COWPEA PODS AND THEIR RATES OF PARASITISM BY *U. LARIOPHAGA* IN 2010 AND 2011. GAMPELA, BURKINA FASO.

Year	Agrosystems	*C. maculatus* eggs/100 pods	*B. atrolineatus* eggs/100 pods	Total eggs/100 pods	Parasitism rates (%)
2010	*Cowpea*	46.12±3.64a	83.31±7.69a	129.44±9.82a	20.33±1.92a
	Cowpea +Sorghum	30.25±2.79b	53.62±7.82b	83.87±8.74b	24.50±4.03b
	Cowpea +Millet	34.25±1.91b	55.5±6.54b	89.75±7.87b	28.86±2.89c
2011	*Cowpea*	42±3.51a	63±4.98a	105±7.51a	20.86±2.23a
	Cowpea +Sorghum	31.5±2.50b	45.87±4.18b	77.37±6.44b	26.76±2.79b
	Cowpea +Millet	26.06±3.06c	34.75±5.29c	60.81±7.98c	45.35±.69c

3.2 Dynamic of bruchid egg-laying in different cropping systems

During both years of experiments *C. maculatus* (Fig. 1) and *B. atrolineatus* (Fig. 2) eggs seemed to be lower on the first pods marked (50 DAS) compared to those marked later (71 DAS). This trend of gradual increase of bruchid egg laying dynamic is noticed in all of the three cropping systems (except for sorghum intercrop and for *C. maculatus* eggs). However the pods from cowpea monocrop have most of the time received a significantly larger number of eggs from both bruchid species.

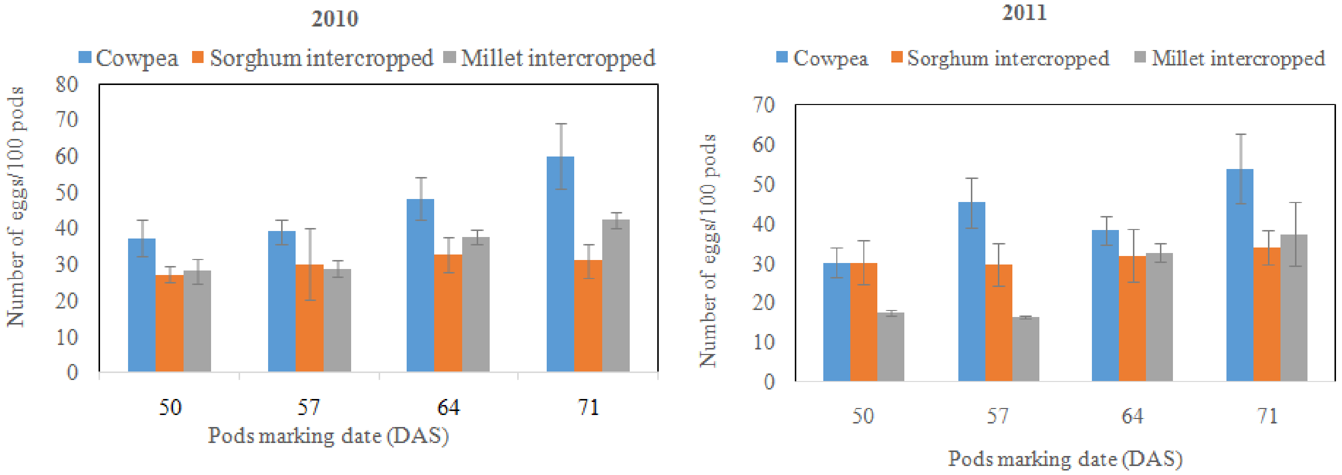

FIGURE 1. EVOLUTION OF THE MEAN NUMBER (+/- SD) OF *C. MACULATUS* EGGS IN RELATION WITH COWPEA POD MARKING DATES AND CROPPING SYSTEMS IN 2010 AND 2011. GAMPELA, BURKINA FASO.

3.3 Dynamic of egg parasitism in different agrosystems

The rates of parasitism of each bruchid species eggs (Fig. 3 and Fig. 4), the largest on the first cowpea pods marked in the crops, tend to decrease over time in all of the three cropping systems during both experimental years. However, this parasitism rate was significantly higher in cowpea-millet intercrop for most of the pod batches (50-71 DAS). The overall analysis of parasitism on the total number of bruchid eggs confirms this trend showing higher rates in cowpea–millet intercrops (Fig. 5).

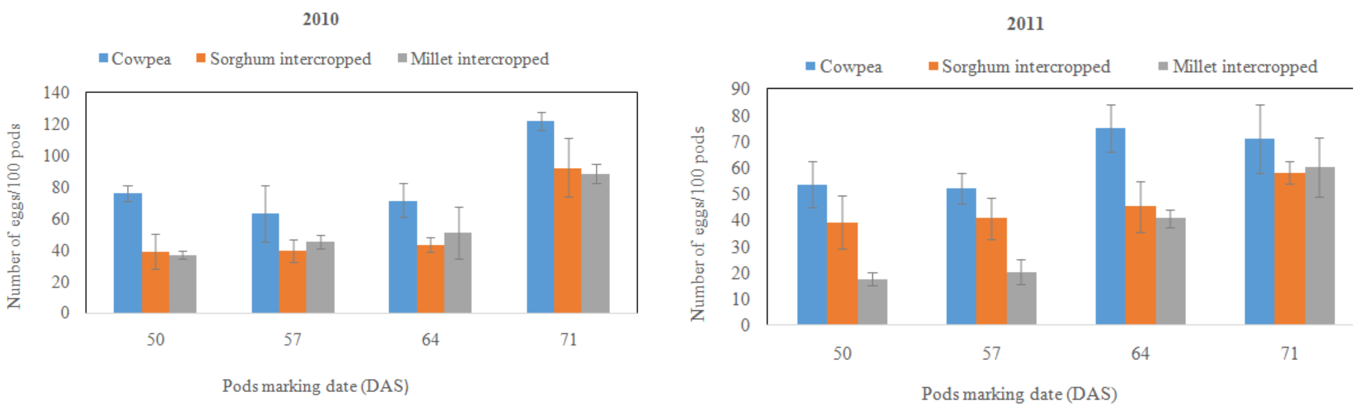

FIGURE 2. EVOLUTION OF THE MEAN NUMBER (+/- SD) OF *B. ATROLINEATUS* EGGS IN RELATION WITH COWPEA POD MARKING DATES AND CROPPING SYSTEMS IN 2010 AND 2011. GAMPELA, BURKINA FASO.

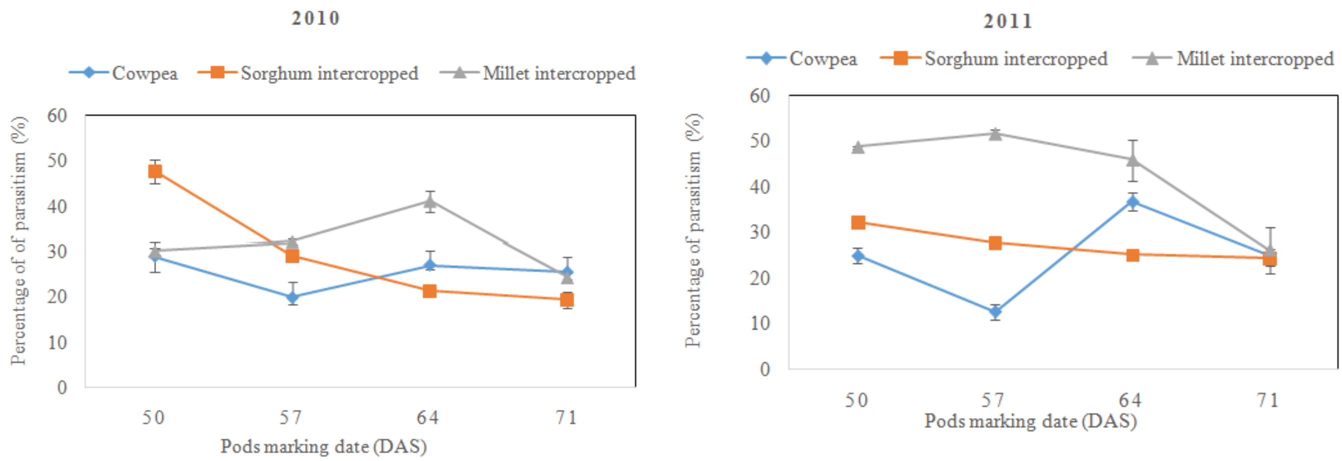

FIGURE 3. EVOLUTION OF THE MEAN RATES OF PARASITISM (+/- SD) ON *C. MACULATUS* EGGS IN RELATION WITH COWPEA POD MARKING DATES AND CROPPING SYSTEMS IN 2010 AND 2011. GAMPELA, BURKINA FASO.

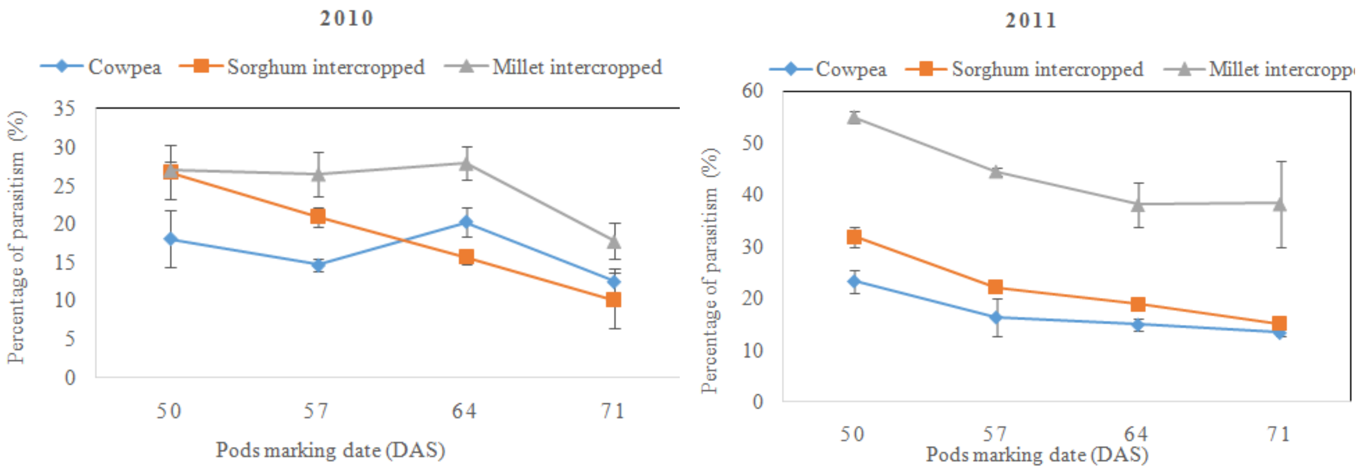

FIGURE 4. EVOLUTION OF THE MEAN RATES OF PARASITISM (+/- SD) ON *B. ATROLINEATUS* EGGS IN RELATION WITH COWPEA POD MARKING DATES AND CROPPING SYSTEMS IN 2010 AND 2011. GAMPELA, BURKINA FASO.

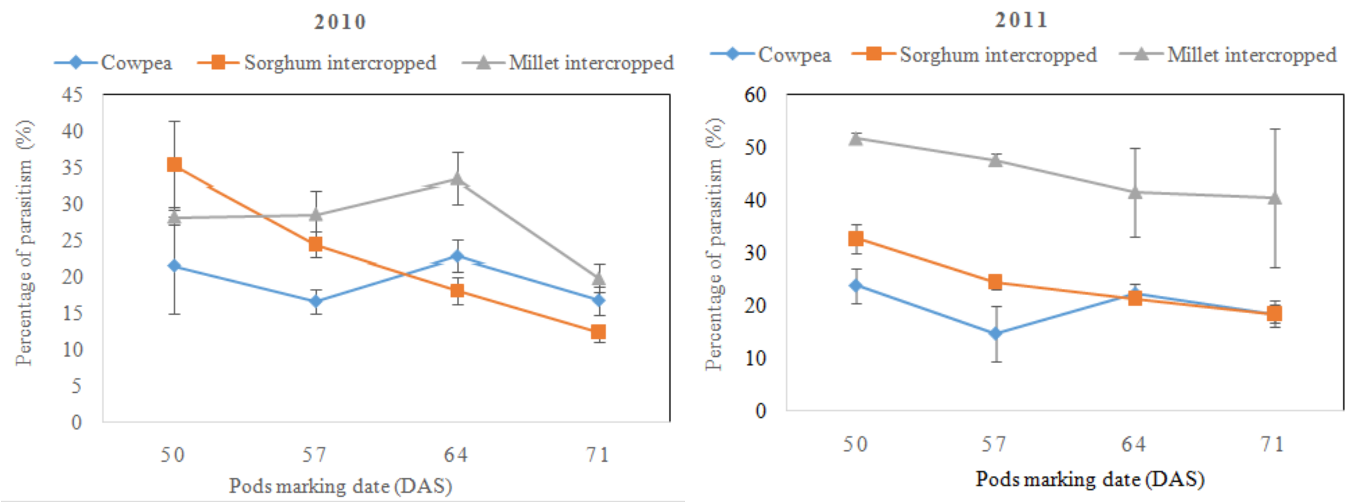

FIGURE 5. EVOLUTION OF THE MEAN RATES OF PARASITISM (+/-SD) ON BOTH BRUCHID SPECIES EGGS IN RELATION WITH COWPEA POD MARKING DATES AND CROPPING SYSTEMS IN 2010 AND 2011. GAMPELA, BURKINA FASO.

3.4 Initial rate of cowpea infestation at harvest in different agrosystems

Initial infestation rates by bruchids at harvest was relatively low (<5% in all the cases) and slightly varied among the cropping systems, cowpea seeds from the monocrop being more infested (TABLE 2).

TABLE 2
EFFECT OF CROPPING SYSTEMS ON THE INITIAL RATES OF COWPEA INFESTATION BY BRUCHIDS AT HARVEST IN 2010 AND 2011. GAMPELA, BURKINA FASO

Year	Agrosystems	Total number of seeds	Infested seeds	Rate of infestation (%)
2010	*Cowpea*	9,600	292	3.04
	Cowpea + Sorghum	10,720	297	2.68
	Cowpea + Millet	10,264	307	2.99
2011	*Cowpea*	10,072	411	4.08
	Cowpea + Sorghum	10,576	372	3.52
	Cowpea + Millet	9,896	325	3.28

IV. DISCUSSION

This study confirmed previous observations on cowpea field egg-laying of two bruchid species, *Callosobruchus maculatus* and *Bruchidius atrolineatus*in Burkina Faso and Niger[20; 21; 4]. These authors stated that cowpea crops were colonized from flowering stage and the number of insect increased later over time in the fields. Consistent with these findings our results showed a gradual increase of the number of eggs laid on the cowpea pods that were formed later. Egg parasitism by *U. lariophaga* ranged 20-45% in relation with the different agrosystems considered. These parasitism rates are close to those (33-44%) found in Niger in fields and in granaries [22]. But surprisingly a comparative analysis of the dynamic of egg-laying and that of parasitism revealed that as number of eggs increased their rate of parasitism decreased. This result is not consistent with the marginal value theorem or theorem of resources concentration [23]. However, we can explain this by the fact that the natural population of the parasitoid remained low throughout the crop growing period so that the expected response was not completed. Although conceivable this hypothesis remains to clarify in future experiments. In all cases *U. lariophaga* host finding and exploitation depend on several factors including distance, time, host patch size and the spatial position of the parasitoid relative to the host patch [24].Our results also revealed a significant reduction of the total number of bruchid eggs on cowpea pods in intercrops. On the opposite, natural parasitism of bruchid eggs due to *Uscana lariophaga* appeared to be higher in intercrops especially in systems where cowpea was intercropped with millet. Previous studies demonstrated that higher populations of natural enemies were found in intercropping systems, specifically in legumes and cereal intercrops. In such cropping systems, neighboring crops provide alternative foods, prey and refuges for predators and parasitoids [25; 26]and improve pest control. Finally from our results the initial infestation of cowpea by bruchid at harvest was low and reduced by intercropping. However, this low initial infestation is enough to allow serious losses during storage period where several generations of *C. maculatus* can overlap on unprotected grains [3; 4]. A substantial increase in the field parasitism (i.e insect field releases) could further reduce or suppress the initial infestation and then ensure proper and sustainable cowpea storage.

V. CONCLUSION

This study gave for the first time useful and precise indications on the temporal variations of bruchid egg laying on the pods and their parasitism in cowpea fields in Burkina Faso. From these results it appeared that both bruchid species have their oviposition activity gradually increased over time, the last pods to be formed being the most infested by bruchid eggs. Unfortunately, egg parasitism gradually decreased at the same time. It is therefore necessary to strengthen the natural parasitism by parasitoid releases, particularly during the pod setting period. The fact that parasitism increased in intercropping systems whereas infestation by bruchid decreased recommends to consider this cropping systems as optimal. One of the main goal of this study was to determine the optimal period of parasitoid releases in the fields. Given the results we suggest producing cowpea in intercropping with cereals, mainly millet, and to release parasitoids during all the pod setting period. However, the release method including the number of insects to release and parasitoid production remain to be precisely determined.

ACKNOWLEDGEMENTS

The contribution of Dr Olivier Gnankine from the University Ouaga I Pr Joseph KI Zerbo through relevant suggestions is greatly acknowledged. Many thanks to *la Commission Universitaire pour le Développement (CUD)* for supporting this research and granting M. Kam Koï Wenceslas. The technical support provided by Gampela farmers and technicians is fully recognized and acknowledged.

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