Plant Pathology Journal

ISSN 1812-5387

science alert

ANSInet
an open access publisher
http://ansinet.com

Plant Pathology Journal 4 (1): 14-20, 2005
ISSN 1812-5387
© 2005 Asian Network for Scientific Information

Field Occurrence of Bruchid Pests of Cowpea and Associated Parasitoids in a Sub Humid Zone of Burkina Faso: Importance on the Infestation of Two Cowpea Varieties at Harvest

[1]Sanon Antoine, [2]Dabiré Clémentine, [1]Ouedraogo Albert Patoin and [3]Huignard Jacques
[1]Laboratoire d'Entomologie Fondamentale et Appliquée, UFR/SVT Université de Ouagadougou, 03 BP 7021 Ouagadougou 03, Burkina Faso
[2]Institut de l'Environnement et de Recherches Agricoles, 01 BP 476 Ouagadougou, Burkina Faso
[3]Institut de Recherche sur la Biologie de l'Insecte (ESA CNRS 6035) Avenue Monge, Parc de Grandmont, 37200 Tours, France

Abstract: The cowpea is a very important legume for peasant farmers in West Africa but this crop is very sensitive to bruchid attacks during storage. A study was carried out in a sub humid zone of Burkina Faso to determine the relation between the dynamic of bruchid and parasitoid populations in the fields and cowpea infestation at harvest. The variations in insect numbers were weekly estimated by net captures during the growth of an early and a late cowpea variety. Adults of two bruchid species, *Callosobruchus maculatus* (Fab.). and *Bruchidius atrolineatus* (Pic) appeared early in the fields before cowpea flowering and their population regularly increased over time and from early to late cowpea variety. The Pteromalid *Dinarmus basalis* Rond was the only larval parasitoid encountered. Its adults appeared later than bruchids and their parasitism activity increased over time. At harvest, 35% of the early cowpea pods and 74.5% of the late cowpea pods were infested by bruchid eggs. 58.5 and 72% of the bruchid eggs laid respectively on the early and the late cowpea variety were parasitized by *Uscana* sp. The level of cowpea seed infestation by bruchids at the beginning of storage was estimated to be 1 and 2.7% for the early and late cowpea variety respectively. The parasitism rate of bruchid larvae by *D. basalis* was estimated at this period to be 7.8% for early cowpea variety and 18.2% for the late variety. These results are discussed in view of developing an integrated control method based on the enhancement of the pest natural enemies in the fields and/or into storage systems in combination with beneficial farming practices.

Key words: Population dynamic, pests, parasitoids, integrated control method, beneficial farming practices

INTRODUCTION

Cowpea (*Vigna unguiculata* Walpers) is an important food crop for many people in West Africa[1,2]. This area is the world's major producer of the crop with some 4.8 million ha cultivated[3,4]. The main constraint faced by the farmers is the difficulty of storing cowpeas. The larvae of several bruchid species develop in the cowpea seeds and cause considerable losses[5-7]. In the Niamey region of Niger, adults of two bruchid species *Bruchidius atrolineatus* (Pic) and *Callosobruchus maculatus* (Fabricius) appear in the fields soon after the cowpea pod setting at the end of the rainy season[7-10]. The females lay eggs on the maturing pods before they are harvested. Then, the bruchid populations continue to develop in stored cowpeas. Adults of *B. atrolineatus* enter a reproductive diapause after one generation[10]. In contrast, *C. maculatus* grows rapidly in numbers during the storage period and is responsible for major losses[5,11]. In Niger, the Trichogrammatidae *Uscana lariophaga* (Steffan) (Hymenoptera) parasitizes the eggs of both bruchid species in the fields and can reduce the rates of cowpea infestation at harvest[9,12]. Other parasitoids of the Hymenoptera order including *Eupelmus* spp. (Eupelmidae) and *Dinarmus basalis* Rondani (Pteromalidae) attack the larvae but were only recorded in the storage systems [13,14]. Biological control of bruchids using these parasitoids has been investigated. The strategy of conserving and enhancing indigenous parasitoids seems to be a viable option[15,16]. However, the development of such a method involves a good knowledge of ecology and interactions between bruchids and their parasitoids in the fields as

Corresponding Author: Sanon Antoine, Laboratoire d'Entomologie Fondamentale et Appliquée, UFR/SVT Université de Ouagadougou, 03 BP 7021 Ouagadougou 03, Burkina Faso
Tel: +226 50 337372 E-mail: sanonant@bf.refer.org

well as in granaries. Unfortunately, studies on the occurrence of these parasitoids in the cowpea fields are virtually lacking. The parasitoid species present in each region, their abundance and reproductive abilities could influence the cowpea contamination by bruchids and their population building during storage.

This study reports the fluctuations of bruchid and their larval parasitoid populations in the crops of two cowpea varieties in a sub humid zone of Burkina Faso. Cowpea pods were harvested at the end of the rainy season and examined to determine the number of bruchid eggs and the rates of their parasitism by the oophagous parasitoid of the genus *Uscana*. It is known that the initial parasitism at the beginning of storage influences the outcome of biological control in the granaries. For this reason, we also analysed the level of cowpea seed infestation during the first month of storage and the occurrence of larval parasitoid at this period.

MATERIALS AND METHODS

Cowpea varieties: Cowpeas used in the present study belonged to the early KN-1 and the late Local Moussa varieties. The KN-1, with brown seeds, develops in sixty days under optimal conditions while Local Moussa exhibits white seeds and matures in eighty days.

Experimental conditions: The studies were carried out during the rainy season in 1999 and 2000, in the Sudanian sub humid zone of Bobo-Dioulasso, in western Burkina Faso. In this area, the mean annual rainfall is estimated to be 900 to 1300 mm[17]. The main part of the rainy season occurred between June and October. During this period, mean temperature and relative humidity are 21-35°C and 67-83%, respectively.

Experimental design: The trial design used was a 2x4 Randomised Complete Block design. The two varieties were considered as treatment and there were 4 replicates. Each plot was 10x10 m with a buffer of 50 cm between plots. Two consecutive blocks were separated by 3 m. The cowpea varieties were planted, during the two years, in early July. Visual observations on the phenology of the crops were used to determine the main stages of cowpea growth, I. e. 50% flowering, 50% pod setting and maturing. To fight against flower Thrips (Thysanoptera), the crops were sprayed, at 50% flowering, with 1 l ha^{-1} of Decis® containing 12.5 g Deltamethrin/kg.

Infestation of cowpea by bruchid adults and their larval parasitoids: By 28 days after planting (DAP) onwards, samples of insects were taken each week in the crops until harvest time. The insects, sampled by 25 sweep nets on two rows in each experimental plot, were collected into sampling bottles (100 cc each) containing 70% diluted ethanol. They were brought back in the laboratory and then were identified and counted.

Reproductive activity of the larval parasitoids in the cowpea fields: The reproductive activity of the bruchids' larval parasitoids was also analysed by traps placed in the crops. Each trap was made of a 60 cm iron stake surmounted by a cylindrical cage. The cage exhibited a little opening front door and screen bars all around. A waterproof iron hut covered the top of the cage to protect against rainfall water. One trap was implemented per experimental plot. Each week, cowpea seeds containing 40 *C. maculatus* L_4 larvae were placed into petri dishes and introduced in the cages. Previous studies demonstrated that bruchid L_4 larvae were suitable for parasitization by the known larval parasitoid species[18]. After a 72 h exposure, the seeds containing the hosts, parasitized or not, were removed from the cages and brought back to the laboratory. The seeds were then opened and the bruchid larvae were extracted. The number of host attacked by each parasitoid species and the number of eggs laid were recorded. The eggs of the main larval parasitoids are different and easy to recognize. The eggs of *E. vuilleti* (L = 800 μm, l = 160 μm) have a 60 μm pedicle. Those of *D. basalis* are smaller (L = 600 μm, l = 150 μm) and have no pedicle[19,20]. The rate of host patches exploited was determined each week by the percentage of parasitized patches among the 8 patches displayed in the fields.

Infestation of cowpea pods by bruchid eggs and parasitism by *Uscana* sp.: At harvest time, 75 ripe pods were randomly sampled in each plot and brought back to the laboratory. The pods were carefully examined and the number of eggs laid by each bruchid species was determined. The eggs of *B. atrolineatus* and *C. maculatus* were easily distinguishable using the same criteria than Alzouma[21]. The number of eggs parasitized by *Uscana* sp., rapidly turning black, was also recorded. Data were used to estimate the rates of infestation of the cowpea pods [(number of pods bearing bruchid eggs/total number of pods examined) 100] and the parasitism rates of the bruchid eggs [(number of parasitized eggs/total number of eggs recorded) 100].

Insects emerging from the pods during the first month of storage: After the above observations, the pod samples were placed into separate Plexiglas boxes (26x14x8 cm) in local indoor ambient conditions. Adults of bruchids and parasitoids, which emerged from the pods, were daily collected, identified and counted for 30 days. This duration allowed the development of the first generation of bruchid at this period[11]. At the end of the survey, the seeds were shelled and we determined the total number of cowpea seeds and the number of seeds presenting at least one bruchid emergence hole. The data were used to estimate the rates of cowpea seed contamination by bruchids [(number of seeds with bruchid emergence hole/total number of cowpea seeds) 100] and the importance of larval parasitoids at the beginning of storage.

Statistical analysis: The mean number of insects adults collected in the fields and the standard deviations were calculated for each sampling date. When necessary, data were transformed using the formula Ln (x+1) for direct counting data, or Arcsin transformation for calculated percentages before Analysis of Variance (ANOVA). In cases where significant differences existed between means, the ANOVA was followed by a Fischer PLSD test. Means were regarded as different when the test provided discrimination at the 5% level.

RESULTS

Fluctuation of the bruchid and larval parasitoid populations in the cowpea fields: Adults of two bruchid species, *C. maculatus* and *B. atrolineatus* were caught in the fields (Fig. 1). *B. atrolineatus* was numerically dominant with some 51-53% of the bruchids collected during the two years of study. Bruchids were recorded early, before 50% flowering, whatever the cowpea variety (Fig. 1). The early KN-1 variety was first infested in all the cases. *D. basalis* was the only larval parasitoid encountered. Its adults appeared later than bruchids in the crops. The densities of bruchid and their larval parasitoid regularly increased and remained high at the end of the study (Fig. 1).

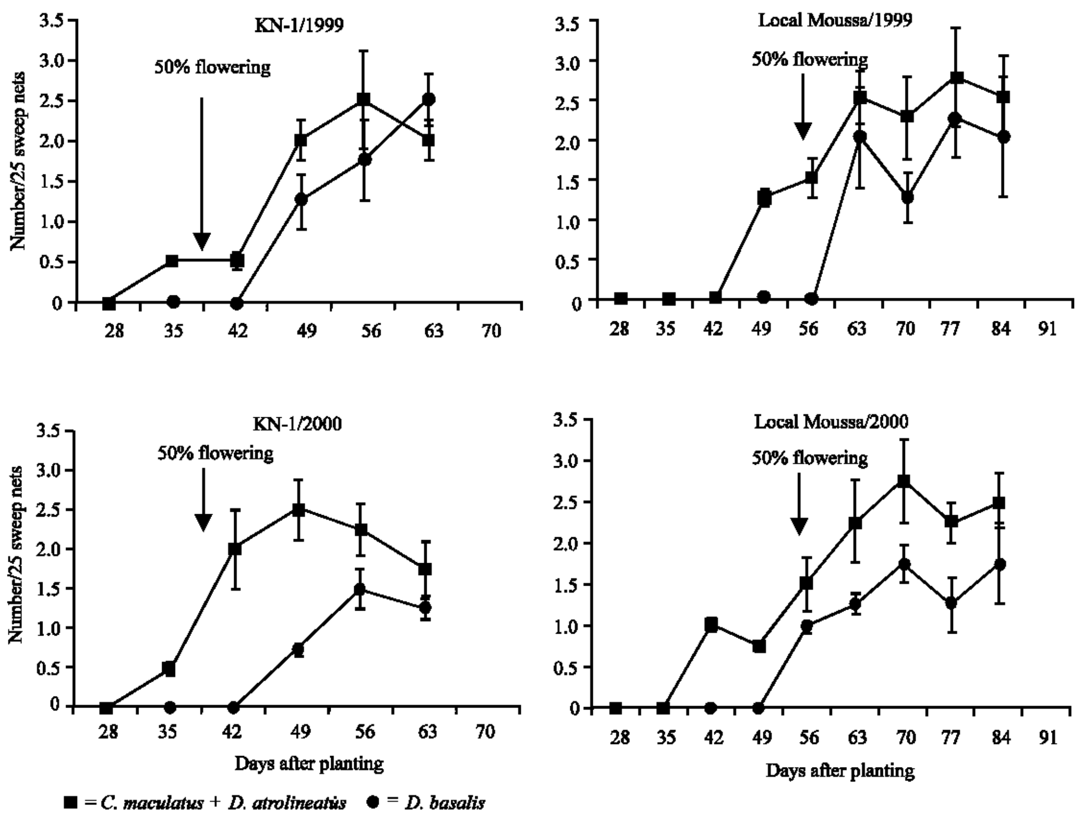

Fig. 1: Variations in mean numbers (±SD) of bruchids and larval parasitoids caught in the cultures of two cowpea varieties during the crop growth in 1999 and 2000

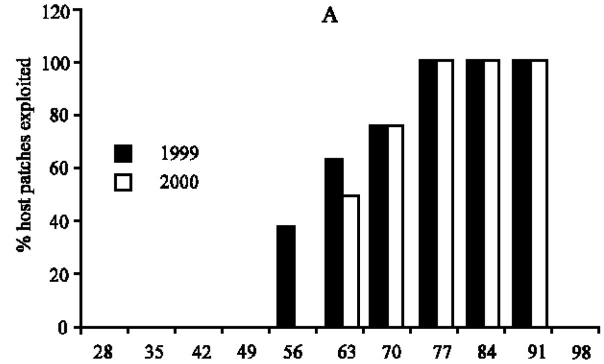

Fig. 2A: Temporal variations in the rates of host patches exploited

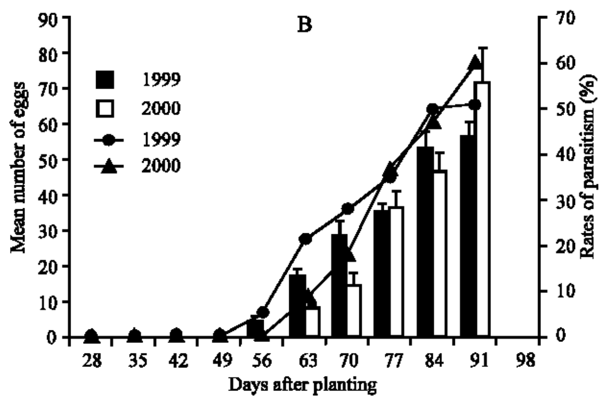

Fig. 2B: Temporal variations in the parasitism rates (curves) and the mean number (±SD) of eggs laid (histograms) by *D. basalis* in the cowpea fields in 1999 and 2000

Reproductive activity of the larval parasitoids in the cowpea fields: Trapping the larval parasitoids by displaying host patches in the crops confirmed that *D. basalis* was the only larval parasitoid species present in the zone of study. Although the adults appeared in the fields 49 DAP, parasitism of the hosts occurred only on 56-63 DAP onwards. The rates of exploiting the host patches, their parasitism and the number of eggs deposited on the hosts regularly increased up to the end of the study (Fig. 2A and 2B).

Infestation of cowpea pods by bruchid eggs and attack by *Uscana sp.*: Cowpea pods were infested by the eggs of *C. maculatus* and *B. atrolineatus*. The Local Moussa was significantly more infested than the KN-1 during the two years of study (Table 1). *B. atrolineatus* eggs were numerically dominant (Table 2). Although *B. atrolineatus* females laid the larger number of eggs on the pods, parasitism by *Uscana* sp. was higher on *C. maculatus* eggs (Fig. 3). Global parasitism rates ranged between 57.5 and 59.5% for eggs deposited on KN-1 pods and 69.5-74.5% for eggs laid on Local Moussa.

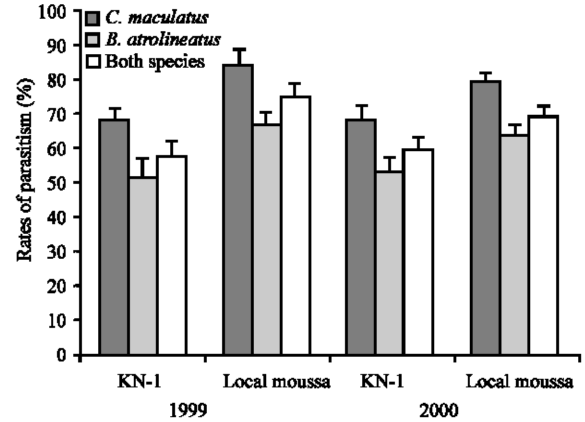

Fig. 3: Rates of parasitism (±SD) of both bruchid species eggs deposited on the pods of two cowpea varieties in 1999 and 2000

Table 1: Mean rates of cowpea infestation (%) by bruchids at harvest in a 75-pod sample

		Proportion of cowpea pods infested by			
Year	Variety	*C. maculatus*	*B. atrolineatus*	*C.m.+B.a.*	Total
1999	KN-1	13.50±2.08b	19.50±3.69b	6.75±1.71b	39.75±3.40b
	Local Moussa	26.50±4.65a	30.00±5.09a	21.75±5.27a	78.25±7.85a
2000	KN-1	9.500±5.26b	10.75±3.77c	10.25±4.03b	30.50±7.55c
	Local Moussa	30.00±4.69a	23.00±4.83b	17.75±4.50a	70.75±10.53a

C.m+ B.a.= Percentage of pods infested by both *C. maculatus* and *B. atrolineatus*

Means (±SD) in the same column, followed by different alphabetic letter, are significantly different at p≤0.05 using Fischer PLSD test.

Table 2: Mean number and proportion of bruchid eggs laid on the pods of two cowpea varieties in a 75-pod sample

		C. maculatus eggs		*B. atrolineatus* eggs		
Year	Variety	Number	%	Number	%	Total
1999	KN-1	20.75±3.09c	39.7	31.50±4.65c	60.3	52.25±4.64c
	Local Moussa	74.00±5.09a	45.9	87.25±6.34a	54.11	161.25±11.15a
2000	KN-1	16.25±3.30c	41.9	22.5±2.38 d	58.1	38.75±5.56d
	Local Moussa	55.50±5.26b	45.9	65.50±5.00b	54.1	121.00±9.31b

Means (±SD) in the same column, followed by different alphabetic letter, are significantly different at p≤0.05 using Fischer PLSD test

Insect emerging from the pods during the first month after harvest: Insects, which had emerged from the cowpea pods, belonged to *C. maculatus*, *B. atrolineatus* and *D. basalis*. Their number was relatively low but significantly more bruchid and larval parasitoids were collected from the pods of Local Moussa (Table 3). Considering all the data recorded during the two years of study, only 30.6 and 20.5% of the bruchid eggs

Table 3: Mean number of insect adults emerging from both cowpea varieties during the first month of storage in a 75-pod sample

Year	Variety	*C. maculatus*	*B. atrolineatus*	Total	*D. basalis*
1999	KN-1	4.25±1.26b	12.75±2.87b	17.00±3.16b	0.75±0.50b
	Local Moussa	8.50±1.29a	22.25±3.30a	30.75±2.21a	5.75±1.71a
2000	KN-1	3.50±1.91b	8.25±2.63c	11.75±4.50b	1.50±0.57b
	Local	8.75±2.50a	18.50±3.87a	27.25±5.85a	7.25±2.21 a

Means (±SD) in the same column, followed by different alphabetic letter are significantly different at p≤0.05 using PLSD Fischer test.

Table 4: Estimate of the cowpea seed contamination rates at the beginning of storage in a 75-pod sample

Year	Variety	No. of cowpea seeds/sample	No. of perforated seeds/sample	Rate of attack (%)
1999	KN-1	1287.75±16.62b	15.50±5.45b	1.20±0.41b
	Local Moussa	1086.75±13.50a	31.50±5.00a	2.90±0.43a
2000	KN-1	1270.25±28.08b	11.00±4.83b	0.86±0.46b
	Local Moussa	1108.25±9.95a	27.75±5.44a	2.50±0.47a

Means (±SD) in the same column, followed by different alphabetic letter are significantly different at p≤0.05 using PLSD Fischer test.

laid on the pods of KN-1 and Local Moussa, respectively developed to adults. The parasitism by *D. basalis* during the first month of storage varied according to the cowpea variety. Global parasitism rates at this period were estimated to be 7.8 and 18.2%, respectively for KN-1 and Local Moussa during the 2 years of study. The rate of contamination of cowpea seeds at the beginning of storage was <3% but was significantly higher for Local Moussa (Table 4).

DISCUSSION

Results of the present study show that two bruchid species, *C. maculatus* and *B. atrolineatus* are present in the cowpea crops in the sub humid zone of Bobo Dioulasso in Burkina Faso. Adults of both bruchid species appeared earlier than reported elsewhere[9], before 50% flowering of the cowpea plants. Flowers and pods are proved to play an important role in termination of diapause and quiescence in *B. atrolineatus*[22] and *C. maculatus*[23], respectively. Therefore these plant organs could attract the bruchids in the fields and stimulate female oviposition. That could explain why the insects' densities increased over time, when flowering and pod setting intensified in the fields. The same bruchid species were encountered in the drier areas of Niamey in Niger[9] and Ouagadougou in Burkina Faso[22]. On the contrary, a third species, *C. rhodesianus*, has been observed in the Guinean humid zone of Lomé in Togo and tends to replace *B. atrolineatus* in this area[24]. The difference in climatic conditions could explain the spatial distribution of bruchid species as reported for several insect orders[25]. The cowpea pods, examined at harvest, were infested by the eggs of both bruchid species but those of *B. atrolineatus* were numerically dominant. This observation is consistent with previous studies carried out in different areas of West Africa[9,21,26]. Nevertheless the cowpea infestation by bruchids seems to be less important in Burkina Faso in comparison to Niger where *B. atrolineatus* is so far very important in numbers. As a matter of fact, 70-90% of cowpea pods were infested by *B. atrolineatus* in Niger whilst only 25-40% of the pods carried *C. maculatus* eggs[9].

Results of this study also show that larval and oophagous parasitoids were associated with the bruchid populations in the fields. *D. basalis* was the only larval parasitoid species caught by net and traps displayed in the fields. The present study is the first complete report on field occurrence of bruchids' larval parasitoids. Previous reports particularly focused on parasitoïds collected in the granaries during cowpea storage[13,14,26]. In this study, the parasitoids appeared later than bruchids in the fields and their parasitism activity increased over time and from early to late variety. However, the impact of larval parasitoids in reducing the level of cowpea infestation at harvest seemed to be relatively low. Laboratory studies under concentrated host distribution demonstrated that *D. basalis* had high parasitism and host location abilities[20,27]. Probably, the capacity of finding the host under field conditions, where the host are scarce, is more difficult. Survey of granaries in Niamey and Ouagadougou revealed the presence of two larval parasitoid species, *D. basalis* and *E. vuilleti* during cowpea storage[13,14,26]. In Niger, a third species, *E. orientalis*, was temporary observed but it disappeared after a few month of cowpea storage[28]. From these results and those of the present study, it could be supposed that *D. basalis* is a cosmopolitan species while *Eupelmus* spp. are confined to dry areas. Such hypothesis has also been reported in the literature[29].

More than 60% of the bruchid eggs were parasitized in the fields by *Uscana* sp. Parasitism rates were particularly important in comparison to those of previous studies in Niger[9]. In the Niamey region *Uscana* sp. parasitized only 4% of *B. atrolineatus* eggs and 25% of *C. maculatus* eggs in the fields during the year 1983. In 1984, the rates were 8 and 35%, respectively. As previously observed[9], *C. maculatus* eggs were more often parasitized than those of *B. atrolineatus.* A host selection process may explain the preference of *Uscana* sp. for *C. maculatus* eggs. Previous studies[30] demonstrated that in a choice situation, *U. lariophaga* parasitizes the host species from which it had been reared. This hypothesis is consistent since in West Africa, *B. atrolineatus* enters into diapause during the early months of storage and *C. maculatus* becomes the dominant species during most of the year. Probably, the parasitoids found in the field have developed on *C. maculatus* eggs for a long period.

The high parasitism of bruchid eggs partly explains the small number of F1 bruchids emerging during the first month of cowpea storage. Present results also show that the early cowpea variety was less infested by bruchids because it developed in the presence of a low pest population and that of associated parasitoids. The use of early cowpea varieties and early harvest[31] could be an efficient alternative for reducing the field infestation of cowpea by bruchids.

This study demonstrated the importance of the parasitoid activity in the fields on the level of cowpea infestation by the pests at harvest in the zone of study. A preventive biological control strategy could consist in enhancing the oophagous *Uscana* sp in the cowpea fields to minimize the initial level of contamination by bruchid. Larval parasitoids, particularly *D. basalis*, seemed to be less active in the fields compared to storage situation. So, its population could be reinforced at the beginning of storage by augmentations in the granaries to limit the build up of the pest population[32]. This strategy, combined with a judicious choice of the cowpea variety, could allow a sustainable control of bruchid pests of cowpea in West Africa. However, the development of an efficient method at a large scale should consider the ecological variations, which determine the species distribution and their population dynamic[33].

ACKNOWLEDGMENTS

Authors are grateful to European community for supporting research on biological control of bruchid pest of cowpea in West Africa. The National Agricultural Research Institute of Burkina Faso is also acknowledged for facilitating the implementation of field experiments and for logistic support.

REFERENCES

1. Phillips, R.D. and K.H. McWatters, 1991. Contribution of cowpeas to nutrition and health. Food Technol., 45: 127-130.
2. Stanton, W. R., 1970. Les légumineuses à graines en Afrique. Publ. FAO, pp: 199.
3. Rachie, K.O., 1985. Introduction. In: Cowpea Research, Production and Utilization. Singh, S. R. and K.O. Rachie, (Eds.). John Wiley and Sons.
4. Jackai, L.E.N. and R.A. Daoust, 1986. Insect pests of cowpeas. Ann. Rev. Entomol., 31: 95-119.
5. Caswell, G., 1961. The infestation of cowpeas in the Western region of Nigeria. Tropical Sci., 3: 154-158.
6. Huignard, J., 1985. Importance des pertes dues aux insectes ravageurs des graines: Problèmes posés par la conservation des légumineuses alimentaires, source de protéines végétales. Cah. Nutr. Diét. XX, 3: 193-199.
7. Huignard, J., B. Leroi, I. Alzouma and J.F. Germain, 1985. Oviposition and development of *Bruchidius atrolineatus* and *Callosobruchus maculatus* (Coleoptera: Bruchidae) in *Vigna unguiculata* cultures. Insect Science and its Application, 6: 691-699.
8. Alzouma, I., 1981. Observations on the ecology of *Bruchidius atrolineatus* and *Callosobruchus maculatus* (Coleoptera: Bruchidae) in Niger. In: The Ecology of Bruchids attacking Legumes (pulses). Labeyrie, V. (Ed.). Junk the Hague, pp: 205-213.
9. Alzouma, I., 1987. Reproduction et développement de *Bruchidius atrolineatus* Pic (Coleoptera: Bruchidae) aux dépens des cultures de *Vigna unguiculata* L. Walp dans un agrosystème sahélien au Niger. Thèse de Doctorat d'Etat, Tours, pp: 162.
10. Germain, J.F., J. Huignard and J.P. Monge, 1987. Development of two bruchid populations *Bruchidius atrolineatus* Pic and *Callosobruchus maculatus* F. infesting stored cowpea in Niger. J. of Stored Prod. Res., 23: 157-162.
11. Ouedraogo, A.P., S. Sou, A. Sanon, J.P. Monge, J. Huignard, M.D. Tran and P.F. Credland, 1996. Influence of temperature and humidity on populations of *Callosobruchus maculatus* (Coleoptera: Bruchidae) and its parasitoid *Dinarmus basalis* (Pteromalidae) in two zones of Burkina Faso. Bulletin of Entomological Research, 86: 695-702.
12. Lammers, P.M. and A. Van Huis, 1989. *Uscana lariophaga* Steffan (Hym.: Trichogrammatidae), egg parasitoid of the stored insect pests *Callosobruchus maculatus* F and *Bruchidius atrolineatus* Pic (Coleoptera: Bruchidae): population studies in the fields and in storage in Niger. In Proc. of the Intern. Conf. on Integrated Pest Management in Trop. and Subtrop. Ecosyst. Bad Dürkheim, Germany, pp: 1013-1022.
13. Monge, J.P. and J. Huignard, 1991. Population fluctuations of two Bruchid species *Callosobruchus maculatus* Fab. and *Bruchidius atrolineatus* Pic. (Coléoptera, bruchidae) and their parasitoïds *Dinarmus basalis* (Rond) and *Eupelmus vuilleti* (Cwf) (Hymenoptera, Pteromalidae, Eupelmidae) in a storage situation in Niger. J. African Zool., 105: 187-196.

14. Monge, J.P., P. Dupont, A. Idi and J. Huignard, 1995. The consequences of interspecific competition between *Dinarmus basalis* (Rond) (Hym.: Pteromalidae) and *Eupelmus vuilleti* (Crw) (Hym.: Eupelmidae) on the development of their host populations. Acta Oecologica, 16: 19-30.
15. Van Huis, A, P.W. Arendse, M. Schilthuisen, P.P. Wiegers, H. Heerings, M. Hulshof and N.K. Kaashoek, 1994. *Uscana lariophaga*, egg parasitoid of bruchid beetle storage pests of cowpea in West Africa: The effect of temperature and humidity. Entomol. Exp. Applied, 70: 41-53.
16. Van Huis, A., F.A.N. Van Alebeek, M. Van Es and S.B. Sagnia, 2002. Impact of the egg parasitoid *Uscana lariophaga* and the larval-pupal parasitoid *Dinarmus basalis* on *Callosobruchus maculatus* populations and cowpea losses. Entomol. Exp. Application, 104: 289-297.
17. Gbikpi, P., 1996. L'agriculture Burkinabè. Projet d'appui au PASA. CID, Juin, pp: 63.
18. Van Alebeek, F.A.N., 1991. Interspecific host discrimination by two solitary ectoparasitoids of immature stages of Bruchidae. Med. Fac. Landbouww Rijksuniv Gent., pp: 1011-1020.
19. Cortesero, A.M., 1994. La recherche de l'hôte chez *Eupelmus vuilleti* Crw. Analyse des régulations tritrophiques entre la plante, *Vigna unguiculata* Walp, l'hôte, *Bruchidius atrolineatus* Pic, et le parasitoïde. Thèse de Doctorat. Université F. Rabelais, Tours, pp:128.
20. Gauthier, N., 1996. Analyse du superparasitisme chez l'ectoparasitoïde solitaire *Dinarmus basalis* en situation de compétitions intra et interspécifique. *Thèse* de Doctorat, Tours.
21. Alzouma, I. and J. Huignard, 1981. Données prélimaires sur la biologie et le comportement de ponte de *Bruchidius atrolineatus* (Coléoptère, Bruchidae) dans une zone sud sahélienne au Niger. Acta Oecologia, 2: 391-400.
22. Alzouma, I., J. Huignard and B. Leroi, 1985. Etude du comportement de ponte de *Bruchidius atrolineatus* au cours de la maturation des gousses de sa plante hôte (*Vigna unguiculata*) et de ses conséquences sur le développement des oeufs. Ann. Soc. Ent. Fr., 21: 207-217.
23. Bilal, H., 1987. Biologie de la reproduction chez *Callosobruchus maculatus*, formes voilière et non voilière. Thèse de Doctorat d'Etat, Tours, pp:179.
24. Glitho, A.I., 1990. Les Bruchidae ravageurs de *Vigna unguiculata* (Walp) en zone guinéenne. Analyse de la diapause reproductrice chez les mâles de *Bruchidius atrolineatus* Pic. Thèse de Doctorat, Tours, pp: 100.
25. Tauber, M.J., C.A. Tauber and S. Masaki, 1984. Adaptations to Hazardous Seasonal Conditions: Dormancy, Migration and Polyphenism. In: Ecological Entomology. Huffaker, C.B. and R.L. Rabb, (Eds). Wiley NY., pp: 149-183.
26. Sanon, A., 1998. Etude de l'évolution des populations de Coléoptères Bruchidae et de leurs parasitoïdes larvophages dans les systèmes de stockage du niébé (*Vigna unguiculata* Walp.) au Burkina Faso. Importance dans la mise en place de méthodes de lutte biologique. Thèse de Doctorat, Université de Tours, pp: 180.
27. Sanon, A. and A.P. Ouedraogo, 1998. Etude de variations des paramètres démographiques de *Callosobruchus maculatus* F. et de ses parasitoïdes, *Dinarmus basalis* Rond. et *Eupelmus vuilleti* Crw. sur le niébé dans une perspective de lutte biologique. Insect Science and its Applications, 18: 241-250.
28. Levêque, L., 1991. Analyse de la compétition interspécifique entre *Eupelmus vuilleti* et *Dinarmus basalis* au niveau d'un de leurs hôtes communs *Bruchidius atrolineatus* (Coléoptère, Bruchidae). Mémoire de DEA, Université de Tours, pp: 46.
29. Huignard, J., 1996. Lutte biologique contre les Coléoptères Bruchidés ravageurs de niébé dans les systèmes de stockage en Afrique de l'Ouest. Rapport CEE, pp: 78.
30. Van Huis, A., M.G. Wijkamp, P.M. Lammers, C.G.M. Klein Goldewijk, J.H. Van Seeters and N.K. Kaashoek, 1991. *Uscana lariophaga* (Hymenoptera: Trichogrammatidae), an egg parasitoid of bruchid beetle (Coleoptera: Bruchidae) storage pests in west Africa: host-age and host-species selection. Bull. of Entom. Res., 81: 65-75.
31. Olubayo, F.M. and G.R. Port, 1997. The efficacy of harvest time modification and intercropping as methods of reducing the field infestation of cowpeas by storage bruchids in Kenya. J. Stored Prod. Res., 33: 271-276.
32. Sanon, A., A.P. Ouedraogo, Y. Tricault, P.F. Credland and J. Huignard, 1998. Biological control of Bruchids in cowpea stores by release of *Dinarmus basalis* (Hymenoptera: Pteromalidae) adults. Environ. Entomol., 27: 717-725.
33. Labeyrie, V., 1981. Vaincre la carence protéique par le développement des légumineuses alimentaires et la protection de leurs récoltes contre les bruches. Food and Nutrition Bulletin, 3: 24-38.