African Crop Science Journal, Vol. 15, No. 4, pp. 211 - 222
Printed in Uganda.

ISSN 1021-9730/2007 $4.00

POTENTIAL FOR BIOLOGICAL CONTROL OF RICE YELLOW MOTTLE VIRUS VECTORS

N. WOIN, DJONMAÏLA[1], SADOU ISMAEL, SALI BOUROU and T. BEBOM
IRAD, Box 33 Maroua, Cameroon
[1]University of Dschang, Box 222 Dschang, Cameroon

ABSTRACT

Insect pests and disease infestations are the primary constraints in rice *(Oryza sativa)* production systems in Africa and Asia. For Cameroon in particular, the rice yellow mottle virus (RYMV) is increasingly a serious problem to rice production. During the poulations of the various insect vectors of RMYV are not known, and hence the need for this study. Unfortunately, 2002 - 2004, two sampling methods were combined to assess the population of insects vectors of rice yellow mottle virus (RYMV) in the three major irrigated rice ecosystems in northern Cameroon (Lagdo, Maga and Yagoua), and in low land rice fields. Sampling was conducted using sweep net and D-Vac (sucking trap) fortnightly in 2002 and 2003 until mid October in low land rice fields, while in the irrigated fields, samplings occurred between December and April. Rearing using dead insects was conducted simultaneously in the laboratory to identify the parasitoid insect species. From samples obtained at different sites: (i) the dominant structure of the RYMV insect vectors was analysed according to the rice phenology; and (ii) the diversity and the occurrence of potential major groups of predators and parasitoids were assessed. Among the RYMV insect vectors sampled: *Chaetocnema pulla* Chapuis (Coleoptera: Chrysomelidae), *Chnootriba similis* Mulsant (Coleoptera: Coccinellidae), *Trichispa sericea* Guerin-Meneville (Coleoptera: Chrysomelidae), *Locris rubra* Fabricius (Hemiptera: Cicadellidae), *Oxya hyla* Stål (Orthoptera: Acrididae), and *Conocephalus longipennis* (de Haan) (Orthoptera: Tettigoniidae) were the most encountered insect species during the rice growing seasons. With regard to predator populations, spiders (*Araneae)* were the most abundant, with high concurrency of *Pardosa* spp (> 42 %) in all sites. In Maga and Yagoua sites, the carabid beetle species, *Abacetus crenulatus* Dejean and *Abacetus foveolatus* Chaudoir, were the most numerous whereas the Lagdo site was highly colonised by *Clivina. erythropyga* Putzeys. *Paederus sabaeus* Erichson, and *Stenus ravus* Puthz were the most abundant Staphylinid beetles. From reared dead RYMV insect vectors, *Eurytoma* spp., *Pediobius* spp., *Tetrastichus* spp. and *Telenomus* spp. emerged as parasitoids. Results of this study reveal a great potential of biological control against rice yellow mottle virus vectors using predators and parastoids. This potential should be developed to manage the yield losses caused by the virus infection in rice cropping systems.

Key Words: Cameroon, *Oryza sativa*, parasitoids, predators

RÉSUMÉ

Les infestations dues aux insectes et les maladies sont les contraintes primaires dans le système de production du riz (*Oryza sativa*) en Afrique et en Asie. Pour le Cameroun en particulier, le virus marbre jaune de riz (RYMV) est de plus en plus un problème sérieux à la production de riz. Cependant, les populations des divers vecteurs d'insecte de rmyv ne sont pas connu, et donc le besoin pour cette étude. Malheureusement entre 2002 et 2004, deux méthodes d'échantillonnages ont été combinées pour évaluer la population de vecteurs d'insectes de virus marbre jaune de riz (RYMV) dans les trois écosystèmes majeurs de riz irrigué au nord du Cameroun (Lagdo, Maga et Yagoua), et dans les champs de riz de terre bas. L'essai a été dirigé utilisant le coup de balai net et D- vac (suçant le piège) les nuits de 2002 et 2003 jusqu' a mi-octobre dans les champs de riz de terre bas, pendant que dans les champs irrigué, les échantillons sont arrivés entre Décembre et Avril. Utilisation des insectes morts était simultanément dirigée dans le laboratoire pour identifier l'espèce d'insecte parasitaire. Des échantillons obtenus aux sites différents: (i) la structure dominante des vecteurs d'insecte de rymv a été analysée selon la phénologie de riz ; et (ii) la diversité et l'événement de groupes majeurs potentiels de prédateurs et de parasitoides ont été évaluées. Les vecteurs d'insecte de RYMV : *Chaetocnema pulla* Chapuis (Coleoptera : Chrysomelidae), *Chnootriba similis* Mulsant (Coleoptera : Coccinellidae), *Trichispa sericea* guerin meneville (Coleoptera : Chrysomelidae), *Locris rubra* Fabricius (Hemiptera : Cicadellidae), *Oxya hyla* stål (Orthoptera : Acrididae), et *Conocephalus longipennis* (de Haan) (Orthoptera : Tettigoniidae) étaient les espèces d'insecte le plus communes pendant les périodes de croissance de riz. En ce qui concerne les populations de prédateur, les araignées *(Araneae)* étaient le plus abondant, avec haute concurrence de *Pardosa* spp. (> 42 %) dans tous les sites. Sur les sites de Maga et Yagoua, l'espèce de coléoptère de carabid, abacetus crenulatus dejean et *Abacetus foveolatus* Chaudoir, étaient les plus nombreux tandis que sur le site de Lagdo a été extrêmement colonisé par *Clivina. erythropyga* Putzeys. *Paederus sabaeus* Erichson, et *Stenus ravus* Puthz étaient les coléoptères du Staphylin le plus abondant. Les vecteurs d'insecte de RYMV, *Eurytoma* spp., *Pediobius* spp., *Tetrastichus* spp., et *Telenomus* spp. ont émergé comme parasitologies. Les résultats de cette étude révèlent un grand potentiel de contrôle biologique contre les vecteurs de virus marbre jaune de riz utilisant des prédateurs et des parasitoses. Ce potentiel devrait être développer pour gérer les pertes de rendement causées par l'infection de virus dans le système de riz.

Mots Clés: Cameroun, *Oryza sativa*, parasito¿des, prédateurs

INTRODUCTION

Africa produces only 2.7% of the world's rice (*Oryza sativa)* and is the second largest rice importing region in the world (6.5 metric in 2003). Africa's rice imports represent about 25% of the world rice importation (Méndez del Villar, 2003). With an average yield of 2 t ha^{-1}. With the exception of Egypt, rice production in Africa remains significantly below the world average and regional averages such as Asia (3.8 t ha^{-1}), Latin America (3.0 t ha^{-1}) and United States (7.0 t ha^{-1}), according to FAO (published online). Compared to the other West African countries, the yearly amount of rice importation in Cameroon is at least 62 % of thequantity needed.

Insect pests and diseases are the major constraints limiting rice production in Africa and Asia. Of all the rice diseases, the one caused by the rice yellow mottle virus (RYMV), first reported in Kenya in 1966, is one of the most damaging in Africa. The RYMV has by far been reported in many countries in East and West Africa including Cameroon, where in some cases whole fields have been devastated. Based on available evidence, RYMV has only been reported from the African continent and is endemic in every country where it has been reported. Among the known vectors of the disease insects constitute one of the indubitable and important group. Since evidence of the existence of the disease in Cameroon in year 2 000 (Traoré *et al*., 2001), studies have never been carried out on RYMV nor on its vectors.

The aim of this work was to assess the species diversity and population abundance of RYMV insect vectors including those of their potential natural antagonists in lowland/irrigated rice fields in the Sudano-sahelian savannah of Cameroon with a view of establishing the potential of biological control strategies against RYMV vectors.

MATERIAL AND METHODS

Experiments were conducted from 2002 to 2004 in the Sudano-sahelian climate, with a relative humidity of 65 ± 25 %, temperature range of 13-42°C, and mean annual rainfall of 1,000 mm. Three sites, at least 200 km apart, were sampled. These were (1) Lagdo: 9° 3' 0N; 13° 43' 60E - 232 m a.s.l; Maga: 10° 50' 12N; 14° 56' 37E – 305 m a.s.l, and Yagoua: 10° 20' 34N; 15° 14' 26E – 313 m a.s.l. The experimental fields consisted of a plot (0.5 ha) in each site. Sampling in lowland rice was carried out only in Lagdo and Yagoua where field plots were contiguous to farms cropped by maize (*Zea mays* L.).

The RYMV vectors and their natural enemies populating the aerial rice parts were sampled using 2 methods as described:

(i) sweeping with net: 200 doubled sweeps (50 random sweeps per plot along diagonal and median transects); and
(ii) sucking with D-Vac: 10 sucking of one (1') at 15 m and 100 m from the edge of the plot.

Dead RYMV vector materials were reared to confirm emergence of parasitoids

All the experimental fields had not been treated with insecticides in the 10 years preceding the study. All arthropods sampled were labeled, stored at -4°C, sorted in the laboratory under a stereoscopic binocular microscope, and then transferred into 70% alcohol, pending identification.

As species diversity combines the area of 'number of species' (species richness) and the way in which the individuals are apportioned into those species (evenness) (Vandermeer, 1981), the heterogeneity of such a community is determined using the Shannon-Weiner index (Risch *et al.*, 1983).

The frequency distribution was assessed considering dominance class according to Engelmann (1978). Representative specimens of rove and ground beetles were sent to the International Institute of Entomology (CAB International, London) for identification or confirmation.

To compare diversity values estimated with the Shannon–Weiner index (H') on the basis of the frequency distribution of the beetles, parametric statistical techniques were questioned through a t-test (MacArthur, 1965; Poole, 1974) at 5%.

RESULTS

Population abundance of RYMV insect vectors. In the 3 locations of the study, the RYMV insect vectors sampled were: *Chaetocnema pulla* Chapuis (Coleoptera: Chrysomelidae), *Chnootriba similis* Mulsant (Coleoptera: Coccinellidae) *Trichispa sericea* Guerin-Meneville (Coleoptera: Chrysomelidae), *Locris rubra* Fabricius (Hemiptera: Cicadellidae), *Oxya hyla* Stål (Orthoptera: Acrididae) and *Conocephalus longipennis* (de Haan) (Orthoptera: Tettigoniidae).

From 2002 to 2004 (Figs. 1, 2 and 3), *C.similis* was always the most dominant species in Lagdo rice fields, with an overall frequencies between 55 and 70% of the total number of vectors caught;

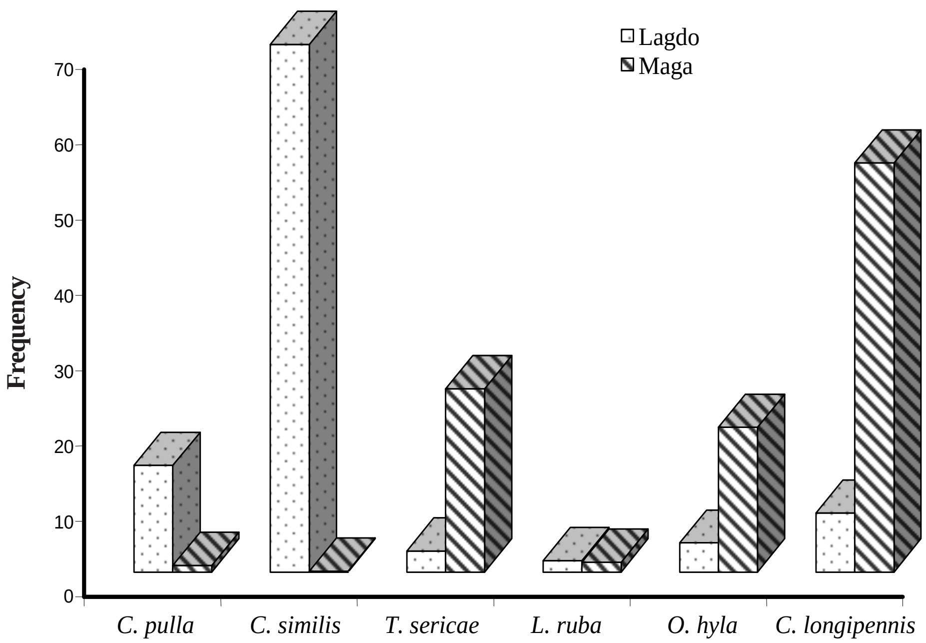

Figure 1. Frequency distribution of RYMV insect vectors in rice plots at Lagdo and Maga, Cameroon in 2002.

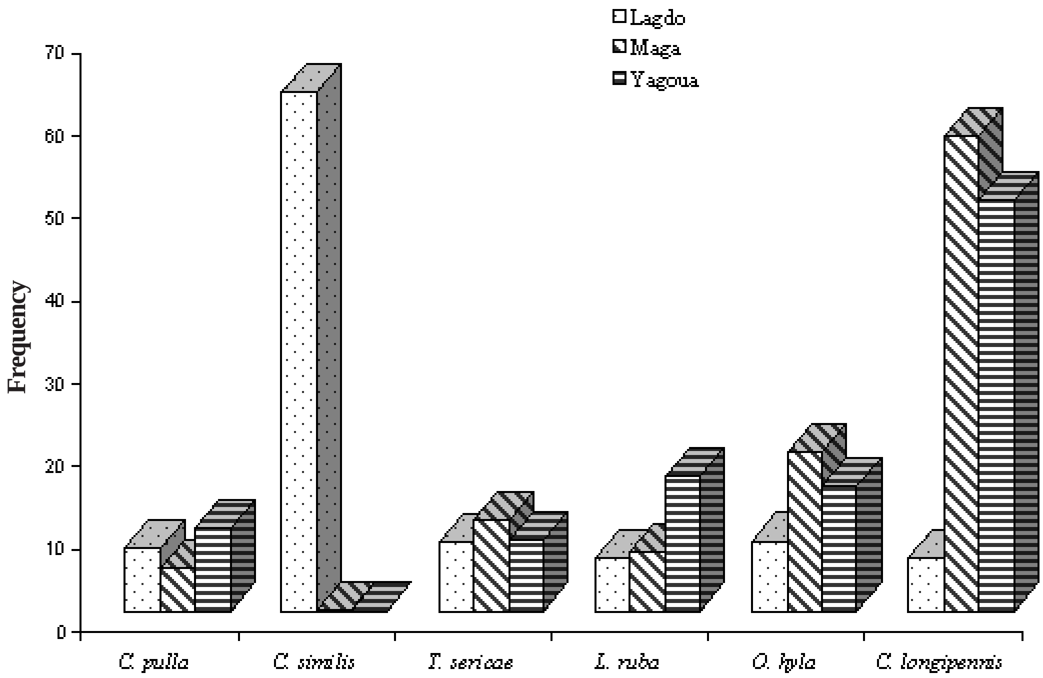

Figure 2. Frequency distribution of RYMV insect vectors in rice plots at Lagdo, Maga and Yagoua, Cameroon in 2003.

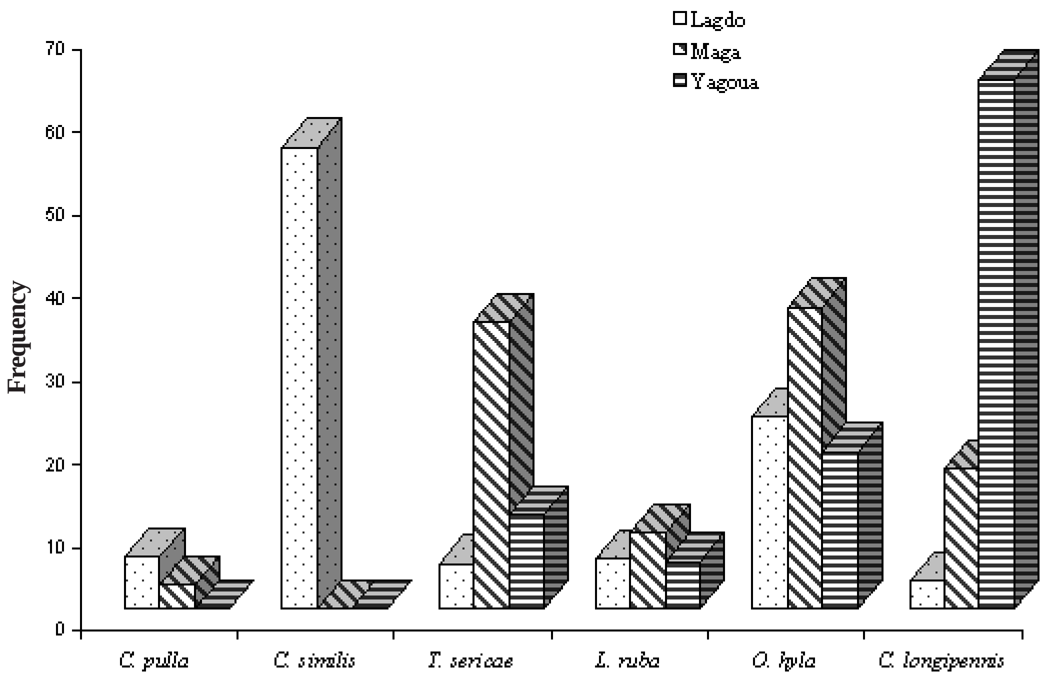

Figure 3. Frequency distribution of RYMV insect vectors in rice plots at Lagdo, Maga and Yagoua, Cameroon in 2004

followed by *O. hyla*. In the same period, *C.longipennis* occurred most frequently in Maga, followed by *O. hyla* and *T.sericea*. In Yagoua, where sampling was carried out only in irrigated rice fields during 2003 and 2004, the meadow grasshopper *C.longipennis* was highly dominant throughout both cropping seasons, followed by *O. hyla, L.rubra, T. sericea* and *C.pulla.*

Populations of predators colonising rice fields in the sites

a) Spiders. Throughout the sampling period 16,968 spider specimens belonging to 28 species and 10 families were collected from the 3 sites, (Table 1). The species richness was different at Lagdo and Yagoua during 2002. Values fluctuated from year to year at Lagdo where populations ranged between 1,862 and 2,394 individuals. The abundance was higher in Yagoua (2,874 specimens) than in Lagdo (2,394 individuals), during the same year. However, this fact was not concomitant with higher species richness in Lagdo. Shannon index marginally varied between sites and years (Table 2).

Ten species (82.40 %) were common to all sites (Table 3). Lycosidae specimens represented 55.08% of the total sample among which *Pardosa* spp. accounted for 42.03%, followed by *Arctosa* spp. (5.60%). In 2 sites, *Pardosa* spp. were the most dominant species throughout the sampling period. Its population abundance in Lagdo ranged from 38.39 to 51.63% of the total specimens collected. This was followed by Maga where 44.40% of specimens belonged to *Pardosa* spp. whereas in Yagoua the species came second (20.76%) after *Langbiana vokrensis* Bosmans and Van Hove (27.35%).

b) The carabids. The overall trend in cumulative frequency distribution (%) of species is presented in Table 4, whereas, Table 5 gives number of ground beetle species collected for the same period. *Abacetus crenulatus* Dejean were the dorminant ground beetle species at Lagdo and Yagoua (Table 4). Overall, *Pterostichinae* ground beetles were the most abundant followed by Scaritinae (Table 5).

c) The Staphylinids. The overall trend in frequency distribution (cumulative values) of rove beetle species is presented in Tables 6 and 7. When considering the accumulation of different species encountered, one notices that the dominant species are limited to only a few: *Paederus sabaeus, Stenus ravus* and *Stenus (Mendicus) S. fulgidus*

d) Some dominant parasitoids. Among the potential parasitoids obtained by rearing dead insect vectors of RYMV, several hemepteran species observed in different localities (Table 8).

DISCUSSION

Based on existing literature, this study represents the first report of the insect vector species being present in Cameroon and their role as a vector of RYMV. The fact that the prevalence of the species investigated differs from one site to another, indicates that pest problems may vary from one area to another in view of the diverse and surrounding conditions under which rice is grown. Habitat preference of *C. similis* appears to be Lagdo. In Nigeria, Alam (1992) indicated that *C. similis* occurs in all climatic zones, from the humid tropical to the Sudanian savanna. However, populations of *C. similis* are lower than that of most other pests reported in Nigeria. Akinsola and Agyen-Sampong (1984) reported similar observations for West Africa as a whole. Various reports (e.g., Bakker, 1971; Reckhaus and Andriamasintseheno, 1997) observed a positive relationship between vector number and RYMV infection.

Conocephalus longipennis has been reported as being a transmission agent for RYMV in West Africa (Abo, 1998; Nwilene, 1999). *Conocephalus* populations were highest in the Guinea savanna zone (E.A. Heinrichs and C. Williams, WARDA, 1995, unpubl. data). The status of this pest in the Sudanian savanna has not been reported. Studies on the continuum toposequence on the WARDA M'bé Farm indicated a trend similar to that of *Chaetocnema*. Populations occurred in all ecologies but were highest in the uplands (Heinrichs and Barrion, 2004). In Latin America, intensification of crop

TABLE 1. Population density of spiders species collected from 2002 – 2004 on rice in Cameroon

Family /species	Lagdo site			Maga site			Yagoua site		Total
	2002	2003	2004	2002	2003	2004	2003	2004	
Araneidae									
Neoscona theisi (Walckenaer)	149	214	148	158	187	129	34	472	1,491
Araneus cereolellus (Strand)	61	37	198	109	89	68	0	11	573
Clubionidae									
Cheiracanthium melanostomelum Roewer	53	73	33	91	79	27	74	382	812
Clubiona spec.	8	14	3	0	24	31	33	61	174
Linyphiidae									
Lepthyphantes spp.	4	0	23	11	43	9	0	78	168
Metaleptyphantes foulfouldei Bosmans	10	11	6	21	20	8	0	199	275
Ostearius melanopygius (O.P. –Cambridge)	6	0	11	13	36	10	0	1	77
Notioscopus spec.	0	2	19	7	23	2	41	0	94
Lycosidae									
Allocosa spec.	87	73	56	108	68	8	0	23	423
Arctosa spec.	61	101	126	159	231	174	89	10	951
Lycosa spp.	63	69	23	44	21	82	63	23	388
Pardosa spp.	860	1,236	1,031	792	948	1,132	539	593	7,131
Pterartoria spp.	29	29	17	31	19	24	44	13	206
T*rochosa* spec.	43	57	15	21	45	53	9	4	247
Oxyopidae									
Oxyopes pallidecoloratus Strand	10	19	32	22	12	21	0	2	118
Oxyopes spec.	45	19	11	21	4	29	23	15	167
Salticidae									
Heliophamus cassinicola Simon	26	29	9	22	7	16	0	26	135
Phidippus spec.	17	31	41	31	27	34	6	24	211

TABLE 1. Contd.

Family /species	Lagdo site			Maga site			Yagoua site		Total
	2002	2003	2004	2002	2003	2004	2003	2004	
Tetragnathidae									
Tetragnatha spp.	42	50	98	58	12	11	3	18	282
Leucauge spec.	0	9	6	3	0	34	2	8	54
Theridiidae									
Argyrodes spp.	96	121	49	102	89	77	124	117	775
Theridion spec.	37	45	19	93	21	9	0	3	227
Thomisidae									
Misumena nana Lassert	11	56	11	4	15	21	23	0	141
Runcinia spec.	68	33	48	29	39	91	0	0	308
Thomisus spnrifer Pickard-Cambridge	58	43	71	108	32	97	13	4	426
Zodariidae									
Langbiana vokrensis Bosmans & Van Hove	11	8	93	5	17	2	94	781	1,011
Suffucioides spp.	7	15	32	0	4	21	0	6	85
Total	1,862	2,394	2,229	2,063	2,112	2,220	1,214	2,874	16,968

TABLE 2. Species richness, abundance and diversity of spiders at Lagbo, Maga and Yagoua, Cameroon

Variable	Lagdo			Maga			Yagoua	
	2002	2003	2004	2002	2003	2004	2003	2004
Species richness	25	25	27	25	26	27	17	23
Abundance	1,862	2,394	2,229	2,063	2,112	2,220	1,214	2,874
Diversity index (H')	2.22a	2.06b	2.20b	2.37c	2.19d	2.07e	2.03f	2.06g
Evenness (E)	0.69	0.64	0.67	0.74	0.67	0.63	0.72	0.66

Values marked with the same letter across years (rows) within a given site are not significantly different (t-Test, p<0.05)

TABLE 3. Dominance class of spiders (cumulative values) at Lagdo, Maga and Yagoua, Cameroon in 2002 - 2004

Sites	Eudominant species (%)	Dominant species (%)	Sub-dominant species (%)
Lagdo	*Pardosa* spp. (74.12)	-	*Neoscona theisi* (7.65) *Arctosa* spec. (6.61) *Araneus cereolellus* (4.36) *Argyrodes* spp. (4.15) *Allocosa* spec. (3.11)
Maga	*Pardosa* spp. (44.40)	*Argyrodes* spp. (10.21)	*Langbiana vokrensis* (7.74) *Arctosa* spec. (7.33) *Cheiracanthium melanostomelum* (6.10) *Lycosa* spp. (5.19) *Notioscopus* spec. (3.38) *Pterartoria* spp. (3.62)
Yagoua	-	*Neoscona theisi* (16.53) *Cheiracanthium melano-stomelum* (13.38) *Pardosa* spp. (20.76) *Langbiana vokrensis* (27.35)	*Metaleptyphantes foulfouldei* (6.97) *Argyrodes* spp. (4.10)

TABLE 4. Dominance class of ground beetles (cumulative values) at Lagdo, Maga and Yagoua, Cameroon in 2002 - 2004

Sites	Eudominant species (%)	Dominant species (%)
Lagdo	*Clivina erythropyga* Putzeys (34.4)	*Abacetus crenulatus* Dejean (18.03)
Maga	*Abacetus crenulatus* Dejean (55.49)	*Clivina dumolinii* Putzeys (10.7)
Yagoua	*Abacetus foveolatus* Chaudoir (50.8)	*Abacetus crenulatus* Dejean (18.0)

TABLE 5. Number of ground beetles collected by means of D-Vac at Lagdo, Maga and Yagoua, Cameroon

Family/subfamily/species	Lagdo	Maga	Yagoua
Carabidae			
Anchomeninae			
Metagonum patroboides (Murray)	1	0	3
Graphipterinae			
Graphipterus obsoletus nigericus Basilewsky	10	21	11
Harpalinae			
Platymetopus xanthographus (Alluaud)	1	0	0
Masoreinae			
Aephnidius madagascariensis (Chaudoir)	3	8	5
Masoreus orientalis Dejean	2	0	1
Oodinae			
Acanthoodes centrosternis (Chaudoir)	3	1	0
Pterostichinae			
Abacetus crenulatus Dejean	12	118	23
Abacetus foveolatus Chaudoir	2	13	6
Abacetus nitens Tschitscherine (?)	1	4	3
Scaritinae			
Clivina erythropyga Putzeys	13	14	7
Clivina dumolinii Putzeys	3	19	5
Clivina sp A	2	2	3
Siagoniinae			
Siagona senegalensis Dejean	3	4	1
Tetragonoderinae			
Tetragonoderus quadrimaculatus Gory	2	0	6
Zuphiinae			
Zuphium fuscum Gory	1	0	3

TABLE 6. Dominance class of rove beetles (Cumulative values) at Lagdo, Maga and Yagoua, Cameroon in 2002 - 2004

Species dominance	Eudominant species (%)	Dominant species (%)
Lagdo	*Paederus sabaeus* Erichson (69.14)	*Stenus ravus* Puthz (17.43)
Maga	*Paederus sabaeus* Erichson (84.90)	-
Yagoua	*Paederus sabaeus* Erichson (53.74)	*Stenus ravus* Puthz (36.30)

TABLE 7. Number of rove beetles collected by means D-Vac and Sweep net (2002-2004)

Genera/species	Lagdo	Maga	Yagoua
Paederus alfieri Koch	2	3	1
Paederus sabaeus Erichson	242	391	163
Paederus saengeri Coiffait	2	3	0
Philonthus coprophilus Jarrige	7	0	2
Philonthus turbidus Erichson	0	1	0
Stenus argentatus Puthz	0	1	1
Stenus bauerinae Puthz	3	0	0
*Stenus fulgidus*Puthz	20	14	9
Stenus furcifer Puthz	0	0	13
Stenus gerardianus Scheerpeltz	1	0	1
Stenus prospector Favel	9	7	0
Stenus ravus Puthz	63	39	92
Stenus tschdensis Puthz	2	1	1
Total	351	460	283

TABLE 8. Hemipteran species with parasitoid status on RYWV insect vectors in Cameroon

Parasitoids	Host(s)	Stage(s) attacked
Eurytoma spp.	*Chaetocnema pulla*	Larva
Pediobius spp.	Oxya hyla	Pupa
Pediobius furvus Gahan	*Trichispa sericae*	Pupa
	Chnootriba similis	Larva
Telenomus sp.	*Conocephalus longipennis*	Pupa/larva
Tetrastichus spp.	*Chnootriba similis*	Larva
	Locris ruba	Pupa/larva

management practices has been shown to result in decreasing importance of *Chaetocnema* spp. in lowland rice (Weber and Parada, 1994).

Many studies have been conducted on polyphagous beetles both in natural vegetation and various habitats in agro-ecosystems (Fagel, 1970 and1973; Puthz, 1971; Thiele, 1977; Luff, 1987; Ishitani and Yano, 1994). However, in paddy rice fields, the population dynamics of these insects have not been documented, probably because of the inundated environment (Yano *et al.*, 1995). In Africa and Latin America where upland rice represents, respectively, 60 and 73 % of total rice-growing area (Jacquot and Courtois, 1993), predatory soil-dwelling beetles may be considered in establishing any integrated insect pest management program.

Despite the early emphasis placed on specialist predators and their potential control of target prey populations, recent evidence indicates that generalist predators may also have important influences on prey. They are abundant polyphagous predators in most agricultural systems and are potentially important pest control organisms (Riechert and Lockley, 1984; Nyffeler and Benz, 1988; Woin, 1999). Spiller's (1992) experimental work with two spider species, demonstrated the potential interference effects that generalist predators may have on each other's predation effects on insect populations. Riechert and Bishop (1990), nevertheless, found that in conserving the spider assemblage by the application of mulch, one can significantly reduce phytophagous insect numbers and plant damage.

However, little is known about the population ecology of Afrotropical species. Among the spiders collected, *Pardosa* spp. were the most abundant as mentioned by Woin (1999).

In Maga and Yagoua, the species *A. crenulatus* and *A. foveolatus* the most numerous whereas the Lagdo site was highly colonized by *C. erythropyga* over the three sampling years. Investigations conducted in the south of Ethiopia (Gebre-Tsadik, 1998) showed that these species were mostly trapped at the aerial part of wheat crop. The most common species, *Paederus sabaeus*, belongs to a genus known as active predators in tropical agro-ecosystems (Ooi and Shepard, 1994; Gebre-Tsadik, 1998). The *Stenus* species were numerous and made up an important percentage of the population. Bernhauer (1939) emphasized the importance of this group of polyphagous predators in the Cameroon environment. From parasitoids identified on larvae and pupae, *P. furvus* was known as enemy of *C. similis* in the sudano-sahalian cropping systems in Cameroon.

ACKNOWLEDGEMENTS

We would like to thank the West African Rice Development Association (WARDA)/ROCARIZ under whose auspices the study was granted. We thank CAB International (UK) for their support in taronomic groupings and identification of arthropods.

REFERENCES

Abo, M. E. 1998. Studies on the transmission of rice yellow mottle virus (RYMV). PhD thesis, Ahmadu Bello University, Zaria, Nigeria.200 p.

Akinsola, E. A. and Agyen-Sampong M. 1984. The ecology, bionomics, and control of rice stem-borers in West Africa. *Insect Science and Its Application* 5:69-77.

Alam, M. S. 1992. A survey of rice pests in Nigeria. *Tropical Pest Management* 38:115-118.

Bakker, W. 1971. Three new beetle vectors of rice yellow mottle virus in Kenya. *Netherlands Journal of Plant Pathology* 77:201-206.

Bernhauer, M. 1939. Zur Staphylindenfauna von Kamerun (42. Beitrag). *Entomological Bulletin* 35:252-262.

Bosmans, R. 1986: Scientific reports of Belgian Cameroon expedition 1981 and 1983. No. 13. New species and new records of spiders of the family Linyphiidae (Araneae). *Revue Zoology Africa* 100:171-204.

Engelmann, H. D. 1978. Zur Dominanzk-lassifikazierung von Bodenarthropoden. *Pedobilogia* 18: 378-380.

Fagel, G. 1970. Révisions des genres *Procirrus* Latreille, *Palaminus* Erichson et voisins de la faune africaine (Coleoptera, Staphylinidae: Paederinae). *Ann. Musée Royal de l'Afrique Centrale, Tervuren, Série in-8° Sci. Zool.* 186 (3):1-444.

Fagel, G. 1973. Révision des *Scopaeus* (Coleoptera-Staphylinidae-Paederinae) de l'Afrique noire. *Etudes du Continent Africain* 1:1-247.

Gebre-Tsadik, T. 1998. Agroecological investigations on cereal aphids and their natural enemies in the framework of Integrated Pest Management in wheat fields in Ethiopia and Germany. PhD Thesis. Druck und Verlag, Darmstadt. 142 p.

Heinrichs, E.A. and Barrion, A. T. 2004. Rice-feeding insects and selected natural enemies in West Africa: Biology, Ecology, Identification. G.P. Hettel Edited. 242 p.

Heinrichs E.A., Williams C., Oyediran, I., Kassoum T.A., Ndongidila A., Harris K., Camara, A.K. and Dias, J.R. 1995. Survey of insect pests of Côte d'Ivoire, Guinea and Guinea Bissau. In: WARDA annual report 1995. Bouaké (Côte d'Ivoire): West Africa Development Association. pp. 43-45.

Ishitani, M. and Yano, K. 1994. Species Composition and Seasonal Activities of Ground Beetles (Coleoptera) in a Fig orchard. *Japanese Journal of Entomology* 62(1):201-210.

Jacquot, M. and Courtois, B. 1993. The Tropical Agriculturalist. Upland rice. pp. 96. CTA/ MACMILLAN.

Luff, M. L., 1987. Biology of polyphagous ground beetles in Agriculture. *Agricultural Zoology Review* 2:237-278.

Mac Arthur, R.H. 1965. Partterns of species diversity. – *Biological Reviews* 510-533.

Méndez Del Villar, M. 2003. Monthly report of the word market of rice. October 2003. InterArroz. Arroz Brasileiro. Online publication.

Mühlenberg, M. 1993. Freilandökologie. 3. Ed., Quelle & Meyer Verlag. Heidelberg. 512 p.

Nwilene, F. E. 1999. Current status and management of insect vectors of rice yellow mottle virus (RYMV) in Africa. *Insect Science and Its Application* 19(2/3):179-185.

.Nyffeler, M., and Benz, G. 1988. Feeding ecology and predatory importance of wolf spiders(pardosa spp.) (araneae, lycosidae) in winter wheat fields. *J. Appl. Ent.* 106:123.134.

Ooi, P. A. C. and Shepard, B.M. 1994. Predators and parasitoids of rice insect pests. In: Heinrichs, E. A.(Eds.), pp. 585-612. Biology and management of rice insects. John Wiley & Sons, New York.

Poole, R. W. 1974. An introduction to Quantitative Ecology. – McGraw-Hill Book, company, New York, Toronto, 531pp.

Puthz, V. 1971: Revision der afrikanischen Steninenfauna und allgemeines über die Gattung *Stenus* Latreille (Coleoptera: Staphylinidae) (56. Beitrag zur Kentnis der Steninen). *Annales Musée Royal de l'Afrique Centrale, Tervuren, Série in-8° Sciences Zoologiques* 187 (4): 1-376.

Reckhaus P.M. and Andriamasintseheno, H.F. 1997. Rice yellow mottle virus in Madagascar and its epidemiology in the northwest of the Island. *Z. Pflanzenkr. Pflanzenschutz*. 104:289-295.

Riechert, S.E. and Bishop, L. 1990. Prey control by an assemblage of generalist predators in a garten test system. *Ecology* 71: 1441-1450.

Riechert, S.E. and Lockley, T. 1984. Spiders as biological control agents. *Annal Review of Entomology* 29:299.320.

Risch, S.J., Andow, D.A. and Altieri, M.A. 1983. Agroecosystems diversity and pest control: data, tentative conclusions and new research directions. *Environmental Entomology* 12:625-629.

Spiller, D.A. 1992. Numerical response to prey abundance by Zygiella x-notata. *Journal of Arachnology* 20:179–188.

Thiele, H.U. 1977. Carabid beetles in their environments. Springer-Verlag, Berlin, Heidelberg, New York. 369 p.

Traoré, O., Pinel, A., Fargette, D. and Konaté, G. 2001. First report and characterization of Rice yellow mottle virus in Central Africa. *Plant Disease* 85:920.

Vandermeer, J. 1981. Elementary Mathematical Ecology. John Wiley & Sons, USA.

Weber, G. and Parada, O. 1994. Development of an integrated pest management system for rice in Latin America. In: Heinrichs EA, editor. Biology and management of rice insects. New Delhi: Wiley Eastern. pp. 733-748.

Woin, N. 1999. Ecological studies on aphids and their predators with special reference to IPM approach in Rice (Cameroon) and Barley (Germany). Doctoral thesis. Martin Luther University Halle-Wittenberg, Germany. 119 p.

Yano, K., Ishitani, M. and Yahiro, K. 1995. Ground beetles (Coleoptera) recorded from paddy fields of the world: A review. *Japanese Journal System of Entomology* 1(1): 105-112.