CHAPTER 22

Maize Crop Intensification and Borer Attacks in The Ivory Coast: Insect Populations

Pascal Moyal

ABSTRACT

Agronomic experiments comparing various modalities of maize cultivation (pure vs intercropped with peanut, at high or low density and fertilization level), with good or bad weeding, and with or without protection against borers were conducted in the Ivory Coast. The main borer was *Eldana saccharina* Walker (Lepidoptera:Pyralidae), which attacks both stem and cob; other important borers were *Busseola fusca* Fuller (Lepidoptera:Noctuidae) found mainly in stem and the cob borer *Mussidia nigrivenella* Ragonot (Lepidoptera:Pyralidae). The borer number per stem or cob appeared to be higher in low density crops than in the high ones: no difference was noticeable between pure crops and intercrops or between well- or badly weeded plots. The insecticide was efficient against stem borers but not against *M. nigrivenella*. No interaction between various factors was observed. The borer density per maize area unit was the same for any cultivation modality or weeding frequency. These results suggest that borer attacks, mainly by *E. saccharina*, are little influenced by environment.

0-87371-919-0/93/$0.00 + $.50

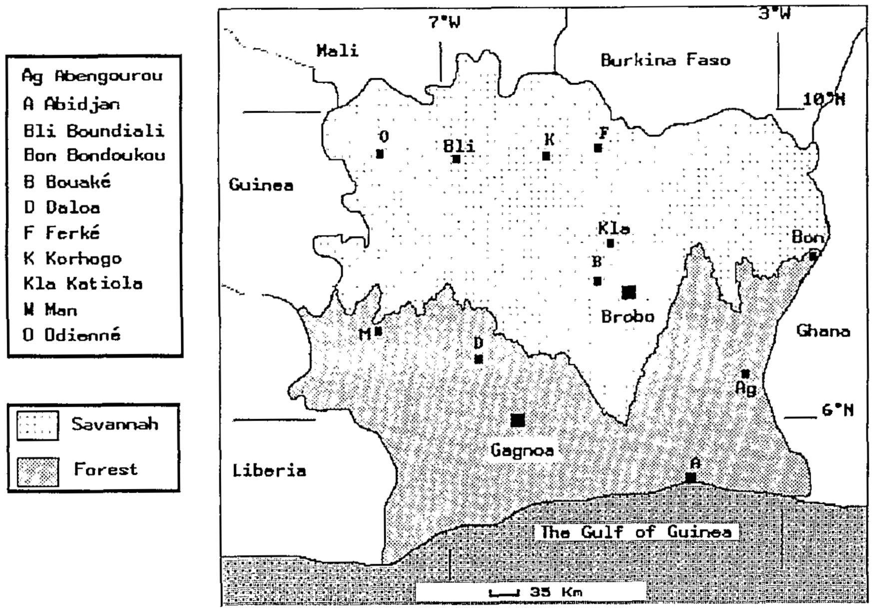

Figure 1. Map of The Ivory Coast with the experiment localization.

I. INTRODUCTION

Maize is the main cereal crop grown in the Ivory Coast, together with rice. It is mainly manually grown and receives few inputs. For instance, 64.0% of the surfaces supervised by the organization in charge of the development of agriculture of the savannah area (CIDT, 1988) are manually grown; 17.3% receive N-P-K fertilizers, 15.1% urea, and 13.4% herbicide (CIDT, 1988). Weedings are more or less frequent, depending on man-power availabilities (Le Roy, 1983). Sowing density is generally low, varying, for instance, from 10,000 to 15,000 plants per hectare in the western central region (SATMACI, 1986). The crop may be pure or mixed with vegetable or perennial crops (Gigou, 1987; Biarnes and Colin, 1987; Chaleard, 1988). In some regions, crops are mainly pure, as, for example, around Katiola (Gigou, 1987) (Figure 1); whereas in the central west (Gagnoa and Daloa regions) and north (around Boundiali), 90% of maize surfaces are intercropped (Le Roy, 1983; SATMACI, 1986). The average yield is about 700 to 900 kg/ha (Ministère de l'Agriculture, 1986).

Borers are, together with jassid vectors of the streak virus, the main cause of crop losses (Moyal, 1988a). At present, six borers have been described; and their biology, morphology, and ecology have been studied for several years (Pollet et al., 1978; Dabire, 1980; Tran, 1981; Odjo, 1984; Moyal, 1988b; Moyal and Tran, 1991a and 1991b). Two of these borers attack only cob: *Mussidia nigrivenella* Ragonot (Lepidoptera:Pyralidae) and *Cryptophlebia leucotreta*

(Meyrick) (Lepidoptera:Tortricidae). The other four are mainly stem borers, which may also attack the cob: *Eldana saccharina* Walker (Lepidoptera: Pyralidae), *Sesamia calamistis* Hampson, *S. botanephaga* Tams and Bowden, and *Busseola fusca* (Fuller) (Lepidoptera:Noctuidae). The aim of this chapter is to compare the attacks of these borers on maize crops at various levels of intensification, in order to examine the entomological risks to the different crop systems.

II. MATERIAL AND METHODS

Two tests were conducted: the first one at Brobo, in the savannah area and the second at Gagnoa, in the forest area (Figure 1). The experimental design was a three-factor and four-block split plot; the first factor compared pure maize crops to maize intercropped with peanut at various levels of intensification. For the first level, where maize and peanut were intercropped at a low level of density and fertilization a plot was 25 m long and 4 m wide with three central rows of maize and two rows of peanut on each side of the maize. Maize was sown every 0.4 m along the row, with 0.80 m between the rows; and peanut was sown every 0.60 m along the row, with 0.30 m between rows. Fertilizing was done with 150 kg/ha N-P-K (10-18-18), and (only in maize) 37.5 kg/ha urea at the beginning of male flowering. The second level was the same intercrop with the same space between rows, but with double density along the rows and double fertilizing. The third level was pure maize in the same conditions as the maize of the first level, and the fourth level was pure maize in the same conditions as the maize of the second level. Each plot of pure maize had five rows. The second factor was weeding frequency: the first level was well weeded with herbicide treatment at sowing (Atrazine-Metholachlor on pure maize, Pendimethaline on intercrop), followed with weeding as often as needed to keep a clean crop; the second level was badly weeded with only two weedings, the first 30 days after emergence (DAE) and the second 60 DAE. The third factor was protection against borers. The first level received no protection; the second level received two insecticide treatments (Deltamethrin, 15 g active ingredient [a.i.] per hectare): 20 and 40 DAE in Gagnoa, and three treatments 20, 40, and 70 DAE in Brobo. The maize variety was Composite Jaune de Bouaké, (CJB) a composite whose growing season is about 100 days and has a maximum yield of 6200 kg/ha (Idessa, 1982). The peanut variety was TE3.

In Gagnoa, sampling began 40 DAE and was then conducted every 20 days; whereas in Brobo, samples were made 40, 60, and 100 DAE. Maize plants were sampled at random on the two rows on each side of the central row of each plot. The central row gave yield estimation: five plants were sampled by plot 40 and 60 DAE and then 10. Stems and cobs were dissected and insects counted.

Statistical analysis consisted of analyses of variance with various classical transformations of variables (log (x + 1), $\sqrt{(x + 0.5)}$, arcsin$\sqrt{x}$ for percentages) (Dagnelie, 1965a and 1980) or rank transformations (Conover and Iman,

Table 1. *Eldana saccharina* **Number in 10 Stems in Brobo at 100 DAE**

Factor	Level				Observations
Crop	MPLD 20.6	MPHD 20.9	MLD 20.3	MHD 22.5	NS[a]
Weeding	Well weeded 23.0		Badly weeded 19.2		NS
Insecticide	Non-treated (NT) 27.6 a		Treated (T) 14.6 b		HS[b]
Interaction crop Insecticide	MPLD-NT 27.5 a	MPHD-NT 31.1 a	MLD-NT 29.5 a	MHD-NT 22.1 a	S[c]
	MPLD-T 13.8 b	MPHD-T 10.8 b	MLD-T 11.0 b	MHD-T 22.9 a	

Note: MPLD: maize-peanut low density; MPHD: maize-peanut high density; MLD: maize low density; MHD: maize high density. Values with same letter have no statistical difference at $p = 0.05$.

[a] NS: not significant at $p = 0.05$.
[b] HS: significant at $p = 0.01$.
[c] S: significant at $p = 0.05$.

1981). Combined analyses of several data were conducted using STAT-ITCF (1987) software (Philippeau, 1982). Newman-Keul's tests were used to compare means (Dagnelie, 1965b and 1980). Generally, no interaction was significant and only the factor results are indicated.

III. RESULTS

A. Stem Attacks

1. Brobo

Attacks were very low 40 and 60 DAE; population density in insecticide-unprotected plots was 0.6 insects per 10 stems 40 DAE, and 1.0 per 10 stems 60 DAE. The pests mainly belonged to *S. calamistis* (86% 40 DAE, 77% 60 DAE). These low populations are insufficient for statistical analyses.

Attacks increased at the end of the growing season with mainly *E. saccharina* 100 DAE (27.6 insects per 10 stems, i.e., 97% of pests found) and some *S. calamistis* (3% of borers). Statistical analysis does not indicate any effect of the crop or weeding (Table 1). The effect of the insecticide treatment, on the other hand, is highly significant. The interaction between crop and insecticide is significant, for the insecticide is no longer efficient 100 DAE in the high density pure maize crop (no difference between *Eldana* populations of plots with or without insecticide protection), when it is still efficient in the other crops (Table 1).

2. Gagnoa

Rank transformations were conducted before each analysis. Pests found in stems 40 DAE belonged only to *B. fusca*. Analysis shows an insecticide effect

Table 2. Insect Number in 10 Stems in Gagnoa, 40 DAE

Factor	Level				Observations
Crop	MPLD 1.9	MPHD 1.6	MLD 4.9	MHD 5.6	NS[a]
Weeding	Well weeded 4.9		Badly weeded 2.1		NS
Insecticide	Non-treated 5.2		Treated 1.8		HS[b]

Note: MPLD: maize-peanut low density; MPHD: maize-peanut high density; MLD: maize low density; MHD: maize high density.

[a] NS: not significant at $p = 0.05$.
[b] HS: significant at $p = 0.01$.

Table 3. Insect Number in 10 Stems in Gagnoa, 60 DAE

Factor	Level				Observations
Crop	MPLD 2.8	MPHD 5.9	MLD 10.8	MHD 6.6	NS[a]
Weeding	Well weeded 6.7		Badly weeded 6.3		NS
Insecticide	Non-treated 11.1		Treated 1.9		HS[b]

Note: MPLD: maize-peanut low density; MPHD: maize-peanut high density; MLD: maize low density; MHD: maize high density.

[a] NS: not significant at $p = 0.05$.
[b] HS: significant at $p = 0.01$.

but no factor effect (Table 2). *B. fusca* was still the main borer 60 DAE (86% of insects), and *E. saccharina* attacks were beginning (13% of insects). Here, too, the insecticide effect only is significant (Table 3). Stem attacks increased slowly from 5 borers per 10 stems in the non-treated plots 40 DAE to 11 borers per 10 stems 60 DAE. Attacks 80 DAE were mainly due to *E. saccharina* (90% of insects) (Table 4). The analysis shows stronger attacks on the pure maize at low-density fertilizing, as well as an insecticide treatment effect. *E. saccharina* represented 94% of the stem borers 100 DAE. This sample analysis was conducted only from the first three blocks because of data missing from the fourth block. The insecticide effect only is significant (Table 5). The trend toward a stronger attack per stem in the low-density maize seems, however, to be confirmed; combined analysis of the samples at 80 and 100 DAE (Table 6) actually confirms this point. At each date, attacks were slightly higher in the well-weeded plots than in the badly weeded ones: this difference is, however, never significant, and the combined analysis of the four sets of data indicates no significant difference.

Table 4. *Eldana saccharina* Number in 10 Stems in Gagnoa, 80 DAE

Factor	Level				Observations
Crop	MPLD	MPHD	MLD	MHD	S[a]
	8.5 b	8.3 b	20.5 a	9.4 b	
Weeding	Well weeded		Badly weeded		NS[b]
	13.0		10.3		
Insecticide	Non-treated		Treated		HS[c]
	18.6 a		4.8 b		

Note: MPLD: maize-peanut low density; MPHD: maize-peanut high density; MLD: maize low density; MHD: maize high density. Values with same letter have no statistical difference at $p = 0.05$.

[a] S: significant at $p = 0.05$.
[b] NS: not significant at $p = 0.05$.
[c] HS: significant at $p = 0.01$.

Table 5. Eldana saccharina Number in 10 Stems in Gagnoa, 100 DAE

Factor	Level				Observations
Crop	MPLD	MPHD	MLD	MHD	NS[a]
	48.4	27.7	39.4	24.7	
Weeding	Well weeded		Badly weeded		NS
	38.6		31.5		
Insecticide	Non-treated		Treated		HS[b]
	43.0		27.1		

Note: MPLD: maize-peanut low density; MPHD: maize-peanut high density; MLD: maize low density; MHD: maize high density.

[a] NS: not significant at $p = 0.05$.
[b] HS: significant at $p = 0.01$.

Table 6. *Eldana saccharina* Number in 10 Stems in Gagnoa, Combined Analysis of 80 and 100 DAE

Factor	Level				Observations
Date	80 DAE		100 DAE		NS[a] (rank transf)
	12.9		35.0		
Crop	MPLD	MPHD	MLD	MHD	HS[b]
	28.2 a	17.6 b	32.4 a	17.6 b	
Weeding	Well weeded		Badly weeded		NS
	27.2		20.8		
Insecticide	Non-treated		Treated		HS
	31.5 a		16.4 b		

Note: MPLD: maize-peanut low density; MPHD: maize-peanut high density; MLD: maize low density; MHD: maize high density.

[a] NS: not significant at $p = 0.05$.
[b] HS: significant at $p = 0.01$.

Table 7. Cob Borer Number in 10 Stems in Brobo

Factor	Level				Observations
Crop	MPLD	MPHD	MLD	MHD	
M.n	10.8	8.9	13.1	7.6	NS[a]
E.s	10.6	6.2	9.9	6.1	NS
Tot. insect	21.6 a	15.3 b	24.0 a	14.1 b	S[b]
Weeding	Well weeded		Badly weeded		
M.n	9.0		9.6		NS
E.s	8.3		8.3		NS
Tot. insect	17.8		18.3		NS
Insecticide	Non-treated		Treated		
M.n	8.9		9.7		NS
E.s	10.8 a		5.8 b		S
Tot. insect	20.2 a		15.9 b		S

Note: MPLD: maize-peanut low density; MPHD: maize-peanut high density; MLD: maize low density; MHD: maize high density; *M.n: M. nigrivenella; E.s: E. saccharina*. Values with the same letter have no statistical difference at $p = 0.05$.

[a] NS: not significant at $p = 0.05$.
[b] HS: significant at $p = 0.05$.

B. Cob Attacks

1. Brobo

Cob attacks were by *E. saccharina* and *M. nigrivenella*, the densities of which were about 1.0 insect per cob (Table 7). Insecticide treatments had no effect against *M. nigrivenella* but were significantly efficient against *E. saccharina*. There is no significant difference when each species is considered alone, but the study of the whole cob borers shows attacks per stem significantly higher in the low-density plots than in the high ones.

2. Gagnoa

Attacks were mainly by *M. nigrivenella*, which represented 86% of the borers. No significant difference was noticed (Table 8).

IV. DISCUSSION

Peasant crops in the Ivory Coast are typical of those found in tropical regions which receive few inputs and where there is often not much weeding (Young, 1981). Young (1981) indicates that in many instances, farmers have evolved a system of cultivation that tends to limit losses due to both pests and diseases; a careful look at these situations must therefore be taken before recommending changes, the effects of large-scale new practices being largely unforseeable (Chalfant and Musick, 1981).

This study enabled us to observe the effect of the introduction of various changes of peasant crop systems on borer populations. Three borer species were important: *E. saccharina*, which is both stem and cob borer, *B. fusca*, which

Table 8. Cob Borer Number in 10 Stems in Gagnoa

Factor	Level				Observations
Crop	MPLD	MPHD	MLD	MHD	
M.n	15.0	16.9	40.9	32.9	NS[a]
Tot. insect	21.3	20.2	43.4	35.6	NS
Weeding	Well weeded		Badly weeded		
M.n	26.4		26.5		NS
Tot. insect	30.3		30.0		NS
Insecticide	Non-treated		Treated		
M.n	26.9		26.0		NS
Tot. insect	31.2		29.0		NS

Note: MPLD: maize-peanut low density; MPHD: maize-peanut high density; MLD: maize low density; MHD: maize high density; *M.n*: *M. nigrivenella.*

[a] NS: not significant at $p = 0.05$.

attacks the stem at the beginning of the cycle; and *M. nigrivenella*, which is a cob borer only. The use of insecticide treatments with Deltamethrin 15 g a.i. per hectare reduced stem borer populations, but had no effect on *M. nigrivenella*. These results confirm previous studies (Moyal, 1988b and 1989). This population reduction lasted until 80 DAE when treatments stopped 40 DAE, as in Gagnoa.

Weeds have variable effects on pests. Parfait and Jarry (1987), for instance, indicate strong attack increases of the bruchid *Acanthoscelides obtectus* on beans in weedy fields. The same is observed with *Mythimna separata* (cosmopolitan armyworm) on maize (Hill and Allan, 1986). On the other hand, many examples of beneficial interactions between crop-weeds-pests are mentioned by Altieri et al. (1977) and Baliddawa (1985), among which are the cases of *Prorachia diara*, *Spodoptera frugiperda*, and *Ostrinia nubilalis* (Hübner) on maize. Perrin and Phillips (1978) indicate trials of undersowing *Brassica* with procumbent clover, which has the same beneficial effects as weeds against aphids and root flies and is a valuable green manure crop that avoids crop losses due to weeds.

In the case of maize borers in the Ivory Coast, no weed effect was observed. Attacks were slightly higher in the well-weeded plots than in the badly weeded ones, but differences are not significant. The low level of early growing season populations possibly concealed the weed effect, which is mainly noticeable when maize size is small. Thus in Brobo, where weed density was high (Moyal, 1993), the early growing season attacks were very low; in Gagnoa, where these attacks were rather high, weed density was low. These results may, however, be considered together with those of Van Huis (1981), who noticed no weed effect on populations of two other maize pests in Nicaragua: *Spodoptera frugiperda* (J. E. Smith) and *Diatrea lineolata* (Wlk).

The comparisons of attacks between pure crops and intercrops also give various results. In most cases reviewed by Parfait and Jarry (1987), pest populations are lower in intercrops than in pure crops. This is also the case for 53% of the phytophagous species in a study of 150 agroecosystems (Risch et al., 1983). There are cases, however, where no difference appears between both crop systems or where attacks are higher in intercrops than in pure crops.

In the precise case of maize pests, *S. frugiperda* populations are reduced in maize-*Phaseolus* intercrops in the United States (Chalfant and Musick, 1981), where they are 20–30% lower than in pure maize crops. The same percentages are mentioned by Altieri et al. (1978). *Ostrinia furnacalis* prefers to oviposit on maize plants with a brownish background rather than those with a green one (Raros, 1973); this explains reduced attacks in maize-peanut intercrops that, moreover, provide a favorable habitat for some predatory spiders (*Lycosa* sp.) of this species (IRRI, 1974). Harwood (1979) indicates that *O. furnacalis* populations are reduced 10-fold in maize-peanut intercrops. Lambert et al. (1987) also noticed a reduction of *O. nubilalis* populations in maize-clover intercrops, particularly when clover is sown soon after maize (less than 10 days). Examples of *Heliothis zea* Boddie and *Chilo partellus* swinh. are also mentioned by Baliddawa (1985). In Nigeria, Adesiyun (1983) remarks that damages by *Busseola fusca* on leaves are lower on sorghum intercropped with millet than on pure sorghum. No significant difference in number of eggs and larvae, however, appears in the case of maize-millet intercrop compared with pure maize. Sometimes the results are less obvious. Thus, Van Huis (1981) finds reductions of *D. lineolata* populations in an intercrop with a local maize variety, but not with a hybrid one. Sometimes the attacks are higher in the intercrop than in the pure crop, as is the case of mites on maize interplanted with legumes in the United States (Chalfant and Musick, 1981).

In the Ivory Coast, no difference between borer populations in pure maize or maize intercropped with peanut was observed. The effect of plant density was only noticeable: it was particularly obvious in Gagnoa for *Eldana saccharina*, whose density per plant was higher in the low stand plots than in the high one. In Brobo, the same situation was noticeable only for the cob borers. The behavior of *E. saccharina* appeared to be rather different in both localities since only 8% of the larvae of this species is found in the cob in Gagnoa vs 28% in Brobo. *E. saccharina*, which can oviposit on the stem as well as on the cob (Moyal, 1988b), seems then to lay more eggs on the cob in Brobo, which possibly indicates important genetic differences between populations of both localities. The study of the population density per maize area unit, however, indicates no difference between the various crops (Table 9). If the results of both localities are considered together, densities per land area unit of the intercropped plots equals 68% of those of pure maize, which is then similar to ratio of the maize area of both crops.

These results indicate that no particular attraction to the maize plots seems to occur at long distance. Everything happens as if only the insects flying above the maize were attracted: the insect number will then be similar for a comparable area of maize and the density per plant increased in low stands. Moreover, the insects flying above the peanut crop do not seem to be attracted by the neighboring maize since there would then be the same density per land area, and there is neither a repellent effect of peanut on borers nor any effect of peanut on borer parasitism or predation. The results are, however, variable and only the important

Table 9. *Eldana saccharina* Number per Maize Hectare (A) and Land Hectare (B) at 100 DAE

Place	Crop				Observations
	MPLD	MPHD	MLD	MHD	
Brobo					
A	84,519	180,013	102,494	128,588	NS[a]
B	50,711	108,008	102,494	128,588	NS
	MPLD	MPHD	MLD	MHD	
Gagnoa					
A	179,844	156,711	139,240	158,042	NS
B	107,906	94,063	139,240	158,042	NS

Note: MPLD: maize-peanut low density; MPHD: maize-peanut high density; MLD: maize low density; MHD: maize high density.

[a] NS: not significant at $p = 0.05$.

differences emerge, particularly because the crop was chosen as the first factor of the experimental design with few replicates. This choice was needed to get large enough (400 m^2) plots of the same crop. The agronomic experimental design may not be most suitable for such a study, as is suggested by Parfait and Jarry (1987), at least in order to explain the observed phenomena. The plot size should also be studied, as noticed by Van Huis (1981), who also chose 400 m^2 plots.

Population densities of the other borers, *Busseola fusca* and *Mussidia nigrivenella*, were rather low; and no crop effect was established for these species.

No difference between intercrop and pure crop is noticeable at the end of these first experiments. As pointed out by Helenius (1989), crop diversification by the use of intercropping cannot be a general strategy, and each case has to be studied in its particular context. Moreover, the conclusions drawn from this experiment are of value only in the frame of experimental design used. As Harwood noticed (1979), intercropping is a complex problem and no generalization can be made. Other intercropping patterns have to be tested; and the agronomic experimental design has to be compared with others first, to estimate suitable plot size, and second, to validate the results on a large scale. Hasse (1981) indicates, for instance, that behavior of *O. furnacalis* females is modified by the peanut-maize intercrop only in the case of little experimental plots adjacent to pure maize plots; and if intercrops alone were available, oviposition would be as important as on pure maize.

Within frame of the experimental design used, it can be concluded from the first results, that evolution from a peasant type of crop to a more intensified one does not lead to attack increase per maize area unit, and results in reduction of population density per plant.

ACKNOWLEDGMENTS

We are grateful to M. Peruzzi, in charge of the Brobo Roussel Uclaf experimental station, who made possible the realization of our trial at this station. This work was supported by a grant from the Ministère Français de la Recherche et de la Technologie.

REFERENCES

Adesiyun, A. A. 1983. Some effects of intercropping of sorghum, millet and maize on infestation by lepidopterous stalk-borers, particularly *Busseola fusca*. *Insect. Sci. Appl.* 4(4):387–391.

Altieri, M. A., Schoonhoven, A. Van, and Doll, J. D. 1977. The ecological role of weeds in insect pest management systems: a review illustrated by bean *(Phaseolus vulgaris)* cropping systems. *Pans* 23(2):195–205.

Altieri, M. A., Francis, C. A., Schoonhoven, A. Van, and Doll, J. D. 1978. A review of insect prevalence in maize (*Zea mais* L.) and bean (*Phaseolus vulgaris* L.) polycultural systems. *Field Crop Res.* 1:33–49.

Baliddawa, C. W. 1985. Plant species diversity and crop pest control. An analytical review. *Insect Sci. Appl.* 6(4):479–487.

Biarnes, A. and Colin, J. P. 1987. Production vivrière et accès à la terre dans un village de Basse Côte d'Ivoire. *Cah. Sci. Hum.* 23(3–4):455–470.

Chaleard, J. L. 1988. La place des cultures vivrières dan les systèmes de production en agriculture de plantation: Le cas du département d'Agboville (Côte d'Ivoire). *Cah. Sci. Hum.* 24(1):35–49.

Chalfant, R. B. and Musick, G. J. 1981. Influence of habitat modification and multiple cropping on insect populations in vegetable and row crops in eastern United States, in Proceedings of Symposia, 9th International Congress of Plant Protection, T. Kommedahl (Ed.), August 5–11, 1979, University of Minnesota, Minneapolis, 57–60.

CIDT (Compagnie Ivoirienne pour le Développement du Textile). 1988. Rapport annuel (synthèse), Campagne 1987–88, Bouaké, Ivory Coast, Unpublished, 92 pp.

Conover, W. J. and Iman, R. L. 1981. Rank transformations as a bridge between parametric and non-parametric statistics. *Am. Stat.* 35(3):124–129.

Dabire, L. 1980. Biologie et écologie d'*Eldana saccharina* Walker (Lepidoptera, Pyralidae; Galleriinae) foreur du maïs en Côte d'Ivoire et Inventaire des autres Lépidoptères foreurs du maïs. Thèse de docteur de troisième cycle. Université Pierre et Marie Curie, Paris, Unpublished, 196 pp.

Dagnelie, P. 1965a. A propos des transformations de variables. *Biom. Praxim.* 6:59–78.

Dagnelie, P. 1965b. A propos de quelques méthodes de comparaisons multiples de moyennes. *Biom. Praxim.* 6:115–124.

Dagnelie, P. 1980. *Théories et Méthodes Statistiques, Vol. 2*, Presses Agronomiques de Gembloux, 463 pp.

Gigou, J. 1987. L'adaptation des cultures dans le centre de la Côte d'Ivoire. *Agron. Trop.* 42(1):1–12.

Harwood, R. R. 1979. *Small Farm Development. Understanding and Improving Farming Systems in the Humid Tropics.* Westview Press, Boulder, CO, 160 pp.

Hasse, V. 1981. The influence of vegetational diversity on host-finding and larval survival of Asian corn borer *Ostrinia furnacalis* Guénée (Lepidoptera, Pyralidae). PhD Thesis, Justus Liebig University, Giessen, 115 pp.

Helenius, J. 1989. The influence of mixed intercropping of oats with field beans on the abundance and spatial distribution of cereal aphids (Homoptera, Aphididae). *Agric. Ecosyst. Environ.* 25:53–73.

Hill, M. G. and Allan, D. J. 1986. The effects of weeds on armyworm in maize. Proceedings 39th New Zealand Weed and Pest Control Conference. New Zealand Weed and Pest Control Society, 260–263.

Huis, A. Van. 1981. Integrated pest management in small farmer's maize crop in Nicaragua. *Med. Landbouwhogesch. Wagen.* 81(6):222.

IDESSA (Institut des savanes). 1982. Variétés de maïs recommandées en Côte d'Ivoire. Ministère de la Recherche Scientifique de Côte d'Ivoire, Unpublished, 11 pp.

IRRI (International Rice Research Institute). 1974. Annual Report for 1973, Los Banos, Philippines, 266 pp.

Lambert, J. D. H., Arnason, J. T., Serratos, A., Philogene, B. J. R., and Faris, M. A. 1987. Role of intercropped red clover in inhibiting European corn borer (Lepidoptera, Pyralidae) damage to corn in eastern Ontario. *J. Econ. Entomol.* 80(6):1192–1196.

Le Roy, X. 1983. L'introduction des cultures de rapport dans l'agriculture vivrière sénoufo. Le cas de Karakpo. Travaux et documents de l'ORSTOM, 156, Paris, 192 pp.

Ministere De L'Agriculture. 1986. Annuaire de statistiques agricoles. Abidjan, Ivory Coast, 180 pp.

Moyal, P. 1988a. Crop losses due to insects in savannah area of Ivory Coast: a review. *Trop. Pest Manage.* 34(4):455–459.

Moyal, P. 1988b. Les foreurs du maïs en zone des savanes en Côte d'Ivoire. Données morphologiques, biologiques, écologiques. Essais de lutte et relation plante-insecte. ORSTOM, Collection Etudes et Thèses, Paris, 368 pp.

Moyal, P. 1989. Essais de lutte chimique contre les foreurs du maïs en zone des savanes de Côte d'Ivoire. *Agron. Trop.* 44(4):333–341.

Moyal, P. 1993. Maize crop intensification and borer attacks in The Ivory Coast. Yields. *Soil Biota, Nutrient Cycling, and Farming Systems*, CRC Press, Boca Raton, FL, chap. 20.

Moyal, P. and Tran, M. 1990a. *Mussidia nigrivenella* Ragonot (Lepidoptera, Pyralidae), cob-borer of maize in Ivory Coast. I. Morphological and biological data. 2nd International Conference on Tropical Entomology, July 31, to August 4, 1989, Nairobi, Kenya, 14 pp., *Insect Sci. appl.* 12(1/2/3):209–219.

Moyal, P and Tran, M. 1991b. *Mussidia nigrivenella* Ragonot (Lepidoptera, Pyralidae), cob-borer of maize in Ivory Coast. II. Ecological data. 2nd International Conference on Tropical Entomology. July 31, to August 7, 1989, Nairobi, Kenya, 16 pp., *Insect Sci. appl.* 12(1/2/3):215–223.

Qdjo, T. A. 1984. Contribution à l'étude de la Biologie et l'Ecologie de *Sesamia calamistis* Hampson (Lepidoptera, Noctuidae) en Côte d'Ivoire centrale. Thèse de doctorat de troisième cycle, Université de Paris-sud, Unpublished, 109 pp.

Parfait, G. and Jarry, M. 1987. Diversité végétale et impact des insectes phytophages: une revue bibliographique des méthodes appliquées au cas des cultures associées. *Acta Oecol. Oecol. Gener.* 8(3):365–378.

Perrin, R. M. and Phillips, M. C. 1978. Some effects of mixed cropping on population dynamics of insect pests. *Ent. Exp. Appl.* 24:385–393.

Philippeau, G. 1982. Théorie des plans d'expérience. *Application à l'agronomie.* ITCF, Paris, 205 pp.

Pollet, A., Roon, N. Van, and Mauritz, R. 1978. Les ravageurs du maïs en Côte d'Ivoire. Données qualitatives et quantitatives pour la basse Côte. *Cah. O.R.S.T.O.M., Ser. Biol.*, 13(1):71–85.

Raros, R. S. 1973. Prospects and problems of integrated pest control in multiple cropping. Saturday seminar. International Rice Research Institute, Los Banos, Philippines, 20 pp.

Risch, S. J., Andow, D., and Altieri, M. A. 1983. Agroecosystem diversity and pest control: data, tentative conclusions and new research directions. *Environ. Entomol.* 12:625–629.

SATMACI (Société d'Assistance Technique pour la Modernisation de l'Agriculture de la Côte d'Ivoire). 1986. Projet Agricole Centre-Ouest. Programme Maïs. Daloa, Ivory Coast, Unpublished, 28 pp.

STAT-ITCF. 1987. Manuel d'utilisation. ITCF, Paris, 55 pp.

Tran, M. 1981. Reconnaissance des principaux foreurs des tiges du riz, du maïs et de la canne à sucre en Côte d'Ivoire. Initiations-documentations techniques, 48, ORSTOM, Paris, 23 pp.

Young, W. R. 1981. Integrated control of corn and sorghum insect pests in the tropics and subtropics, in Proceedings of Symposia, 9th International Congress of Plant Protection, T. Kommedahl (Ed.), August 5–11, 1979, University of Minnesota, Minneapolis, 428–432.