CHAPTER 23

Maize Crop Intensification and Borer Attacks in The Ivory Coast: Yields

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ABSTRACT

The maize yields of two agronomic experiments conducted in The Ivory Coast are analyzed. These experiments compared pure maize or maize intercropped with peanut at high or low density and fertilization level, with good or bad weeding, and with or without insecticide protection against borers. Insecticide protection gave a significant yield increase of 22–36% when compared to the control. Good weeding resulted in a yield increase of 11 and 28% when compared with late weeding. The comparison between pure crops and intercrops at various levels of density-fertilization gave different results in each locality. In one case, there was no difference between these modalities; in the other instance, yields increased with the fertilizer level. The study of rainfall and of its influence on the yield components (plant sterility, grain number per cob-carrying plant, and average weight of grain) enabled us to explain this difference. No interaction between the various factors was noticed. It is concluded that when there is some hydric stress risk, cultivation at low density and fertilization should be preferred whereas in other cases, high densities and fertilizations would give better results. Use of herbicides and insecticides gives good profits when rain conditions are correct, but is of less interest when low-density fertilizing crops have to be recommended because of water stress risk.

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

Table 1. Maize Yields (kg/ha) in Brobo

Factor	Level				Observations
Crop	MPLD 1762 b	MPHD 2954 a	MLD 2078 b	MHD 3188 a	HS[a]
Weeding	Well weeded 2785 a		Badly weeded 2206 b		HS[a]
Insecticide	Non-treated 2272 b		Treated 2720 a		HS[a]

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

[a] HS: significant at $p = 0.01$.

I. INTRODUCTION

Maize grown in The Ivory Coast is mainly attacked by two types of pests: borers, and jassids, which are vectors of the maize streak virus. Some data on crop losses due to these pests have been published (Moyal, 1988a and 1988b). They are, however, limited to rather intensively grown crops. No study has yet been conducted on little intensified crops or intercrops, and this work aims to fill in this gap. In Chapter 22 (Moyal, 1993) it was shown that in the experimental pattern used, attacks by the main borers — *Eldana saccharina* Walker and *Mussidia nigrivenella* Ragonot (Lepidoptera:Pyralidae) — were similar per maize unit area whatever the type of crop, pure or intercropped. This chapter studies the maize yields in the various crop patterns.

II. MATERIAL AND METHODS

The main point was presented in Chapter 22 (Moyal, 1993). Yields were estimated from the production of the central 20 m of the central maize row in each plot. The indicated yield is the ratio of production to maize area and not of production to land area. The cob-carrying plant percentage was measured on the central rows, whereas the number of grains per cob-carrying plant and the average weight of grain was calculated from the 10 plants sampled on the two rows on each side of the central rows, which were also used to estimate borer populations. The effect of borers on yield components was estimated by comparison of plots with or without insecticide protection. The grain humidity was about 17% high at weighing. Because generally no interaction was significant, only the factor results are indicated.

III. RESULTS

A. Yields

In Brobo, all the factors show significant differences (Table 1): the insecticide treatment provided a yield gain of 450 kg/ha, i.e., 20% increase in comparison with non-treated crops. Good weeding enabled a yield gain of 600 kg/ha. High

Table 2. Percentage of Cob-Carrying Plants in Brobo

Factor	Level				Observations
Crop	MPLD 82.4	MPHD 77.8	MLD 82.0	MHD 78.6	NS[a]
Weeding	Well weeded 86.3 a		Badly weeded 76.8 b		HS[b]
Insecticide	Non-treated 78.8 b		Treated 84.2 a		HS[b]

Note: MPLD: maize-peanut low density; MPHD: maize-peanut high density; MLD: maize low density; MHD: maize high density. 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 $p = 0.01$.

Table 3. Grain Number per Cob-Carrying Plant in Brobo

Factor	Level				Observations
Crop	MPLD 430	MPHD 439	MLD 448	MHD 434	NS[a]
Weeding	Well-weeded 465 a		Badly weeded 410 b		HS[b]
Insecticide	Non-treated 424		Treated 451		NS[a]

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 $p = 0.01$.

intensified crops gave higher yields than low intensified crops, and there was no difference between pure crops and intercrops.

In Gagnoa (Table 5), two insecticide treatments resulted in 650 kg/ha yield gain, and good control of low density weeds gave 230 kg/ha yield gain. There was no significant difference between the various crops. No interaction was noticed.

The yield gain due to insecticide or weeding was the same for each of the other two factors (Table 9). Although there was a trend toward a stronger effect of the insecticide treatment in the high-density fertilizing plots than in the low one, no significant difference was noticed.

B. Yield Components

The cob-carrying plant percentage (Tables 2 and 6) was always higher in the insecticide protected plots than in the control plots. The insects had no effect on the grain number per cob-carrying plant (Tables 3 and 7). In Brobo, where a late insecticide treatment was conducted 70 days after emergence (DAE), grains were heavier in treated plots than in the untreated one (Table 4); this was not the case in Gagnoa, where treatments were stopped 40 DAE (Table 8).

Table 4. Average Weight of Grain (mg) in Brobo

Factor	Level				Observations
Crop	MPLD 244 b	MPHD 261 a	MLD 250 ab	MHD 261 a	S[a]
Weeding	Well weeded 255		Badly weeded 253		NS[b]
Insecticide	Non-treated 244 b		Treated 264 a		HS[c]

Note: MPLD: maize-peanut low density; MPHD: maize-peanut high density; MLD: maize low density; MHD: maize high density. Values with the 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 $p = 0.01$.

5. Maize yields (kg/ha) in Gagnoa

Factor	Level				Observations
Crop	MPLD 2304	MPHD 2266	MLD 2059	MHD 2060	NS[a]
Weeding	Well weeded 2286 a		Badly weeded 2059 b		S[b]
Insecticide	Non-treated 1843 b		Treated 2502 a		HS[c]

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

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

Table 6. Percentage of Cob-Carrying Plants in Gagnoa.

Factor	Level				Observations
Crop	MPLD 90.1 a	MPHD 72.4 b	MLD 81.1 ab	MHD 71.4 b	S[a]
Weeding	Well weeded 78.6		Badly weeded 82.2		NS[b]
Insecticide	Non-treated 75.3 b		Treated 82.2 a		S

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

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

Table 7. Grain Number per Cob-Carrying Plant in Gagnoa

Factor	Level				Observations
Crop	MPLD 444 a	MPHD 336 b	MLD 456 a	MHD 324 b	HS[a]
Weeding	Well weeded 393		Badly weeded 387		NS[b]
Insecticide	Non-treated 385		Treated 395		NS

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

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

Table 8. Average Weight of Grain (mg) in Gagnoa

Factor	Level				Observations
Crop	MPLD 270 ab	MPHD 243 c	MLD 283 a	MHD 258 bc	HS[a]
Weeding	Well weeded 264		Badly weeded 263		NS[b]
Insecticide	Non-treated 258		Treated 270		NS

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

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

The high density of weeds in Brobo led to plant sterility (Table 2) and grain non-formation (Table 3), whereas in Gagnoa the low weed density resulted only in a low and non-significant reduction of the grain number per cob-carrying plant (Table 7). The grain weight was not influenced by weed density.

The crop effect was very different in both localities. In Brobo, neither a difference in plant sterility nor in grain number per cob-carrying plant was observed (Table 3), whereas in Gagnoa the low density-fertilizing crops had a higher cob-carrying plant percentage (Table 6) and grain number per cob-carrying plant than the high-density fertilizing crops (Table 7). The average weight of grain was heavier in Gagnoa (but lower in Brobo) in the low intensified crops than in the high ones (Tables 4 and 8).

No interaction was noticed between the various factors.

IV. DISCUSSION

Insecticide treatments increased yields of 20% in Brobo and 36% in Gagnoa. This gain was equivalent whatever the weeding or the cropping. In Brobo, however, the gain was clearly lower although three insecticide treatments were applied (two only in Gagnoa). The explanation is that attacks occurred at the

Table 9. Yield Gain Due to Insecticide and Weeding in Terms of the Other Factors (kg/ha)

	MPLD	MPHD	MLD	MHD	GW	BW	Observations
Insecticide							
Brobo	252	387	530	625	501	396	NS[a]
Gagnoa	500	889	540	707	694	624	NS
	MPLD	MPHD	MLD	MHD	NT	T	
Weeding							
Brobo	452	480	762	621	526	631	NS
Gagnoa	296	196	187	228	192	262	NS

Note: MPLD: maize-peanut low density; MPHD: maize-peanut high density; MLD: maize low density; MHD: maize high density; GW: good weeding; BW: bad weeding; T: insecticide treated; NT: no insecticide treatment.

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

end of the growing season (Moyal, 1993), and the treatments at the beginning of the growing season were then of little value. This confirms previous results (Moyal, 1988b and 1989) in neighboring localities. The treatments at the beginning of the growing season were not, however, completely useless in Brobo; the attacks during this period result in plant sterility, whereas late attacks are prejudicial to the grain filling (Moyal, 1988b); it can be noticed that in Brobo, as well as in Gagnoa, the cob-carrying plant percentage was lower in the insecticide unprotected plots. The low insect number at the beginning of the growing season in Brobo (about six insects per 100 stems) means nearly 6% of stems attacked will be sterile. Sterility is a direct consequence of the insect effect, for the insects found belonged to *Sesamia calamistis* Hampson; this species has a high mortality at the beginning of its larval stages, but its young larvae may produce great damage before vanishing (the scarce larvae found then are the survivors of high populations). Sterility is also an indirect effect of these insects, which delay plant growth; these plants, in which growth has been delayed, are very often sterile (AGPM, 1981).

The average weight of grain was significantly higher in the insecticide protected plots in Brobo; however, in Gagnoa, the difference observed was not significant. The lack of late treatment in Gagnoa and therefore less control of *E. saccharina* populations which are responsible for the bad grain filling, explains this difference. The grain number per plant was not modified by borers. This confirms previous results (Moyal, 1988b) and indicates that borers, although probably prejudicial to the plant water supply, have a very different effect from hydric stress which leads to grain number reduction when it occurs at particular moments in the growing season (Claassen and Shaw, 1970).

The advantage of good weeding was particularly obvious in Brobo, where the high density of weeds reduced both the cob-carrying plant percentage and the grain number per cob-carrying plant. The effect of weeds on yield components is therefore very similar to hydric stress (Claassen and Shaw, 1970; Algans and Desvignes, 1983).

It is generally admitted (AGPM, 1981) that weeding must keep a field clean until maize male flowering and that afterward weeds grow less and are no longer prejudicial to yield. In this instance, where badly weeded plots were cleaned 30 and 60 DAE, the average weight of grain was the same whatever the weeding frequency. This lack of difference means, however, reduced grain filling in the badly weeded plots. As a matter of fact, the grain number per plant was lower in the badly weeded plots; and for same plant feeding, one should have a grain weight higher on badly weeded plots. This, for example, is observed when an early hydric stress occurs, which reduces the grain number and then leads to a higher average weight of grain when no other hydric stress happens during grain filling (Claassen and Shaw, 1970). On the contrary, water stress at the end of the growing season leads to a decrease of the average weight of grain. In Gagnoa, weed density was low and had no effect on yield components.

The only common point between the compared cropping systems is the behavior similarity of the pure crop and the intercrop at the same intensification level. On the other hand, yields and their components varied in a quite different and sometimes opposite manner for both density and fertilizing. Thus, yields of the high-density fertilizing plots were higher in Brobo, whereas they were not different from those of low-density fertilizing plots in Gagnoa. The cob-carrying plant percentage and the grain number per cob-carrying plant were similar for each crop in Brobo, while they were significantly higher in the low-density fertilizing than in the high one in Gagnoa. Finally, the average weight of grain in the high-density fertilizing plots was higher in Brobo and lower in Gagnoa than in the low-density fertilizing plots.

These contradictory results may be explained if they are examined in the light of crop hydric balance terms. The maize variety used is particularly affected by hydric stress occurring between 40 and 70 DAE (BDPA, 1980).

In Gagnoa, the difference between the rainfall and the potential evapotranspiration ([PET], measured with the Turc formula, according to Monteny and Lhomme, 1980) was always negative between 26 and 87 DAE, with a maximum deficit at male flowering (50 DAE) (Table 10). The cumulated deficit during this period was 43.7 mm high. On the contrary, in Brobo no deficit was noticed during the critical period, except a small one of 2.5 mm easily compensated by soil reserves; and rainfall was particularly high during male flowering. The maize received, from 25 to 85 DAE, more than 400 mm rain when, according to Chabalier [1985], a minimum of 300 mm is needed during this period to valorize fertilizing (for high-density fields during the first growing season in the center of The Ivory Coast).

In the present case, the high-density fertilizing crops in Brobo were able to fully show their potentialities: compared with the low-density crops, their yields were higher and their yield components were at least equal. Thus, no plant sterility was observed, whereas increase in density generally results in higher cobless plant percentages (Boyat et al., 1983; Barloy, 1983). The grain filling was better in the high-density fertilizing crops than in the low one, because fertilizing was the main limiting factor.

Table 10. Pluviometry (P) and Turc-PET (mm)[a]

Gagnoa					Brobo				
DAE	P	PET	P/PET	P-PET	DAE	P	PET	P/PET	P-PET
1–5	29.1	14.7	1.98	14.4	1–10	131.8	28.8	4.58	103.0
6–15	77.0	31.6	2.44	45.4	11–21	26.0	35.5	0.73	−9.5
16–25	107.8	35.7	3.02	72.1	22–31	47.2	29.4	1.61	17.8
26–36	26.7	33.6	0.79	−6.9	32–41	41.8	36.0	1.16	5.8
37–46	11.6	31.2	0.37	−19.6	42–52	208.0	30.6	6.8	177.6
47–56	32.1	36.6	0.88	−4.5	53–62	62.6	28.1	2.23	34.5
57–67	18.4	30.5	0.6	−12.1	63–72	29.6	32.1	0.92	−2.5
68–77	31.2	31.8	0.98	−0.6	73–82	56.0	33.8	1.66	22.2
78–87	168.0	37.1	4.5	130.9	83–92	39.2	31.2	1.26	8.0
88–97	46.6	35.2	1.3	11.4	93–102	48.8	35.7	1.37	−13.1

Note: PET: potential evapotranspiration in mm/J; Ta: mean temperature of air in °C; Rg: global radiation in cal/cm²/J.

[a] Turc-PET = 0.013 · (Ta/(Ta + 15)) · (Rg + 50).

On the contrary, in Gagnoa plant sterility rose in the high-density fertilizing crops where there was a strong competition for water (28% of plants were sterile vs 14% in the low stands). The water stress affected all the components of the yields of the high-density fertilizing crops: fecundation and grain filling were less effective than in the low densities. On the other hand, the water stress was not very noticeable in the low-density plots. These results are similar to those of the low-density plots in Brobo. Moreover, the average weight of grain is higher in Gagnoa than in Brobo.

This effect of hydric stress on high densities is the general one mentioned, for instance, in France (Maiscope, 1982) and in Nigeria (Norman et al., 1984). High density results in higher plant sterility because of an increase of protandry and shadowing (Barloy, 1983); however, in the density limits of the tests conducted, this was not the case when rainfall was high, as it was in Brobo. On the other hand, the water stress effect was obvious at these density levels.

Low-density fertilizing should then be recommended when a water stress risk exists, as for maize crops sown in March-April in the central area or in June in the central western part of The Ivory Coast. Gigou (1987) also found this to be the case for rain-fed rice in the central area of the Ivory Coast.

This study, the aim of which was the borer effect on maize grown in various crop systems, was restricted to maize; therefore, it does not allow a complete analysis of the interest of intercrops vs pure crops.

For instance, the "Land Equivalent Ratio" (LER), which is the sum of the ratios (yield of the crop in the intercrop/yield of the pure crop) for each crop of the intercrop (Willey and Osiru, 1972) would have had to have been calculated. A pure peanut crop was then needed to study this question. The results only show that, according to the trial pattern, the maize production per maize area unit is not different in a pure crop or an intercrop. The latter was, in fact, a juxtaposition of both crops; this design may be of value to reduce pest attacks or to secure the yields in varying the risks, but it probably does not allow optimum soil use.

Table 11. Financial Result (FCFA) from Low to High Density

Intensification level	Brobo	Gagnoa
Bad weeding, no insecticide treatment	24,980	−25,620
Bad weeding, insecticide treatments	30,380	−13,680
Good weeding, no insecticide treatment	23,540	−25,980
Good weeding, insecticide treatments	27,300	−15,620

Table 12. Financial Result (FCFA) Following Use of Insecticide Treatments

Intensification level	Brobo	Gagnoa
Low density	640	10,800
High density	5,240	21,920

Francis et al. (1978), for instance, use another pattern and other comparison criteria; they compare the productions of the intercrop and the pure crop at the same density, i.e., they add beans between maize plants without changing fertilization. These authors, however, indicate that this method is possible only with rather low densities and not with pure crop optimal densities. They get LER higher than 1.0 and up to 1.68. Salez (1986) does not keep the density of the pure crop but increases the soil occupation in the intercrop with the same fertilizing; he gets the best LER with intercrops by mixing 62.5% of plants of the pure maize crop and between 61 and 74% of plants of the pure soybean crop. On the other hand, Schmidt and Frey (1988) used the same pattern as we did; however, in order to compare the alternating sowing rhythm (1 row-1 row, 2-2, 3-3), obtained LER close to 1.0 and indicate that in the 1-1 intercrop maize suffered much more from peanut competition for water in the dry periods.

The study of possible interest of the intercrop both with respect to borers and yield is then a complex question because: first, intercropping (as pointed out by Harwood [1979]) is the least understood of all the cropping methods; and second, the experimental pattern may induce misinterpretations, in particular, about the pest attack-yield interaction (Hasse, 1981; Parfait and Jarry, 1987). This test, which was the first of this kind conducted in The Ivory Coast, must then be continued with a study of various intercropping patterns and designs. The results, however, allowed us to compare very different situations and to evaluate various ways of intensification. No interaction between the various intensification factors was noticed for the synergy between insecticide treatment and fertilizing observed by Van Huis (1981) in Nicaragua. Finally, one can compare the financial results of the maize crop according to the various intensification methods (Tables 11–14). Calculation components are as follows: insecticide treatment, 5,000 FCFA* per hectare, considered the same for both densities; herbicide treatment for the

* 1 FCFA = 0.02 French franc.

Table 13. Financial Result (FCFA) Following Use of Herbicide Treatment

Intensification level	Brobo	Gagnoa
Low density	11,680	−2,920
High density	9,440	−4,120

Table 14. Financial Result (FCFA) of Various Intensification Ways from a Bad Weeded and Insecticide-Unprotected Field

Intensification level	Brobo	Gagnoa
Low density		
Bad weeding; insecticide treatments	−1,880	8,960
Good weeding; no insecticide treatment	9,140	−4,760
Good weeding; insecticide treatments	12,280	7,800
High density		
Bad weeding; insecticide treatments	3,520	20,920
Good weeding; no insecticide treatment	7,720	−5,120
Good weeding; insecticide treatments	14,640	17,800

well-weeded plots, 12,600 FCFA per hectare; N-P-K fertilizer, 110 FCFA per kg; and urea, 79 FCFA per kg (CIDT, 1988); maize cost price, 40 FCFA per kilogram. The man-power cost for spreading, which is low, is not taken into account. Seeds are free.

Because no difference was noticed between pure crop and intercrop at the same intensification level, they were taken together. It can therefore be established that the choice of high-density fertilizing is always beneficial in Brobo and never in Gagnoa (Table 11). The insecticide treatment, which is very interesting in Gagnoa, is of no value in Brobo, where one more treatment was conducted and where the treatment period was not the most suitable one (Table 12). The insecticide treatments seem more interesting in the highly intensified plots, but the high variability did not allow us to establish significant differences. Further studies will have to explain this point. Use of herbicides, which is interesting in Brobo, leads to a loss in Gagnoa where weed density was low.

Finally, in spite of this financial variability, the combined use of herbicides and insecticides always enables a gain in comparison with every other combination of these factors (Table 14) and should be recommended for crops sown in June in the central Ivory Coast. The change from a badly weeded and insecticide-unprotected low-density fertilizing crop to a highly intensified crop gives a profit of 39,620 FCFA per hectare in Brobo (sum of the first row of Table 11 and the last of Table 14).

Considering crops sown in June in the central western area of The Ivory Coast for which low density and fertilizing have to be recommended, the use of herbicide or insecticide treatments leads to a much lower profit (7800 FCFA per hectare) and more studies are needed to estimate the value of using these inputs in various conditions of weed and pest densities.

ACKNOWLEDGMENTS

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

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