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# The invasion of *Chromolaena odorata* (L.) King & Robinson (*ex Eupatorium odoratum*), and competition with the native flora, in a rain forest zone, south-west Côte d'Ivoire

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**Abstract.** The geographical isolation of south-west Côte d'Ivoire and the high levels of forest cover delayed the invasion of *Chromolaena odorata* (L.) King & Robinson, well installed elsewhere. The species was first recorded in 1980, and fields became infested from 1984 onwards.

Between 1979 and 1987 a large number of complete inventories were made on a variety of fields by means of permanent quadrats. No strong relation was found between the accessibility of a field and year of first registration of *Chromolaena odorata* seedlings. Of much more importance was whether a field had been prepared by clearing a secondary or a primary forest, and the number of years it was under cultivation.

If cultivation ceased after 1 year, fallow trees rapidly provided overstorey shade, followed by the degeneration of *Chromolaena odorata*. On fields with prolonged cultivation, repeated weeding exhausted the pool of fallow tree seed. On such fields thicket-forming by *Chromolaena odorata* prevents the establishment of other species. Both strategies result in a prolonged site pre-emption. With too frequent disturbances a *Chromolaena odorata* thicket is replaced by grassland. However, the plant re-invades as soon as perturbation ceases, followed eventually by reforestation.

Analysis of the life cycles of the native regrowth flora demonstrated the preponderance of species with long juvenile stages over those flowering in the first year of establishment. This group consists mostly of annuals. Few species are both perennial and able to set seed the first year. The latter are particularly successful on fields with prolonged cultivation, and among them other recent invaders are found.

The spread of *Chromolaena odorata* in Côte d'Ivoire is significant for both permanent agriculture and forestry, being an obstruction to the replanting of trees, coffee, cocoa, and timber.

**Key words.** *Chromolaena odorata*, invasion, competition, forest fallow, rain forest, West Africa.

**Résumé.** Tant son isolement géographique que son fort couvert forestier on retardé l'envahissement du sud-ouest de la Côte d'Ivoire par *Chromolaena odorata* (L.) King & Robinson, bien installé ailleurs. Une première fois relevée en 1980, cette espèce n'a vraiment envahi les champs qu'à partir de 1984.

De 1979 à 1987, un grand nombre de relevés ont été effectués à l'aide de quadrats permanents sur plusieurs types de champs. Aucune relation marquée n'a pu être établie entre l'accessibilité d'un champ et la première apparition de pousses de *Chromolaena odorata*. Que le champ succède à une forêt primaire ou secondaire, ainsi que le nombre d'années de culture se révèlent d'une bien plus grande importance.

Si le champ est abondonné après un an de culture, *Chromolaena odorata* dégénère sous le couvert rapidement assuré par les ligneux de jachère. Pour les champs cultivés plus longtemps, la répétition des sarclages entraîne l'épuisement du stock de graines des ligneux. Sur ces champs, la formation d'un fourré de *Chromolaena odorata* interdit l'installation d'autres espèces. Cette stratégie lui permet de demeurer longtemps la seule espèce présente. Trop souvent contrarié dans son développement, un fourré de *Chromolaena odorata* est remplacé par des herbacées. Non perturbée, la plante se réinstalle aussitôt, suivie en définitive par la forêt.

L'analyse des cycles végétatifs de la flore du recrû démontre la prépondérance d'espèces à longs stades juvéniles sur celles qui fleurissent dès la première année de leur installation. Ce groupe compte surtout des annuelles. Seules quelques espèces pérennes parviennent à produire des graines dès la première année. Ces dernières dominent particulièrement sur les champs à culture continue. Parmi elles se trouvent d'autres espèces dont l'envahissement est récent.

Obstacle à la replantation du café, du cacao et du bois d'oeuvre, l'expansion de *Chromolaena odorata* en Côte d'Ivoire est surtout préjudiciable à l'agriculture permanente et à la sylviculture.

**Mots-clés.** *Chromolaena odorata*, envahissement, compétition, jachère forestière, forêt tropicale humide, Côte d'Ivoire.

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## INTRODUCTION

The shrub *Chromolaena odorata* (L.) King & Robinson is one of the most troublesome weeds in many humid tropical countries. Its prolific regeneration from seeds frustrates attempts to eliminate the plants manually. It is capable of resprouting after burning, and converts forest fallow into thickets by its vigorous growth and sprawling habit.

The plant is a native of tropical America. It was probably introduced in to Asia more than once (Chevalier, 1949; van Borssum Waalkes, 1953) for its ability to suppress *Imperata* sp. and other coarse grasses. For this reason Chevalier (1952) advised its introduction in West Africa, but Vayssière (1957) was opposed because of unfamiliarity with the plant's possibilities as a host for pests. However, *Chromolaena odorata* was introduced in the Côte d'Ivoire in the fifties to serve as a cover crop in coffee and oilpalm plantations. Quencez & De Vernou (1983) mention its presence in Eloka, 50 km east of Abidjan, in 1962, where it caused no problem; but it gained the reputation of a pest 20 years later, all over the south-eastern region of Côte d'Ivoire. In Ghana Hall, Kumar & Enti (1972) reported the spread of an obnoxious weed *Chromolaena odorata* as early as 1967. Its western outbreak was perhaps the result of spread from Côte d'Ivoire. At that time it was already known in Nigeria as a pest in cocoa plantations (Adenikinju, 1975).

*Chromolaena odorata* is generally known in Côte d'Ivoire as 'herbe Indépendance' because the year of its firm establishment, in 1960, coincides with the actual year of independence. Its spread through the Côte d'Ivoire followed the direction of the dominant winds, helped by secondary sources of infestation due to transport of seeds by road-building equipment (Delabarre, 1977). In the seventies *Chromolaena odorata* had travelled from east to west and had reached its northern, climatic frontier. The only region still free from *Chromolaena odorata* was a thickly forested area in south-west Côte d'Ivoire. Part of this region, the land between the Cavally river and the Taï National Park, is the subject of this study (Fig. 1). Here, the plant was introduced in 1980 by machines improving the major earth road. Road improvement stopped 40 km south of the village Taï and no operations of any importance were effected further south after 1980. As late as 1986, the region of Grabo, a hundred kilometres south of Taï, had probably remained uninfested, but the species is established by now because much forest near Grabo had been cut recently with the help of heavy machinery (L. Gautier, pers. comm.). In 1989 a vegetation survey took place (De Rouw, Vellema & Blokhuis, 1990) which showed the presence of *Chromolaena odorata* in all suitable habitats, not only in the study area but also in areas much further south.

The Taï National Park consists largely of untouched rain forest. Old field vegetation is concentrated near villages or abandoned settlements, and patches of primary and late secondary forest can be found very near villages. The area occupied by primary forest increases markedly towards the Park. The region receives an annual rainfall of about 1900 mm, the greater part falling within two rainy seasons. Food cultivation is concentrated in the heaviest rainy season, from March to August. The soils are acid, thoroughly leached and chemically poor, with a rather high clay content. People practice an extensive form of shifting cultivation which means that a mature forest is felled and burnt and one crop of rice is grown. Little weeding is done. Forest is then allowed to regenerate before being cropped again. Along with subsistence farming, most families possess cocoa and coffee plantations. Treecrops, especially when young, are often interplanted with maize and tuber crops. The area now occupied by treecrops has very much increased over the last 10 years. the Taï forest ecosystem has been the object of many studies. Primary forest vegetation has been studied mainly by Guillaumet (1967), secondary forest by Alexandre *et al.* (1978), Kahn (1982) and Jaffré & de Namur (1983), agriculture by Moreau & de Namur (1978) and de Rouw (1987). A synthesis of work has been published (Guillaumet, Couturier & Dosso, 1984).

This article reports the successful invasion of *Chromolaena odorata* in a forest area. It describes the competition with the local weed and regrowth flora. Reflections are made on *Chromolaena odorata* as a plant which added novel demographic attributes superior to any of those present in the original pool of the Taï weed flora. The study was part of a larger research programme dealing with weed invasion and fallow degeneration due to intensification of land use.

## METHODS

Between 1979 and 1987 a total of 308 surveys were made on a variety of fields in the vicinity of Taï village. A survey consisted of identifying all plants in a 9 $m^2$ sample and counting the number of individuals per species. Young fallows were sampled in the same way in order to study seral processes. Environmental measurements included slope, soil profile, etc. The field's crop history was recorded and the distance to roads was estimated. The surroundings were checked for possible seed sources.

Fields were chosen subjectively to be representative for the region: shifting cultivation fields with rice as a dominant crop or permanently cultivated fields with cocoa or coffee as main crops, and fields which differentiated in time since last cutting, ranging from primary forest to short fallows of 6 years.

Fields (12) were either sampled regularly by means of permanent quadrats, or only once (37). Permanent quadrats were laid out in rice fields for shifting cultivation fields demonstrated greater vegetation dynamics than permanently cropped fields and thus needed to be studied more closely. Those 12 fields were chosen to represent the range of vegetation and soil present in the country. Permanent quadrats were sampled twice during the cropping season and once at the end. If cultivation continued another year the procedure was repeated. If cultivation ceased the quadrats were sampled yearly to study regeneration. The number of permanent quadrats per fields varied according to the number of weeding levels tested, three quadrats for three levels and two quadrats for two. There was always one repeat. A rice field thus sampled gave 3×3×2=18 or 3×2×2=12 observations per year. Field 1 was studied

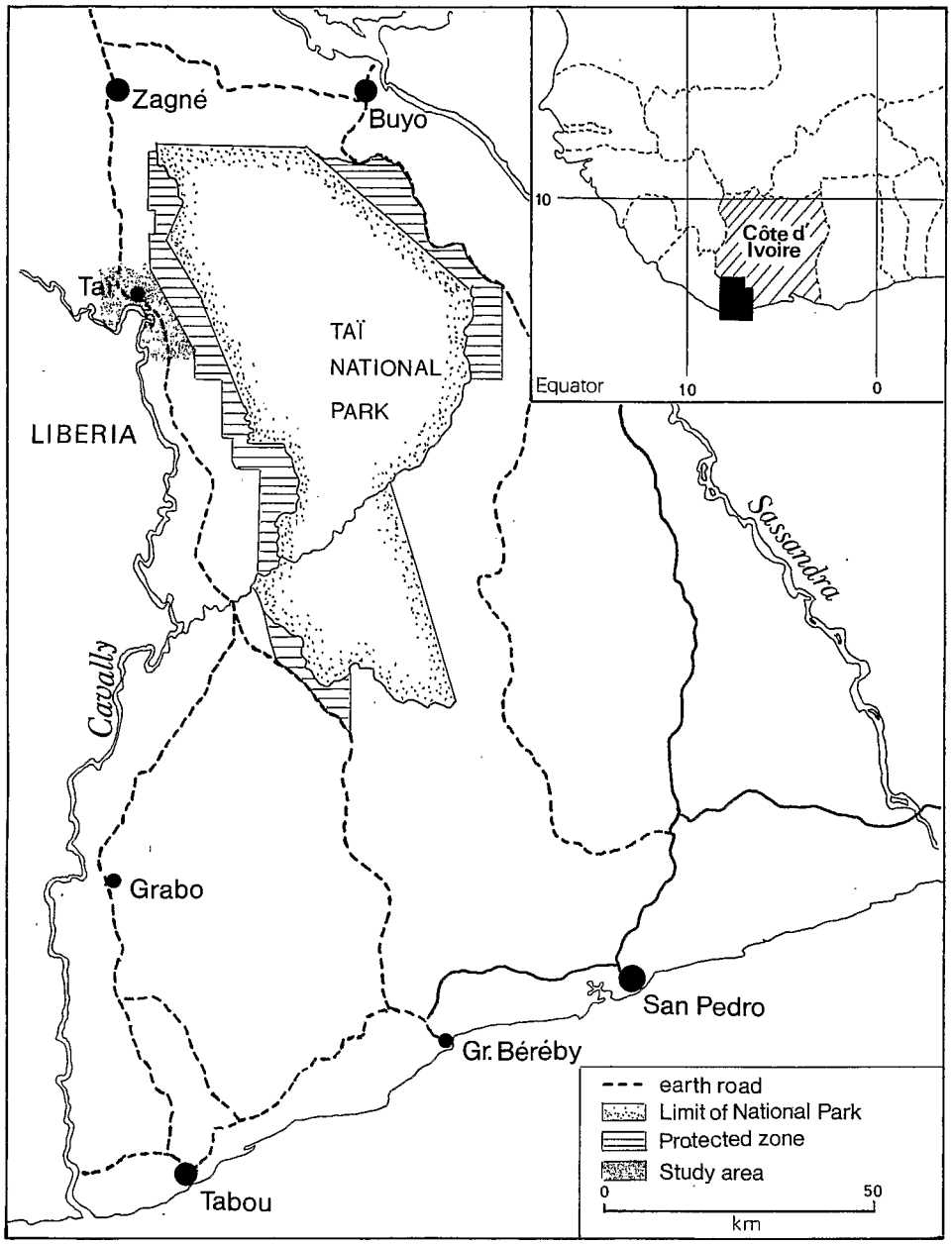


FIG. 1. Location of study area.

during 3 years of rice cultivation (54 samples) and 2 years of fallow (1983–87); field 2 during 2 years of cultivation (36 samples) and 2 years of fallow (1984–87); fields 3 and 4 during 2 years of cultivation (24 samples each) and 1 year of fallow (1985–87); field 5 during 1 year of cultivation (12 samples) and 2 years of fallow (1985–87); field 6 during 1 year of cultivation (12 samples) and 1 year of fallow (1985–86); fields 7 and 8 during 1 year of cultivation (12 samples) and 1 year of fallow (1986–87); field 9 during 1 year of cultivation (12 samples, 1985); fields 10, 11 and 12 during 1 year of cultivation (12 samples each, 1986). Thus, in the period 1983–86 a total of 234 recordings were made in permanent quadrats in rice fields. These observations were supplemented by similar recordings at a wide range of fields, rice fields and cocoa/coffee fields. Those were surveyed once, two samples of 9 m² were taken. In the period 1979–87 a total of 74 such samples were taken from 37 fields, 3 fields in 1979, 10 fields in 1982, 1 field in 1984, 6 fields in 1985, 16 fields in 1986, and 1 field in 1987.

## RESULTS

### Invasion

The first seedling of *Chromolaena odorata* was observed in August 1984 in field 1 at the end of the cropping season. The plot had been surveyed previously, twice in 1984, and three times in 1983 in May, June and August.

Table 1 helps to obtain a crude estimate of the rate of infestation. The observations made in 1979 are left out, for

TABLE 1. Number of fields and samples observed per year with number of fields infested by *Chromolaena odorata*.

| | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 |
|---|---|---|---|---|---|---|
| Total no. of samples | 20 | 18 | 38 | 108 | 116 | 2 |
| Total no. of fields sampled | 10 | 1 | 3 | 13 | 23 | 1 |
| Fields with permanent quadrats | 0 | 1 | 2 | 7 | 7 | 0 |
| Fields sampled once | 10 | 0 | 1 | 6 | 16 | 1 |
| No. of fields with *Chromolaena odorata* | 0 | 0 | 3 | 10 | 21 | 1 |

*Chromolaena odorata* arrived only in 1980. To classify a field as 'infested' it is sufficient to detect one plant of *Chromolaena odorata* in one of the two samples, once during the cropping period. A field is called free of *Chromolaena odorata* if no such plant was found in that field in any of the samples during the cropping season. The fields sampled in 1982 and 1983 were free of *Chromolaena odorata*. In 1984 all three fields under observation carried *Chromolaena odorata*. The species appeared at the time the rice was decaying. From 1985 onwards most of fields had *Chromolaena odorata* plants and germination takes place all through the cropping season.

In Fig. 2 three periods are selected: 1982 in which 10 fields were studied, 1985 with 13 fields and 1986 with 23 fields. The location of the fields in relation to earth roads usable by vehicles seems to be unimportant. By 1985, 8 out of 13 fields carried *Chromolaena odorata* plants. The fields exempt from the weed are located somewhat inland, but 4 out of 8 fields where *Chromolaena odorata* was present were only accessible by a footpath. 21 of 23 fields surveyed in 1986 had *Chromolaena odorata* plants. This seems to be unrelated to the quality of the access route. The time elapsed between the arrival of *Chromolaena odorata* in 1980 and its appearance in a field is caused by the high levels of plant cover almost everywhere. The low rate of forest disturbance has probably slowed down the rate of invasion. However, heliophyl vegetation always borders tracks and also many footpaths.

The fields in the survey varied chiefly in crops grown and field history. There did not seem to be any difference in infestation with the crop grown and concerning field history few things were important. The variety of agricultural practices produces three major field types, differentiating in quality and quantity of weeds. Fields can be made by cutting and burning a primary forest (type A). We call a forest primary if no traces of previous shifting cultivation cycles are visible. Such marks remain perceptible in the vegetation for farmers and the author for at least 60 years. The vegetation 3 months after burning is rather sparse, 20–60 individuals per m$^2$. Weeding is hardly necessary. The majority of plants consist of secondary forest trees and stout woody climbers. Broad-leaved herbs are few, grasses are rare and sedges may be locally frequent. Fields can be made by clearing a secondary forest (type B). Usually fallows between 16 and 25 years old are used. The field carries a weed and regrowth vegetation which is more dense (50–100 individuals per m$^2$, 3 months after burning). One weeding round is usually necessary. Compared to fields in primary forest we observe that most seedlings are still of secondary tree species, though the proportion of herbs is larger. Grasses are infrequent and sedges can be locally abundant. Type A and type B apply to the first year of cultivation. The usual cycle forest–crop–forest can be side-tracked if the field is used for more than 1 year. All fields, whether derived from a primary or a secondary forest, where cultivation continues a second year or where cultivation has become permanent, belong to type C. Weeds have become numerous, over a 100 individuals per m$^2$ 1 or 2 months after each weeding. Seedling of fallow trees become rare, herbaceous dicotyledons frequent and grasses start to invade the field. Fig. 3 gives densities of *Chromolaena odorata* plants per m$^2$. The surveys are distributed according to these field types; type A is represented by 34 samples, type B by 74, and type C by 194 samples. For each field type, samples are arranged according to the year survey took place. Below the thick line are indicated the number of samples taken from permanent quadrats and those samples free of *Chromolaena odorata*. If the plant occurred in a sample the number of individuals per square metre is shown above the line. If the sample came from a permanent plot field number is given. Fig. 3 illustrates what was evident in the Taï region: *Chromolaena odorata* did not affect primary forest and secondary fields alike, nor did first season fields and second season fields respond in the same way. Although few primary forest fields enter the study, it is noteworthy that samples continue to carry low densities of *Chromolaena odorata* plants: one per m$^2$ in 1986 and 1987 (Fig. 3a). The low levels of *Chromolaena odorata* during the first year of cultivation can be explained partly by the geographic remoteness of these places. But most often those fields were made close to settlements and the primary forest felled represented a last remnant surrounded by young fallow and fields already infested by the weed. *Chromolaena odorata* started to penetrate secondary forest fields in 1984 (Fig. 3b). From the beginning, numbers per m$^2$ are higher than those in fields produced from primary forest. It should be emphasized that *Chromolaena odorata* adults had not infiltrated these forests prior to felling, as all fallows were already well developed closed forests at the time the weed arrived. Fields used for prolonged cultivation carried highest densities plants per m$^2$ and these numbers were rapidly reached. Also the percentage of samples invaded is the highest (Fig. 3c). One explanation is that in the case of first year cropping all *Chromolaena odorata* plants present have grown from seed that some year, whereas second year fields carry a population of *Chromolaena odorata* which is partly built up by plants issued from seeds the second year, and partly by in-

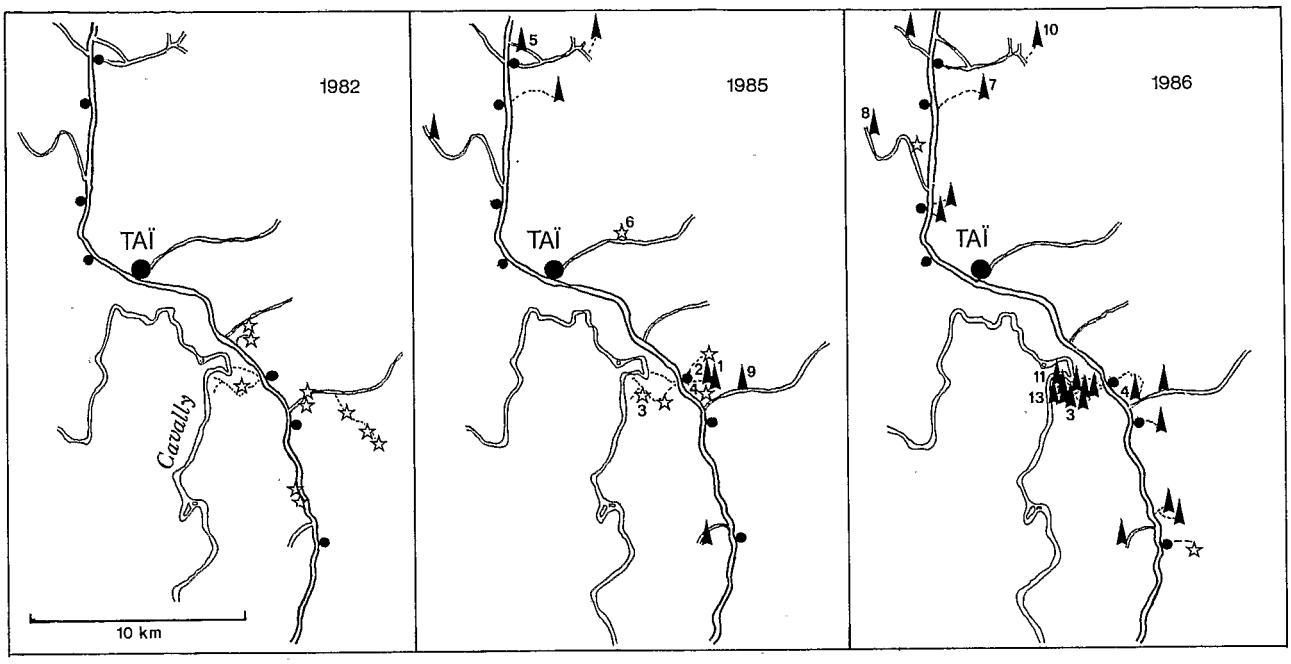


FIG. 2. Fields with *Chromolaena odorata* plants (pyramid) and fields without *Chromolaena odorata* (star), in 1982, 1985 and 1986. Fields with permanent quadrats are numbered. Broken line is footpath; thin line is small timber extraction road; thick line is main earth road.

dividuals established the first year, having survived repeated weeding and burning.

## Competition

As was said above, three field types can be distinguished as to weed and regrowth flora. The types A and B refer to situations where a single severe perturbation is followed by a more or less undisturbed growth of the vegetation. The type C is produced as severe perturbations occur more than once.

Rice fields prepared in primary forest (type A) carry a vegetation which is rather sparse. *Chromolaena odorata* germinates together with other plants during the cropping season and meets with a severe competition of the tree seedlings. The height growth of these tree species (3–6 m within a year) outstrips that of other species. *Chromolaena odorata* is just able to produce one or two poor seed crops while already degenerating as the forest fallow grows thicker and higher.

If a secondary forest is converted to arable land (type B) the field carries a weed and regrowth vegetation which is more dense. *Chromolaena odorata* seedlings are more numerous here. Competition of the latter with other plants follow a similar pattern. *Chromolaena odorata* is unable to occupy the general crown layer for more than a year in spite of an extensive lateral spread of shoots. Tree saplings pierce the *Chromolaena odorata* layer and it is readily overgrown. The effect of weeding is simple. The general strategy of fallow tree species permits the entire seed population to germinate in the first months after burning in an all-or-nothing effort. Two or three weeding rounds suffice to exhaust most of the tree seed pool. Vacated space is filled by low herbs, *Chromolaena odorata* and other forbs. The more weeding is done, the more *Chromolaena odorata* is freed from competition with trees, the longer it can maintain site tenure. However, if a field is cultivated just 1 year and allowed to succeed back to forest afterwards, *Chromolaena odorata* will always decline in abundance and be shaded out within 2 or 3 years.

If a field is recultivated with foodcrops or if attempts are made to plant permanent crops such as cocoa or coffee (type C), weeds become numerous. *Chromolaena odorata* becomes firmly established. The species has a tendency to form dense tickets where regeneration by other plants is precluded, numerous seeds are produced annually resulting in a persisting seed and seedling bank. After each cutting and burning the release of established individuals rapidly covers the ground. Fig. 4 shows a typical infested field. Rice was cultivated the first year and maize, okra and other food crops the second year. In November, 5 months after the harvest, *Chromolaena odorata* bears flowers and fruits.

Although the invasion of *Chromolaena odorata* in the south-west of Côte d'Ivoire is recent and our experience with the plant as a competitor with the native flora therefore limited, some patterns emerge. Permanent dominance of *Chromolaena odorata* is enhanced by cutting and burning a vegetation regularly; this means annually, every other year or every 2 years. A *Chromolaena odorata* stand can be suppressed by more frequent removal of the vegetation. It is replaced by a population of mainly stoliniferous grasses, vines and other low herbs. Where these vegetations are left undisturbed for several years, *Chromolaena odorata* reinvades, slowly suppressing and eliminating the grasses. As secondary forest tree species were observed penetrating thickets of *Chromolaena odorata*, it is probable that dominance of *Chromolaena odorata* is temporal and cannot resist reforestation in the long term.

Fig. 5 shows the experimental field 1 being prepared for

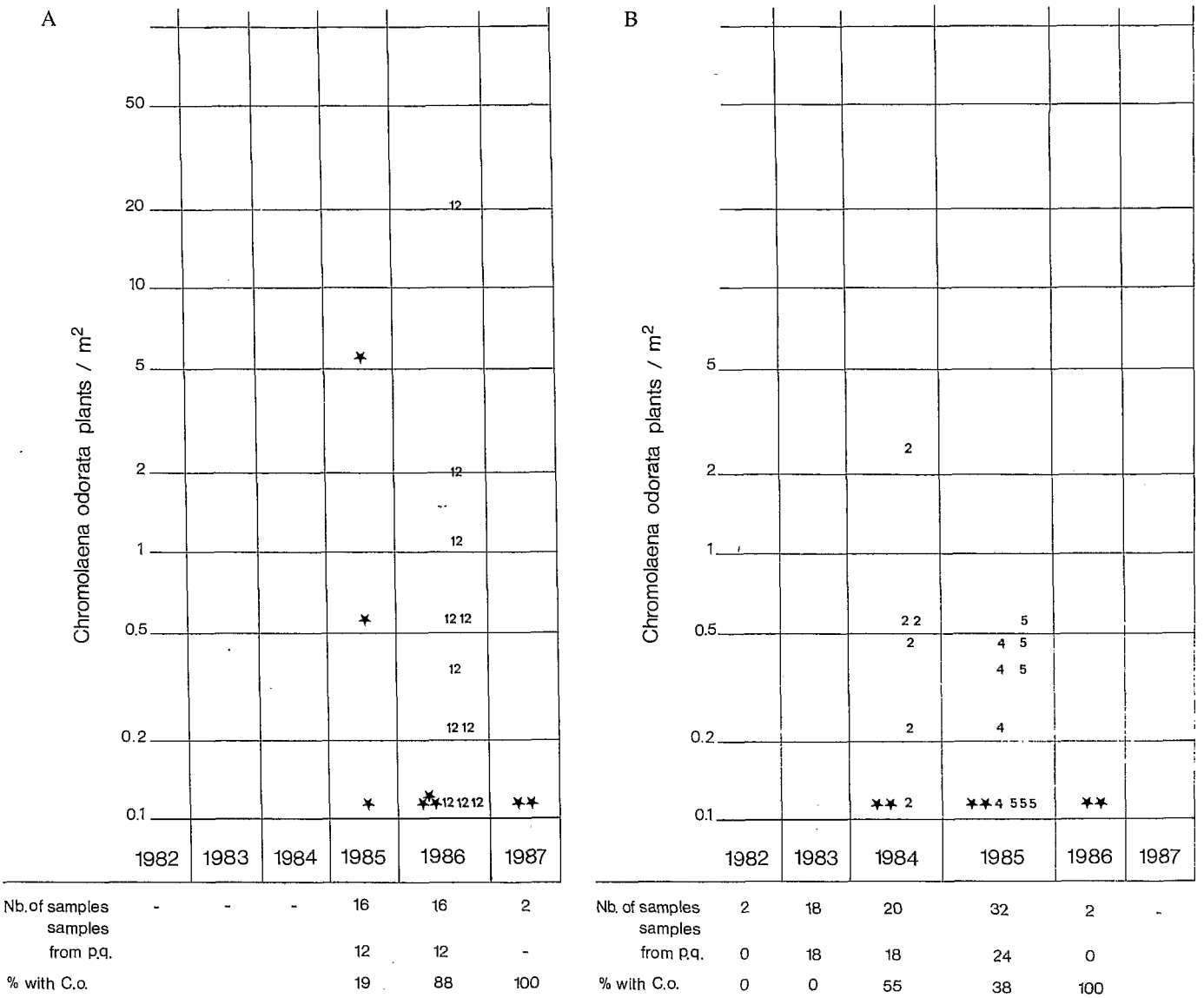


FIG. 3. Number of samples containing *Chromolaena odorata* plants and number of individuals per m², per year. Samples taken from permanent quadrats are represented by their field number; samples from fields sampled once are indicated with a star. (A) Samples from fields prepared in primary forest, first year of cultivation; (B) samples from fields prepared in secondary forest, first year of cultivation; (C) samples from fields with prolonged cultivation.

renewed cultivation. Three years of rice cropping had resulted in a vegetation heavily infested by grasses (A). After 2 years of rice cultivation followed by 1 year fallow a thicket of *Chromolaena odorata* was produced, though some trees, indicated on the photograph, have pierced the canopy (B). Further back a young forest can be seen (C) grown after 1 year of rice and 2 years of fallow. In the background (D) can be seen a remnant of the original forest 22 years old, which was felled to make the field.

## Advantage over native flora

Has *Chromolaena odorata* added a demographic attribute to the community which was rare among the resident flora and which can be regarded as having contributed to its success? The plots investigated in the survey carried 295 secondary and weed species. More than 700 primary forest species were also recorded but they are not further considered here. They are essentially sprouts released by damaged plants of the original forest and each species is represented by few individuals. Three life cycle patterns can be distinguished: (A) species with a long juvenile stage, ranging from decades to a few years; trees, lianes, sub-woody vines (206 species); (B) species with a short juvenile stage, completing their genetically controlled life cycle more or less with the annual crop; herbs, sub-woody herbs (annual, biennial, 72 species); (C) species with a short juvenile stage, producing seed the first year but which do not die afterwards; perennial grasses, forbs, herbs, sub-woody vines (17 species).

*Chromolaena odorata* belongs to group C. Other early flowering perennials are less robust, less resistant to cutting

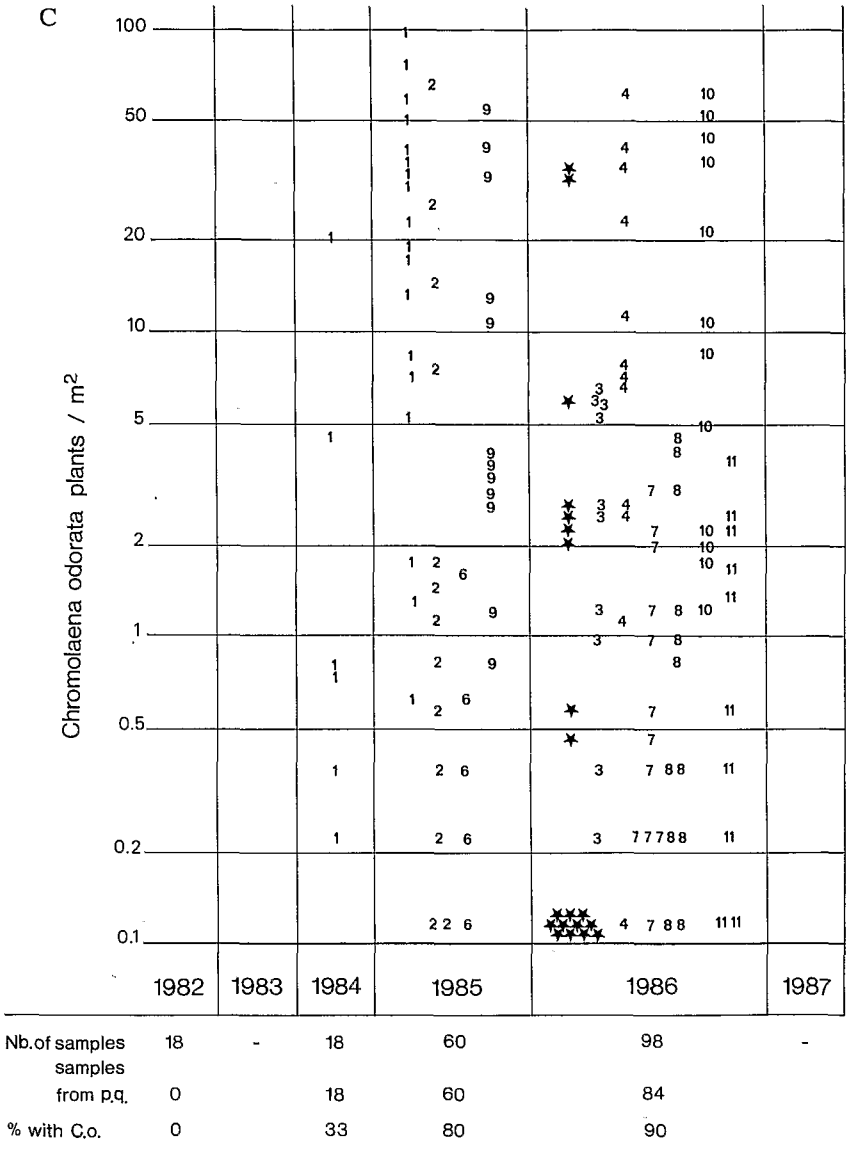


FIG. 3 (*continued*).

and burning and often sciaphytic. Using the terminology of Noble & Slatyer (1980): the advantage of this attribute is a presence mechanism where seeds and adults continue to be present together after the first year, while perennials with long juvenile stage lose their presence as seeds (group A), and annuals lose their presence as adults (group B).

In Table 2 the species of the secondary forest and weed flora are arranged according to the three life cycle patterns and the three field types discussed previously. Fields established in primary forest and cultivated for the first year have few annuals (24 species). A perennial with a short juvenile stage, apart from *Chromolaena odorata*, is the small shade-loving grass *Panicum brevifolium* L. Fields prepared in secondary forest are floristically richer, especially in annual weeds (60). The group of perennials with short juvenile stages comprises grass species with variable shade tolerance and herbaceous heliophyl climbers: *Mikania* spp. and *Thunbergia* spp. Prolonged cultivation produces vegetation with a reduced woody component (42), many annuals and all perennials of group C recorded in the survey (17). Added are some of the rather coarse grasses, *Setaria* spp. and the well-known cover crops escaped from industrial tree crop plantations elsewhere in Côte d'Ivoire.

It is noteworthy to mention two other invaders of recent date though prior to the arrival of *Chromolaena odorata*. The soft-wooded tree *Trema orientalis* L. is able to produce great quantities of seeds, often in the first year of establishment. In addition a complex mechanism regulates germination, making it one of the rare trees to overcome repeated weeding (Alexandre, 1978; de Rouw & Van Oers, 1988). The tree-like shrub *Solanum erianthum* D. Don does not produce seeds in the first year but proves to be extremely resistant to weeding due to the development of rootsuckers (Portères, 1959; Alexandre, 1982).

Generally speaking, recent invaders are most successful

FIG. 4. Field infested by *Chromolaena odorata* (with flowers and fruits), second year of cultivation, 5 months after the harvest of the main crop, maize.

TABLE 2. Number of secondary forest species and weed species accordingto growth form, life cycle and field types (308 samples of 9 $m^2$).

| | (Sub)woody species, long juvenile stage | Herbaceous and sub-woodyspecies, annual, biennal | Herbaceous and sub-woodyspecies short juvenile stage |
|---|---|---|---|
| Total no. of species established from seed | 206 | 72 | 17 |
| First year of cultivation: primary forest cleared (7 fields, 34 samples) | 151 | 24 | 2 |
| First year of cultivation: secondary forest cleared (11 fields, 74 samples) | 206 | 60 | 7 |
| Prolonged cultivation (33 fields, 194 samples) | 42 | 62 | 17 |

on fields of type C.

## DISCUSSION AND CONCLUSIONS

Crawley (1987) states that we are unable to predict whether a particular introduction will succeed or fail. No model can inform us about a 'vacant niche' or whether the demographic attributes of an alien are superior; our only indication being the 'commonness' and 'widespreadness' of a species, properties appearing to be transferable. This will come as no surprise to anyone observing the distribution of *Chromolaena odorata*, for commonness in other humid

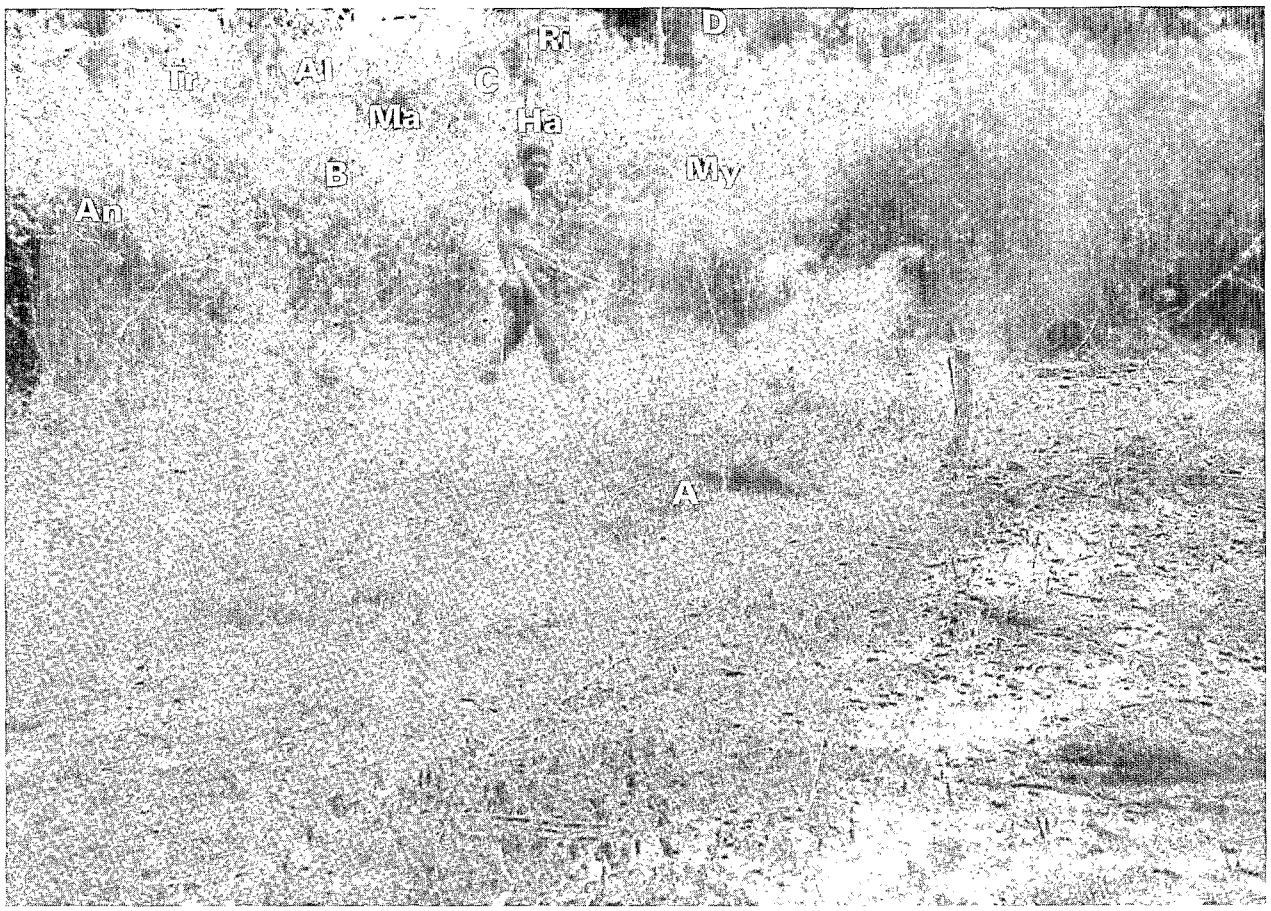


FIG. 5. Experimental field with permanent quadrat being prepared for renewed cultivation. A: 3 consecutive years of rice cultivation; B: 2 consecutive years of rice cultivation and 1 year of fallow. *Tr=Trema orientalis, An=Anthonotha macrophylla, Ha=Harungana madagascariensis, Al=Alchornea cordifolia, My=Myrianthus arboreus.* C: 1 year of rice cultivation and 2 years of fallow, *Ma=Macaranga hurifolia, Ri=Ricinodendron heudelotii.* D: secondary forest 22 years old, which was partly felled to make the field.

tropical regions made its invasion in south-west Côte d'Ivoire plausible. Crawley (1987) also ranks communities in terms of their invasibility. Areas of low levels of plant cover which are in addition subject to frequent perturbations, come first. The increase and the intensification of agricultural activities in the Taï region meet with these requirements: it was the geographic isolation and biogeographic factors which delayed the invasion until 1980.

The ability of *Chromolaena odorata* suppress *Imperata* sp. cannot be observed in the Taï region for the latter is (still) absent. The same is true for the coarse grass *Pennisetum purpureum* Schumm. However, *Chromolaena odorata* does invade grassland and suppresses the performance of these species. After some time, *Chromolaena odorata* weakens and tendencies towards the establishment of forest can be seen. We do not know how a grassland progresses towards reforestation without a transient phase of *Chromolaena odorata*. So we cannot answer the question whether dominance of *Chromolaena odorata* favours or hampers the process of forest succession.

It seems likely that a population of *Chromolaena odorata* is not only checked by overstorey shade but is also restrained by an impoverished environment. Where degradation had been most severe, grassland was only slowly colonized by *Chromolaena odorata*. In other places where cultivation had been particularly intense, a stand of *Chromolaena odorata* resisted reforestation for many years, although all disturbance had ceased.

In a field study in south and south-east Côte d'Ivoire, farmers praised the ability of *Chromolaena odorata* to control and keep out *Imperata* sp. and some of them even attributed a fertilizing effect to the plant. Population is dense here and this is why many forest fallows have been replaced by vegetation dominated by *Chromolaena odorata* (N'Guessan & Tie Bi Tra, 1986). Data from north-east India report the presence of *Chromolaena odorata* in fallow vegetations for at least 5–6 years (Saxena & Ramakrishanan, 1984a; Toky & Ramakrishnan, 1983), or even 20 years (Kushwaha, Ramakrishnan & Tripathi, 1981). Here too, the original forest fallow is likely to have degraded as population pressure had shortened fallows from 10–20 years to 4–6 years (Saxena & Ramakrishnan, 1984b). In the south-west Côte d'Ivoire the period during which *Chromolaena odorata* is present in old-farm vegetation varies according to the frequency of disturbance, from 2 years to over 5 years in exceptional cases. As the plant

arrived only recently, it is likely that the populations of seeds, seedlings and adults are still expanding. So not only the number of fields infested will increase, but the degree of infestation too. This will probably make the competition of *Chromolaena odorata* with the resident flora a longer struggle.

Gómez-Pompa & Vázquez-Yanez (1974) give twenty-one models of life cycle patterns along a time gradient in the successional process. They stated that for each set of changes there is a set of species that have a life cycle which is adapted to the time available. In this article three 'sets of changes' were discussed. The first two refers to situations where a single severe perturbation (cutting and burning) is followed by the growth of the vegetation. It did not make much difference, from the life cycle pattern point of view, whether a primary or a secondary forest had been cut, or whether the field was weeded once or not at all. The third situation is produced where severe perturbations occur more than once (the field is cleared and or burnt for another year of cultivation). The spectrum of life cycles now undergoes a change, to the benefit of early flowering perennials. These cutover fields have greatly expanded in the last decade and this coincides with the invasion of species adapted to regular disturbances; one of them, *Chromolaena odorata*, is particularly successful.

## Some reflections on agriculture and forestry

The forest zone of Côte d'Ivoire produces chiefly cocoa, coffee and timber, ranking respectively first, second and third in contribution to foreign exchange. The country sold 655,000 tons of cocoa in the season 1987–88, 30% of the world market. It is the first cocoa-producing country and third for coffee (Gill & Duffus, 1988). Each year about 4 million cubic metres of hardwood are exported and between 5.5 and 7.5 cubic metres of wood are used within the country. 40 years ago Côte d'Ivoire possessed 14.5 million hectares of forest; in 1986 less than 3 million remained. The rate of destruction is estimated at 300,000 hectares a year (Bertault, 1986).

The invasion and establishment of *Chromolaena odorata* had important consequences for agriculture and forestry. Problems are particularly acute where land use is permanent. Most plantations, whether coffee, cocoa, oilpalm or rubber, were established in primary or in old secondary forest. Degeneration due to stand senescence started after 10, 20, or more, years, depending on crop, management and site conditions. As soon as the crop's canopy breaks up, *Chromolaena odorata* invades. Replanting such plantations is extremely difficult because the costs of weeding, herbicides and other inputs exceed the profit expected. This applies especially for coffee and cocoa with their current drop in world market prices. It is far more convenient to convert a mature forest into a tree crop plantation. This was and is done on a large scale, resulting in millions of hectares of low-yielding plantations and abandoned fields covered with *Chromolaena odorata* thickets. Reforestation meets with equally great difficulties. The inputs needed to combat *Chromolaena odorata* – labour and herbicides –makes planting of the usual timber trees, Fraké, Framiré, Samba and Iroko, no longer an economic proposition.

However, the Ivorian government is increasingly conscious of the necessity to find alternative land use of the enormous stretches of fallow land and to preserve the last remnants of primary forest.

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