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Report

Impacts of Type of Fallow and Invasion by *Chromolaena odorata* on Weed Communities in Crop Fields in Cameroon

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ABSTRACT. In the humid forest regions of southern Cameroon in central Africa, sectoral and macroeconomic policy reforms introduced in the late 1980s have led to intensified land use, which in turn has resulted in, among other environmental consequences, shortened fallow systems dominated by the Asteraceae shrub, *Chromolaena odorata* (L.) King and Robinson, rather than by secondary forest species. A trial was established to determine the effect of shortened fallow duration and invasion by *C. odorata* on the weed flora in subsequent mixed food cropping systems. Plots were established in cleared 5- to 7-year-old fallow fields in which the vegetation was either dominated by *C. odorata* or not, and in which the dominant fallow vegetation in the previous crop–fallow rotation had been either *C. odorata*, forest, or herbaceous (not dominated by *C. odorata*). Cassava (*Manihot esculenta* Crantz), maize (*Zea mays* L.), and groundnuts (*Arachis hypogaea* L.) were intercropped and weed species were assessed 6, 14, and 30 weeks after crop planting. Soil analyses were conducted to assess the influence of edaphic traits on the distribution and abundance of dominant weed species. The results clearly indicated an enrichment of the weed flora with time after planting, but little difference between fallow histories. Two groups of weed species corresponded with soil characteristics: *C. odorata*, *Cyathula prostrata, Mariscus alternifolius, Mikania cordata, Musanga cecropioides,* and *Trema orientalis* were preponderant on soils with high clay, N, and C contents, and *Ageratum conyzoides, Cyperus* sp., *Haumania danckelmaniana, Paspalum conjugatum, Pouzolzia guineensis, Richardia brasiliensis, Sida rhombifolia, Stachytarpheta cayennensis, Talinum triangulare,* and *Triumfetta cordifolia* were preponderant on sandier soils with high pH, P, and Mg contents.

INTRODUCTION

Historically, and particularly for small-scale farmers in the tropics, fallows are a major component of the traditional farming system. They are valued for many purposes, such as restoration of ecosystem soil fertility or as key reservoirs of non-timber forest products which can generate off-farm income. However, one of the most important functions of fallows in poor-farmer agricultural systems is to reduce the weed pressure on subsequent crop fields (Nye and Greenland 1960). Weed pressure is usually less intense when the fallow periods are long enough (more than 5 years) for natural forest vegetation to regenerate because the resulting shade eliminates weeds persisting from the previous cropping cycle (de Rouw 1995, Roder et al. 1995, Ikuenobe and Anoliefo 2003).

In the humid forest zone of southern Cameroon, macroeconomic constraints of the past two decades, coupled with increasing demographic pressure, have led to increased resource use pressure and subsequent shortening of fallow durations. One of the resulting environmental consequences is the invasion of these land-use systems by the Asteraceae species, *Chromolaena odorata* (L.) R. M. King and H. Robinson (Weise 1995, Weise and Tchamou 1999). Shortened fallows dominated by *C. odorata* have gradually replaced the traditional “bush” fallows in the area.

Native to tropical America, *C. odorata* is a perennial shrub forming dense tangled bushes of 1.5–2.0 m height, reaching up to 6 m when climbing up trees (Roder et al. 1995). The plant was introduced to Africa in 1937 and started to spread in the 1970s throughout Central and West Africa, from Senegal in the west to the Central African Republic and the Democratic

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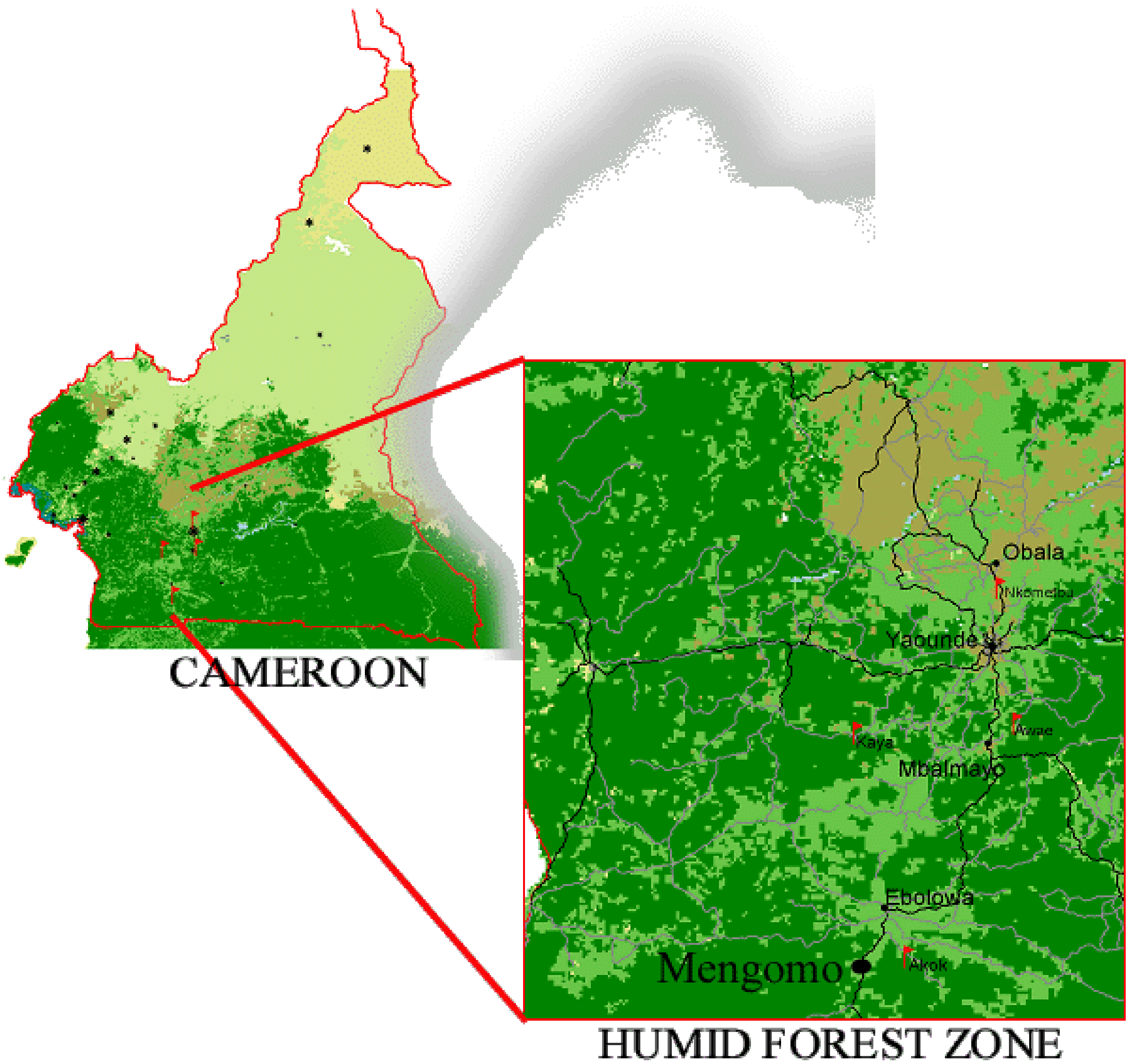
Republic of Congo in the east (Obatolu and Agboola 1993). *C. odorata* was introduced to Cameroon from Nigeria in the early 1960s as a cover crop for cocoa. Nowadays, the plant is usually an aggressive competitor with food crops in southern Cameroon and is one of the dominant weed and fallow species in slash-and-burn farming areas (Roder et al. 1995, Weise 1995, Weise and Tchamou 1999). In the local shifting cultivation system, methods used to control weeds, particularly *C. odorata*, are mechanical and include slashing, hand pulling, and hoeing.

It is often suggested that, as a short-fallow species, *C. odorata* has serious adverse effects on agricultural productivity and on the weed community composition in subsequent food crops (McFayden and Skarratt 1996). However, little is known about the impact of fallow invasion by *C. odorata* on weed communities during the subsequent cropping phase in southern Cameroon. Such knowledge would be an important component of the development of an integrated weed management strategy adapted to the local farming system.

Fig. 1. Map of Cameroon showing the study site (Mengomo) located in the southern part of the humid forest zone.



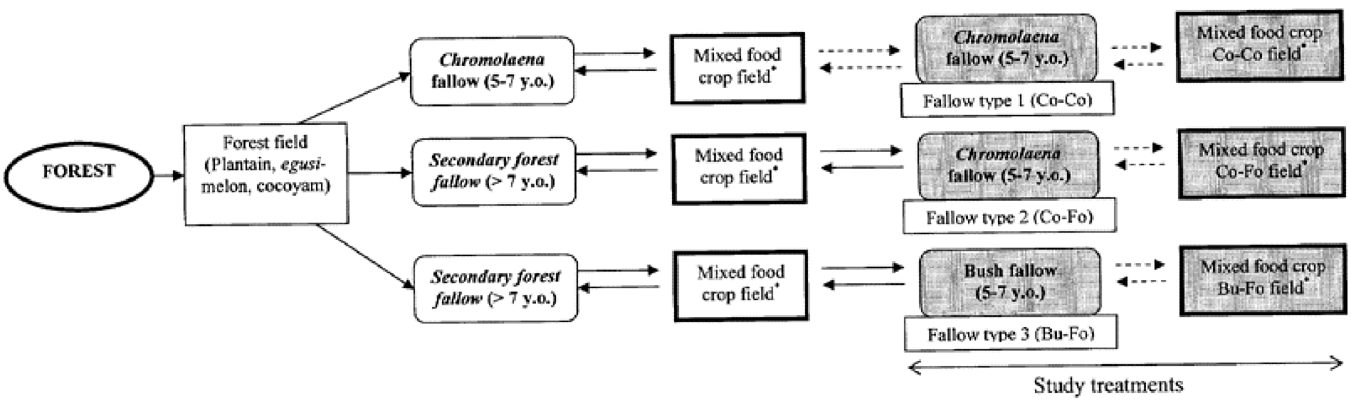
The objective of this study was to examine the impact of fallow vegetation on subsequent weed community composition and dynamics in cropping systems, and to relate this to site edaphic traits, determining whether these are related or not to domination by *C. odorata*.

MATERIALS AND METHODS

Experimental Site

The trial was conducted at Mengomo, a village located in the southern part of the Cameroonian humid forest zone (Fig. 1). Situated at 2°20’N and 11°03’E, Mengomo is a small community (598 inhabitants and 83 households) that lies 52 km south of the city of Ebolowa, along the national highway connecting Cameroon with Gabon and Equatorial Guinea. It is characterized by a hot and moist equatorial climate, with a minimum mean annual temperature of about 20°C and a maximum of 29°C (National Meteorological Station of Yaoundé, mean of 11 years: 1983–1994 in Santoir and Bopda (1995)). The mean annual rainfall is ca. 1800 mm, falling in a bimodal pattern of two rainy seasons (March–July and August–November) and two drier seasons (July–August and November–March) of unequal duration. The main natural vegetation is a mosaic of semi-deciduous tropical forest and fallow fields of various duration and vegetation (Letouzey 1968). The farming system is one of the least intensified among villages of the area, and production is highly oriented toward subsistence.

Fig. 2. Fallow and food crop field types studied in the humid forest zone of southern Cameroon. *The duration of the mixed food crop field is one cropping season, i.e. almost 12 months.



Treatments and Experimental Design

The study was conducted over the cropping season of 1998 (from March 1998 to February 1999), and repeated in 1999 (from March 1999 to February 2000) on farmers’ fields. In August 1998 and 1999, plots were selected according to the field history, especially to the type of short (5–7 years) fallow that preceded the crop, considered in the analyses as “experimental treatments” (Fig. 2).

The selection of 5- to 7-year-old fallows for this study was based on the fact that fallows of 2–3 years are rarely used by local farmers for food crop production (apart from home gardens) because they are believed to favor pest and weed species that can invade subsequent adjacent food crop fields and, also, because of the availability of fallow lands of longer duration in the area (Weise 1995, Ngobo 2002). Fallow lands more than 10 years old are also avoided by local farmers because of the higher labor input required to prepare them for cropping (Gockowski et al. 1998). Therefore, a fallow of 5 to 7 years duration is typical of agricultural land management practice in Mengomo.

Fallow fields for each treatment were randomly distributed throughout the study area and the trial was repeated over two successive years (although on different farmers’ fields). Each year, on average ten fields were selected per fallow type throughout the village. The land-use history and the age of each fallow field were determined from information gathered from the field's owner, and a rapid field inspection was made of the vegetation. Although it was impossible to identify fields with matching cropping histories, every effort was made to include, in each fallow type, only sites for which differences in land-use history were relatively small. In each selected field, uniformity of the vegetation was visually checked, along with evenness of slope and similarity of soil conditions, and plant species composition was recorded (Table 1).

Fallow fields studied in the experiment were of three types: those currently dominated by *C. odorata* that were also dominated by *C. odorata* in the previous fallow rotation (Co–Co); those currently dominated by *C. odorata* that had been forests prior to the preceding cropping phase (Co–Fo); and those currently dominated by bush vegetation (not dominated by *C. odorata*) that had been forests prior to the preceding cropping phase (Bu–Fo).

Table 1. Relative frequency (%) of the most common species found in three types of 5- to 7-year-old fallows at Mengomo in southern Cameroon in 1999

Species	Family	Co–Co*	Co–Fo	Bu–Fo
Aframomum sp.	Zingiberaceae	36	50	75
Agelaea sp.	Connaraceae	27	60	88
Alchornea cordifolia	Euphorbiaceae	82	60	63
Chromolaena odorata	Asteraceae	100	100	63
Cissus sp.	Vitaceae	45	80	100
Clerodendrum sp.	Verbenaceae	73	60	38
Cnestis ferruginea	Connaraceae	73	80	63
Cyperus sp.	Cyperaceae	82	30	50
Desmodium adscendens	Fabaceae	73	60	50
Dichapetalum sp.	Dichapetalaceae	73	70	63
Dioscorea sp.	Dioscoreaceae	100	60	75
Haumania danckelmaniana	Marantaceae	91	80	100
Microdesmis puberula	Euphorbiaceae	18	80	75
Milletia sp.	Papilionaceae	82	80	88
Nephrolepis biserrata	Davalliaceae	45	90	88
Palisota hirsuta	Commelinaceae	64	80	63
Penianthus longifolius	Menispermaceae	36	80	63
Sabicea sp.	Rubiaceae	36	90	88
Tabernaemontana crassa	Apocynaceae	73	50	88
Trichilia sp.	Meliaceae	27	60	88

*Co–Co: *Chromolaena odorata*-dominated fallows that were also *C. odorata*-dominated fallows prior to the previous cropping phase; Co–Fo: *C. odorata*-dominated fallows that were forests prior to the preceding cropping phase; Bu–Fo: Bush fallows (not dominated by *C. odorata*) that were forests prior to the preceding cropping phase.

Field Establishment and Sampling Procedure

In March 1998 and February 1999, the vegetation in each field was cleared according to the local farmers' practice, i.e., using a cutlass. Herbaceous species were cleared first, then shrubs and trees, the stems of which were cut at about 1 m aboveground. Trees were felled 2–3 weeks later (depending on the climatic conditions), followed by an overall burn in each field.

At each site, plots were established in the center of the fallow field and parallel to any visible topographic contour. Each plot consisted of eight contiguous 5 x 5 m grid cells arranged in two parallel strips separated by a 3- to 4-m alley and surrounded by a guard row 1 m wide. Each grid cell included a 3 x 3 m (i.e., 9 m^2) area for weed measurement and final crop harvest. Following local farmers' agricultural practice, mixed food cropping was adopted in this experiment, with cassava (*Manihot esculenta* Crantz) intercropped with maize (*Zea mays* L.) and groundnut (*Arachis hypogaea* L.) (Table 2). Cassava cuttings were planted immediately after burning, at a density of 10 000 stems ha^{-1}, in rows that were 150 cm apart and at a within-row spacing of 150 cm. Plots were then slightly hand-ploughed and groundnut seeds planted between cassava rows. Finally, maize seeds were planted between cassava rows at a density of 40 000 plants ha^{-1} in rows spaced 150 cm apart and within-row spacing of 50 cm, with three seeds per mound. Three weeks after planting, maize was thinned to two plants per mound. No herbicides or fertilizers were applied to the plots.

Table 2. Diary of cultural operations at Mengomo (1998–1999 and 1999–2000 cropping seasons)

	Year 1 1998–1999	Year 2 1999–2000
Cassava cuttings planted	Mid-April	Mid-March
Maize seeds sowed	April 22–May 02	2–7 April
Maize seeds re-sowed (3 plots)	May 10	Not needed
Groundnut seeds sowed	April 22–May 10	2–7 April
Maize and groundnut harvest	Late July (119 DAP*)	Late June (97 DAP)
Cassava harvest	350 DAP (May 1999)	376 DAP (April 2000)

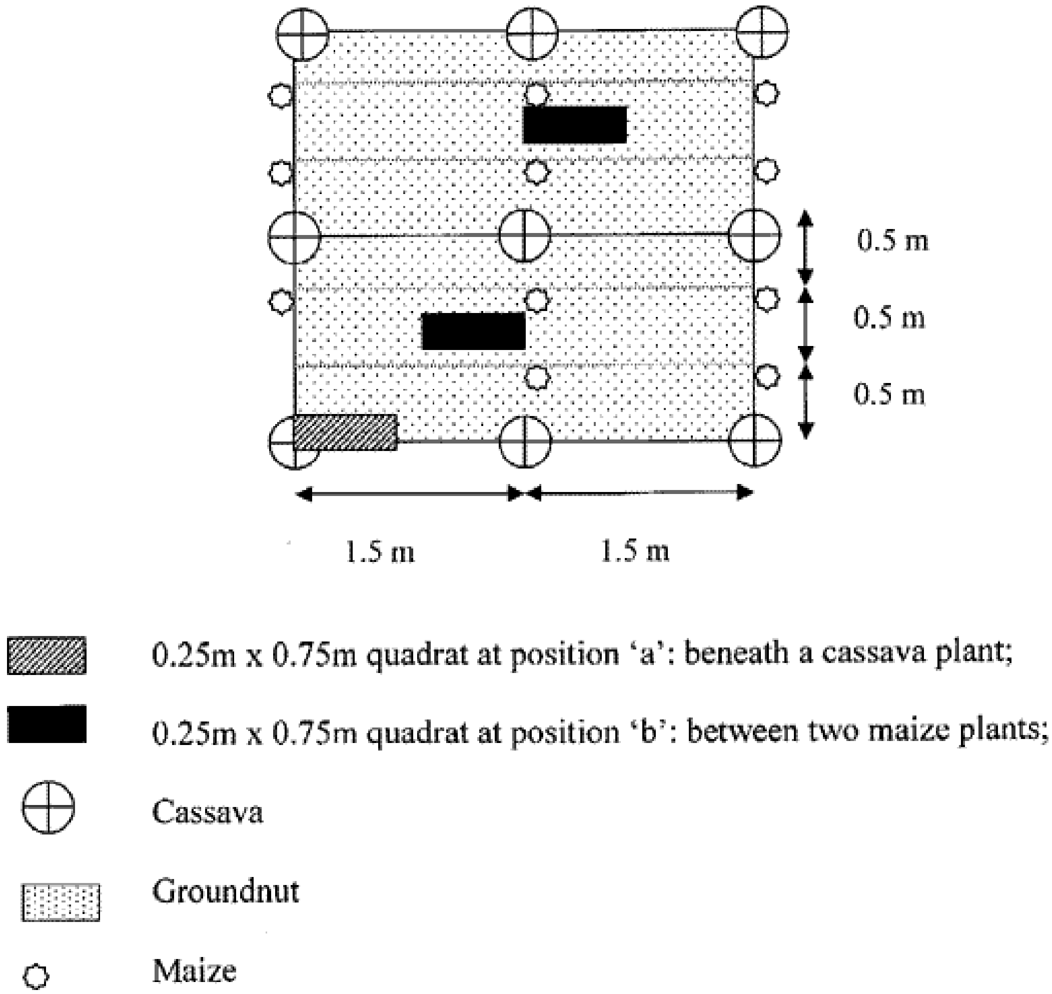
*DAP: days after planting.

Each year, data on weed vegetation were collected 6, 14, and 30 weeks after planting from three 0.25 x 0.75 m quadrats in each 5 x 5 m grid cell (Fig. 3). Quadrats were set up in each grid cell within the harvest area of 9 m^2 in such a way that weeds were assessed once beneath a cassava plant (position "a"), and twice between two maize plants (position "b"). The dimensions of the quadrats (0.75m long and 0.25m wide) were chosen to represent half the distance between cassava rows and half the distance between maize within-rows, respectively (de Rouw 1991). The sampling strategy was adopted based on the assumption that cassava and maize plants will have different effects on the weed flora (de Rouw 1991). However, to simplify interpretation of the results, weed data were averaged for each grid cell before analysis.

For the purpose of this study, weeds were defined following Slaats et al. (1998), as all "invading species" that were present in a plot, but that were not specifically planted. This definition included native and exotic species, as well as crops that were not planted for the experiment.

Two weeks after planting, soil was sampled in each plot at 0–5 and 5–10 cm depth, using a precision bucket auger of 5 cm diameter and 5 cm depth. For each 5 x 5 m grid, six soil cores were collected and pooled for each soil depth, and used for analyses (resulting in a total of 48 cores and eight soil samples per plot for each soil depth). Soil samples were air dried at room temperature and ground to pass a 2-mm sieve. They were analyzed for soil physical properties at the Mbalmayo site of the International Institute of Tropical Agriculture (IITA) and for chemical properties at the Yaoundé site of IITA. Analytical procedures followed Powers et al. (1981) and Motomizu et al. (1983).

Fig. 3. Layout for weed assessment in each grid cell: once at position ‘a’ and twice at position ‘b’.



Data and Statistical Analysis

The trial was analyzed as a completely randomized design with individual fields as experimental units. Some plots were excluded from the evaluation because of excessive shade from surrounding vegetation or unscheduled weedings by farmers. Weed data were averaged for each plot before analysis, and each year was analyzed separately. For each plot, mean weed density for each species in the weed flora was calculated by summing all densities from the 24 quadrats and dividing by 24. Similarly, weed density on a treatment basis was calculated by summing all mean weed densities from all plots in a given treatment, and dividing by the total number of plots per treatment. Weed frequency for each species per plot, expressed as a percentage, was calculated by tallying all quadrats in which the species was present and dividing by 24. In the same way, weed cover for each species per plot was the averaged cover percentage of that species within the plot (i.e., across the 24 quadrats).

Table 3. Average values for soil physical and chemical parameters measured at 0–5 cm depth in mixed food crop fields established after clearing three short-duration fallow types at Mengomo in southern Cameroon in 1999 (mean ± standard error)

	Co–Co*	Co–Fo	Bu–Fo	LSD (á = 0.05)
Bulk density (g cm^{-3})	0.99 (0.02)	1.12 (0.03)	1.04 (0.05)	0.10
Sand (%)	50.09 (1.59)	39.70 (1.95)	41.92 (1.55)	4.99
Clay (%)	39.36 (1.43)	49.83 (2.13)	45.48 (1.97)	5.36
Silt (%)	10.56 (0.49)	10.48 (0.26)	12.60 (0.61)	1.37
pH (H_20)	5.49 (0.10)	4.96 (0.19)	4.39 (0.11)	0.41
Total N (g kg^{-1})	0.17 (0.00)	0.21 (0.01)	0.24 (0.01)	0.03
Total C (g kg^{-1})	2.65 (0.08)	3.14 (0.22)	3.49 (0.18)	0.49
C:N ratio	15.47 (0.21)	14.84 (0.31)	14.73 (0.17)	0.70
P (mg kg^{-1})	28.89 (2.02)	21.59 (2.72)	21.95 (1.18)	6.18
Ca (cmol kg^{-1})	4.20 (0.32)	4.46 (1.19)	2.41 (0.33)	2.15
Mg (cmol kg^{-1})	1.25 (0.06)	1.08 (0.11)	0.75 (0.05)	0.23
K (cmol kg^{-1})	0.29 (0.02)	0.33 (0.02)	0.32 (0.02)	0.06
Al (cmol kg^{-1})	0.05 (0.02)	0.38 (0.12)	0.71 (0.16)	0.32

*See text for treatments codes.

A relative importance value (RIV) was computed as the mean of the relative frequency, relative density, and relative cover percentage for each species per treatment (Wentworth et al. 1984, Bàrberi et al. 1997, Swanton et al. 1999, Ekeleme et al. 2002). The RIV accounts for species number (density), species distribution patterns (frequency), and species contribution to the weed community (cover), thus limiting problems arising from patchiness (Bàrberi et al. 1997), single large individuals, or infrequent species. The RIV values were used to rank each species in the weed flora in order of importance (Swanton et al. 1999, Chikoye and Ekeleme 2001). Weed species with relative frequency values <4% were considered rare and subsequently excluded from further analysis and discussion.

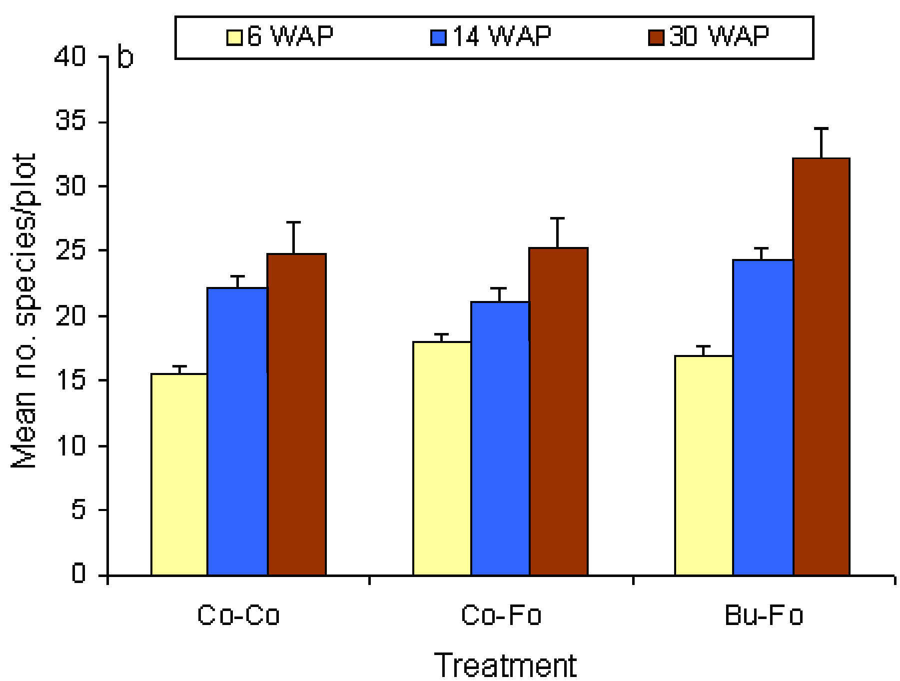
Variation in RIV of the weed flora in the three treatments was assessed by ANOVA (Proc GLM SAS, SAS Institute Inc. 1990), for each sampling time. Comparisons of mean values between treatments were done by least-significant difference test (LSD), at á = 0.05. Before analysis, weed density values were transformed as x = log 10 (x+1) whereas cover values were transformed as y = arcsin $(y)^{-0.5}$ to down-weight large numbers and ensure homogeneity of variance (Sokal and Rohlf 1995). Repeated ANOVA (Proc GLM SAS) was conducted to test within-plot effects of time and between-plot effects of treatments, and the time by treatment interaction.

The effect of site edaphic traits on weed species composition was tested using canonical variate analysis (CVA) within the computer program CANOCO, version 4.0 (ter Braak and Šmilauer 1998). Relative density values of each species were used in the ordination (Chikoye and Ekeleme 2001). These were transformed as log (x+1) before analysis (ter Braak 1995). Canonical variate analysis was used in this study because sites were grouped into classes (i.e., Co–Co, Co–Fo and Bu–Fo sites), and the objective was to determine how the weed species composition differed between sites of different classes. Because CVA seeks a weighed sum of the species abundances that maximizes the ratio of the between-class sum of squares and the within-class sum of squares of the sites along the first ordination axis, the differences between classes are clearer than would be possible on the basis of the abundance values of species taken separately (Jongman et al. 1995). A Monte Carlo test, using 199 permutations, was used to assess the importance of the ordination on the first and second axes, at the 0.05 significance level (ter Braak and Prentice 1988). Ordinations were plotted as site-environment biplots with focus on inter-species distances and Hill's scaling. In the CVA ordination diagrams, distances between site class means represent Mahalanobis distances (ter Braak and Šmilauer 1998). Separate analyses were performed for the 1998 and 1999 experiments, for each sampling date. There was no significant difference in soil properties between the samples taken from 0–5, 5–10 or 10–15 cm depths, so the upper 0–5 cm soil depth values were considered in the analyses.

Scores of the first two CVA axes were subjected to ANOVA (Proc GLM SAS), and the relationship between CVA sample scores on these axes and soil parameters was examined by correlation (Spearman correlation coefficients). Soil parameters that were highly correlated with the derived ordination axes were used for stepwise selection of soil variables to incorporate in the final models, using a cut-off point of $P = 0.10$ (ter Braak and Šmilauer 1998).

Finally, a redundancy analysis (RDA) was performed on all data sets for each sampling time, with scaling focused on inter-species distances and species data centered and standardized. The species–environment tables obtained were examined to determine the strength of association between particular species and a given soil parameter. Species were considered to be correlated to a particular soil parameter when $r > 0.30$, and to be strongly correlated when $r > 0.40$ (Tabachnick and Fidell 2001).

Fig. 4. Mean species richness in mixed food crop fields established after clearing three short-fallow types at Mengomo, southern Cameroon in 1999. Co–Co: *C. odorata*-dominated fallows that had also been *C.odorata*-dominated fallows in the previous cropping rotation; Co–Fo: *C. odorata*-dominated fallows that had been forests prior to the preceding cropping phase; Bu–Fo: bush fallows (not dominated by *C. odorata*) that had been forests prior to the preceding cropping phase. WAP = weeks after planting.



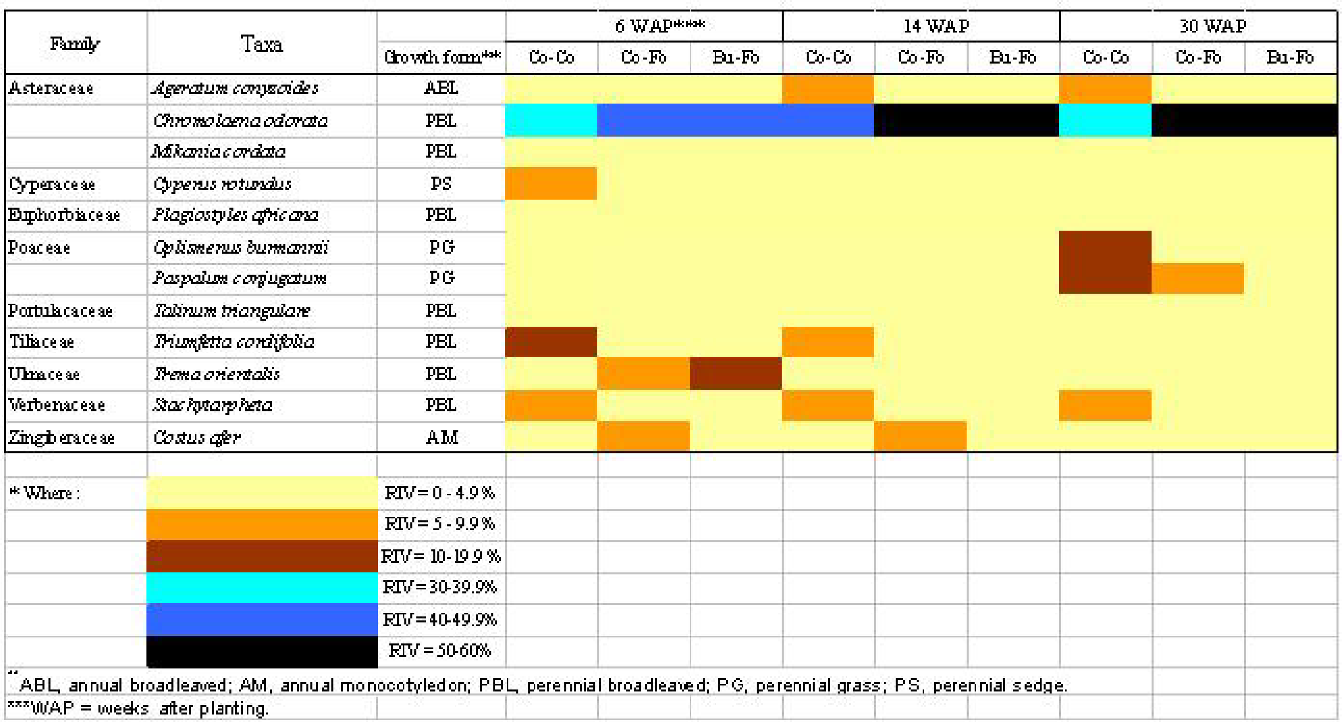
RESULTS

Weed Species Composition

In each year, approximately 200 species, belonging to 61 families, were recorded across all treatments. Grasses and sedges were minor (about 3 and 2% of the weed population, respectively), but broadleaved dicotyledonous weeds (accounting for more than 80%) and monocotyledons other than sedges (nearly 13%) dominated the weed flora. Leguminous species were consistently dominant (37 genera), followed by Euphorbiaceae (16 genera), Asteraceae (14 genera), and Rubiaceae (nine genera).

There was a clear enrichment of the weed flora with time after planting in all treatments (Fig. 4). There was a significantly (P < 0.05, canonical discriminate analysis, Proc CANDISC SAS) richer weed flora in the Bu–Fo treatment with time after planting (Fig. 4) but otherwise no treatment differences in species composition. The Mahalanobis squared distance was slightly higher between Co–Co and Bu–Fo fields, compared with the distance between Co–Fo and Bu–Fo fields, and Co–Co and Co–Fo plots.

Fig. 5. Relative importance value* (%) of weed flora in mixed food crop fields established after clearing three fallow types at Mengomo, southern Cameroon in 1999. Taxa are ordered alphabetically by family and within each family.

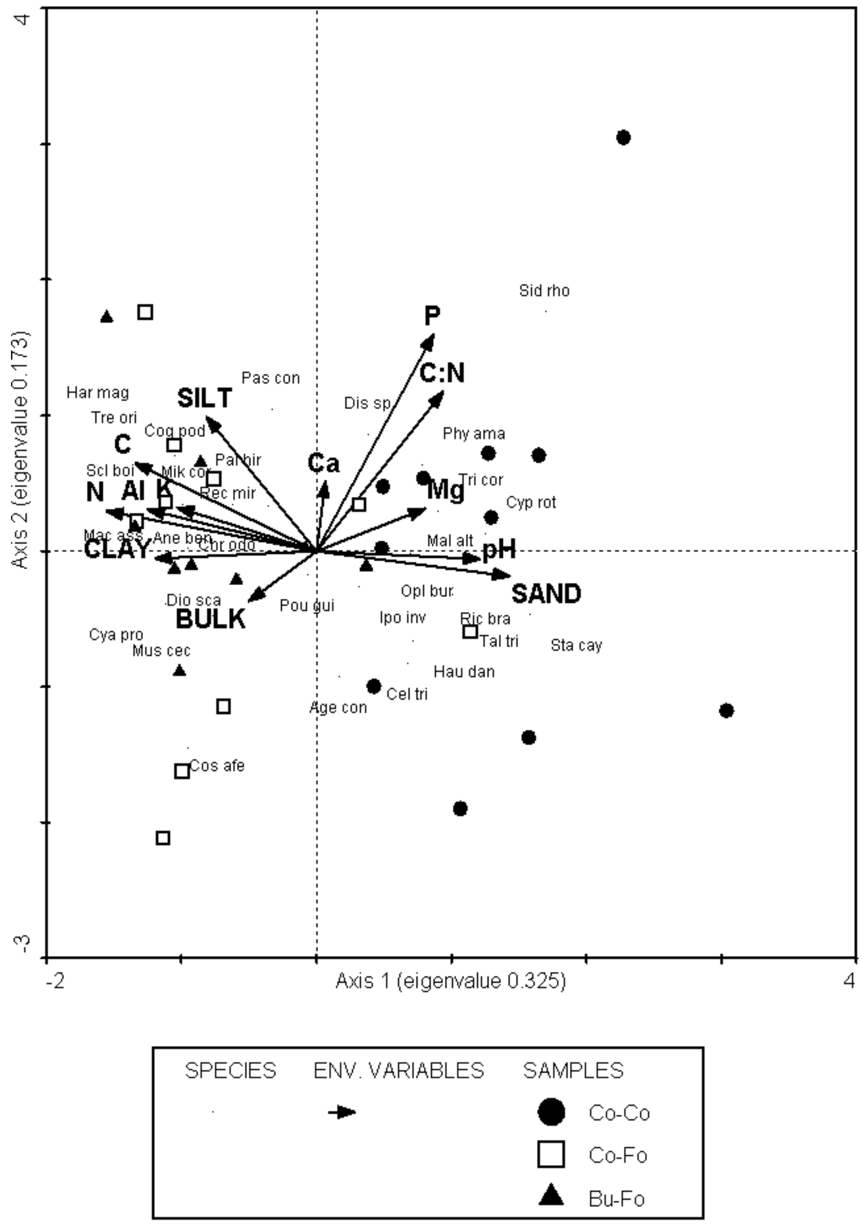


Dominant Weed Species

The clear trend over the 2 years of study is that fields established after clearing a short fallow that had been a forest in the previous cultivation cycle had more weed species than plots established after *C. odorata*-dominated fallows, irrespective of the time of observation: 103 species in Co–Fo and Bu–Fo treatment plots vs. 93 in Co–Co plots.

C. odorata had the highest RIV and was by far the most important weed in terms of density, frequency, and cover across all treatments (Fig. 5). However, dominant weeds associated with *C. odorata* differed between treatments over time. In Co–Co fields, the most important weeds after *C. odorata* (RIV = 30–51), in decreasing order of importance, were *Sida rhombifolia* L., *Stachytarpheta cayennensis* (Rich.) J. Vahl., *Triumfetta cordifolia* A. Rich., and *Ageratum* *conyzoides* L. In Co–Fo and Bu–Fo plots, the most important weeds associated with *C. odorata* were *Trema orientalis* (L.) Blume, *Cogniauxia podolaena* Baill., and *Mikania cordata* B. L. Rob. Grasses did not play an important role in the weed flora of any treatment plots, except toward the end of the cropping period in *C. odorata*-dominated treatment plots.

Fig. 6. CVA ordination diagram of the weed flora at 6 weeks after planting in mixed groundnut–cassava–maize fields established after clearing three different short-fallow types at Mengomo, southern Cameroon in 1999. Species are coded as: Age con = Ageratum conyzoides; Ane ben = Aneilema beninense; Chr odo = Chromolaena odorata; Cos afer = Costus afer; Cyp rot = Cyperus rotundus; Cyp sp = Cyperus sp; Dio sca = Diodia scandens; Hau dan = Haumania danckelmaniana; Ipo inv = Ipomoea involucrata; Mac ass = Macaranga assas; Mik cor = Mikania cordata; Mus cec = Musanga cecropioides; Opl bur = Oplismenus burmannii; Pas con = Paspalum conjugatum; Phy ama = Phyllanthus amarus; Pip umb = Piper umbellatum; Pla afri = Plagiostyles africana; Scl boi = Scleria boivini; Sid rho = Sida rhombifolia; Sta cay = Stachytarpheta cayennensis; Tal tri = Talinum triangulare; Tre ori = Trema orientalis; Tri cor = Triumfetta cordifolia; Tri mau = Tristema mauritiana; Ver con = Vernonia conferta; Xan sag = Xanthosoma sagittifolium. Soil variables are indicated as BULK = bulk density; CLAY = clay content; SAND = sand content; SIILT = silt content; N, C, C:N (C:N ratio), P, pH, Mg, Ca, K, and Al.



Weed Species Composition in Relation to Soil Parameters

Crop fields established after clearing fallows persistently dominated by *C. odorata* (Co–Co treatement) had significantly lower soil clay and silt contents than Co–Fo and Bu–Fo treatment plots ($P < 0.05$) and, consequently, the lowest bulk densities. The difference in soil nutrient content between Co–Fo and Bu–Fo treatment plots was not significant. Soils under Co–Co fields were less acidic than soils under other treatments.

The variation in weed species composition and abundance during the cropping phase in relation to soil physical and chemical characteristics was determined from the position of the centroid and by the direction and length of the vector in the ordination diagram. For reasons of clarity of the diagram, and to make the interpretation easier, we considered only the site–environment biplots from the CVA carried out on 1999 data recorded 6 weeks after planting and soil parameters that were significantly associated (at $P < 0.05$) with the first two ordination axes (Fig. 6).

There was a significant ($P < 0.05$, ANOVA on CVA sample scores) separation of Co–Co plots from the other two treatments. Sample scores on the first ordination axis were correlated with almost all soil parameters, but significantly with N content ($P < 0.0001$), sand content, soil pH ($P = 0.001$), Al, and Mg concentrations ($P = 0.001$ and $P = 0.01$, respectively). Plots that loaded positively on the first axis had low total N and Al concentrations, were sandier and less acidic, and had high Mg concentrations. The second axis was significantly correlated with pH ($P = 0.001$), total C and total N contents ($P < 0.001$ and $P = 0.003$, respectively), and some cation (Ca, Mg, and Al) concentrations.

Based on the strength of their correlation (RDA ordination) with soil parameters, two groups of weed species were identified (Table 4): *C. odorata*, *Cyathula prostrata*, *Mariscus alternifolius*, *Mikania cordata*, *Musanga cecropioides*, and *Trema orientalis* were preponderant on soils with high clay, N, and C contents; *Ageratum conyzoides*, *Cyperus* sp, *Haumania danckelmaniana*, *Paspalum conjugatum*, *Pouzolzia guineensis*, *Richardia brasiliensis*, *Sida rhombifolia*, *Stachytarpheta cayennensis*, *Talinum triangulare*, and *Triumfetta cordifolia* were predominant on sandier soils with high pH, P, and Mg contents.

Soil parameters explained about 47% of the total variance in species dispersion. Only two of the 13 variables significantly influenced the weed species distribution and were retained in the CVA forward selection. These variables were total N and P contents ($P < 0.05$). Thus, the final model explained 27.8% of the variation in weed species dispersion, and the resulting ordination was significant ($P = 0.005$, Monte Carlo test).

DISCUSSION

Weed Species Composition

There were differences in species composition (richness and abundance) of the weed community depending on the type of fallow that preceded the cultivation phase. Weed infestations was less rampant on plots planted following a *C. odorata*-dominated fallow than on fields established following a short fallow not dominated by *C. odorata*. The ability of *C. odorata* to out-compete and suppress weeds has already been reported in previous studies on weed communities in mixed food crop fields in tropical Africa (Akobundu et al. 1992, de Rouw 1995, Roder et al. 1995, Akobundu et al. 1999, Ikuenobe and Anoliefo 2003). The rapid and vigorous growth of *C. odorata* provides rapid ground cover, and its potential allelopathic effects prevent the spread of other weeds. Therefore, *C. odorata*-dominated fallows were more “effective” in controlling weed infestation (especially weed diversity) in subsequent food-crop fields than fallows not dominated by *C. odorata*. Weed suppression is a very important characteristic of a “good” fallow plant (Roder et al. 1995). Easily controlled weeds used as living mulches to suppress more competitively harmful ones constitute an effective weed management strategy and may be responsible for the total absence in the study plots of important nuisance weeds, such as *Imperata cylindrica* Beauv. (Akobundu et al. 1999).

In addition to high weed infestation, a disadvantage of cropping after short fallows was the low weed:forest species ratio. Poor secondary forest regeneration observed in frequently cropped plots (i.e., Co–Co plots) has already been reported by Slaats (1992) and de Rouw (1995) and may be due to a succession of short fallow periods that eliminate the seed and seedling bank of forest plants, thus providing opportunities for annual weeds to produce several crops of persistent seeds. These trends indicate poorer secondary succession in Co–Co fields compared with recently forested Co–Fo and Bu–Fo fields.

Table 4. Correlation coefficients between species density variables and soil parameters and significance levels from the Monte Carlo test (cutoff point *P* = 0.10) in CVA forward selection for weed density data collected 6 weeks after planting from mixed food crop fields established after clearing three different fallow types at Mengomo in southern Cameroon in 1999. Only correlation coefficients >0.30 are reported.

Weed species[a]	Sand	Clay	Silt	Density	pH	N	C	C:N	P	Ca	Mg	K	Al
Group 1													
Chr odo	-0.56	0.50				0.57	0.56					0.33	0.35
Cya pro	-0.37	0.39			-0.32	0.36	0.33					0.31	
Mar alt	0.37	-0.36			0.40	-0.33					0.42		-0.33
Mik cor			0.37								-0.32		
Mus cec	-0.46	0.47							-0.32				
Tre ori	-0.37		0.46		-0.56	0.61	0.60				-0.43		0.61
Group 2													
Age con	0.44	-0.35	-0.33		0.32		-0.31						
Cyp rot	0.46	-0.37	-0.33		0.38	-0.54	-0.40	0.47	0.37				-0.39
Hau dan	0.39	-0.31				-0.44	-0.47						
Pas con					0.34				0.40	0.61	0.49	0.33	
Pou gui					0.42		-0.37	-0.42		0.43	0.45		-0.34
Ric bra	0.38	-0.36		-0.36	0.37	-0.35	-0.34						-0.34
Sid rho	0.34	-0.32			0.49	-0.44	-0.33	0.42	0.38		0.37		-0.37
Sta cay	0.57	-0.50			0.55	-0.53	-0.46		0.31		0.41		-0.45
Tal tri						-0.35	-0.33					-0.49	
Tri cor	0.48	-0.45				-0.39	-0.32		0.45				
CVA forward selection results													
P value	0.37	0.42	0.98	0.07	0.65	0.01	0.30	0.54	0.01	0.39	0.05	0.23	0.66
F-ratio	1.06	1.11	0.33	1.52	0.86	3.80	1.18	0.91	2.26	1.04	1.58	1.19	0.78
Significance	ns	ns	ns	*	ns	*	ns	ns	*	ns	*	ns	ns

[a]Weed species: Age con = Ageratum conyzoides; Chr odo = Chromolaena odorata; Cya pro = Cyathula prostrasta; Cyp rot = Cyperus rotundus; Hau dan = Haumania danckelmaniana; Mar alt = Mariscus alternifolius; Mik cor = Mikania cordata; Mus cec = Musanga cecropioides; Pas con = Paspalum conjugatum; Pou gui = Pouzolzia guineensis; Ric bra = Richardia brasiliensis; Sid rho = Sida rhombifolia; Sta cay = Stachytarpheta cayennensis; Tal tri = Talinum triangulare; Tre ori = Trema orientalis; Tri cor = Triumfetta cordifolia.
* indicates significance at the 0.10 level.
ns = nonsignificant.

In this study, in line with findings of studies on weed community composition in humid tropical zones (e.g., Roder *et al.* 1995, Ikuenobe and Anoliefo 2003), grasses did not play an important role in the weed flora. Fields planted after fallows dominated by *C. odorata* had more sedges and grasses that persisted in the subsequent cropping phase for a longer period than the other treatments. However, grasses and sedges did generally become more predominant in the weed flora toward the end of a cultivation period, more so in fields established after clearing frequently cropped *C. odorata*-dominated fallows. Although Chikoye and Ekeleme (2001) reported a weak relationship between the species from the seedbank and those from the weed flora, the changing weed community composition may be a result of dissimilarity in seedbank composition. Nevertheless, further studies are needed to evaluate the impact of short fallows on the germination of seeds of the dominant weed species identified in this study

The changes in the dominant species have greater significance for weed management than the more subtle shifts in species composition (Johnson and Kent 2002). In intensively cropped short-fallow systems (e.g., Co–Co plots), particularly toward the end of the cultivation phase, the relative shift in dominance from perennial dicotyledons (e.g., *Stachytarpheta cayennensis* and *Triumfetta cordifolia*) to the very difficult to remove sedges (e.g., *Cyperus* sp. and *Scleria boivini* Steud.) creates a significant problem for farmers. The rapid multiplication of these weeds, the very sharp edges of their leaves and the ability of the tubers to lie dormant make it impractical to control infestations by manual means alone.

Influence of Soil Parameters on Weed Species Composition and Abundance

The results of this study indicate that soil physical and chemical properties are significantly correlated with the weed species composition across the three study environments, accounting for up to 28% of the variation in weed species distribution and abundance. According to Zimdahl (1999) and others, this may be attributed to the interaction of positive effects of the fallow vegetation prior to the cropping phase on soil fertility and negative effects of competition for light, water, and nutrients, as well as a potential effect of microclimate (Bazzaz 1996, Légère and Samson 1999, Chikoye and Ekeleme 2001). Different weed communities in soils with different texture than those in this study have also been reported elsewhere (Chikoye and Ekeleme 2001).

At the treatment level, differences in species composition may reflect the adaptation of weeds to specific soil conditions. A high abundance of *Plagiostyles africana* Prain ex De Wild., *Aneilema beninense* Kunth, *Costus afer* Ker-Gawl., and *Piper umbellatum* L. was observed in clay soil with relatively high bulk density and K concentration. *Triumfetta cordifolia*, *Stachytarpheta cayennensis*, *Sida rhombifolia*, and *Talinum triangulare*, which were among the most dominant species in intensively farmed systems (Co–Co and Co–Fo fields), are likely adapted to growing in sandy environments with high pH and Mg concentrations. The low abundance of these latter species on clay soils suggests that they do not grow well on heavy soils.

The centroids for *C. odorata* were located near the center of the ordination diagram, indicating the ubiquitousness of the species, which confirms results from other studies (e.g., Chikoye and Ekeleme 2001, Ikuenobe and Anoliefo 2003). Ability to survive under a diverse set of growing conditions is one of the reasons for the biological "success" of this weed (Slaats 1992). However, the fact that the soil parameters measured in this study significantly accounted for only 28% of the variation in the weed species composition and abundance suggests that the relationship between weed data and soil characteristics may result from the site-to-site variation observed in the study, particularly in the 1999 experiment. Other aspects of weed biology (such as seed size, dispersal, production, germination requirements, seedbank, longevity, seed dispersal at harvest) should also be considered in trying to explain the presence and dominance of certain weed species with regard to short-fallow management type.

CONCLUSION

C. odorata is the dominant weed and fallow species in slash-and-burn agricultural systems of the humid forest zone in Cameroon. Confirming the findings of Roder et al. (1995, 1997) and Ikuenobe and Anoliefo (2003), this study identified some of the properties that render *C. odorata* a "good" fallow plant: namely, fast development during the cropping phase, thus providing a protective cover and allowing better weed suppression than in fallow systems not dominated by *C. odorata*.

However, *C. odorata* in fallows may also present serious negative constraints in repeatedly cropped agricultural systems. Its presence is associated with an increased abundance of "nuisance" weeds (such as *Sida rhombifolia* and *Stachytarpheta cayennensis*), grasses, and sedges that are problematic for the resource-poor farmers of the study area. These species may be better adapted to growing in sandy sites with low soil acidity and high Mg concentrations. The correlation between the soil parameters measured in this study and the abundance of weed species across the three short-fallow types highlights the importance of identifying biophysical factors that may determine fallow weed composition. To better understand the mechanisms involved in the relationship between *C. odorata* and ecosystem performance in tropical forest areas, as suggested by Roder et al. (1995) and Ikuenobe and Anoliefo (2003), future studies on improved fallow systems need to investigate not only the impacts of the presence or absence of *C. odorata*, but also the effect of *C. odorata* on soil properties and nematodes, and its allelopathic effects on weeds and crops.

Responses to this article can be read online at: http://www.ecologyandsociety.org/vol9/iss2/art1/responses/index.html

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