The problem of weeds under continuous cropping systems in the scrub and thicket vegetation belt of the Central Region, Ghana

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SUMMARY

The long term effects of three cropping systems, monocropping, two-course rotation (maize/cowpea or sweet potato) and three-course rotation (maize/sweet potato/cassava), on the quantity and quality of both the above-ground weed flora, and the non-dormant portion of the soil's weed seed bank were studied at the Teaching and Research Farm of the School of Agriculture in Cape Coast. After 14 years of continuous cropping, it was realized that there were no significant differences in species composition of the weed flora among the three cropping systems whilst the rotations were significantly less weedy than monocropping. The intensity of rotation had some influence on the population of monocots which were more abundant in monocropping than in the two-course and three-course rotations, in the order of decreasing population. Fears of a shift from the easy-to-control annuals to the hard-to-control perennials were unfounded. The only problematic perennial found in appreciable numbers was *Cyperus rotundus*. Only seven out of the total of 32 species recorded in the weed flora were found in the non-dormant portion of the seed bank. The two-course rotation with relatively higher tillage frequency had the lowest number of non-dormant seeds followed by monocropping and three-course rotation, in order of increasing populations. An average of 82,539 non-dormant seeds were recorded in an area of 1 m^2 in the top 20 cm of moist soil in the study. The bulk of the seeds was contributed by mostly the short cycle and tufted annual monocots including *Brachiaria lata*, *Dactyloctenium aegyptium* and *Eleusine indica*. It was estimated that only one out of a total of 48,821 non-dormant seeds of *Dactyloctenium aegyptium* could develop and reach maturity. Corresponding figures for *Eleusine indica* and *Brachiaria lata* were one out of 32,240 and 2,896 non-dormant seeds, respectively. *Cyperus rotundus* was the only species in which the quantity of tubers in the seed bank was related to and could be used to predict the level of shoot infestation, regardless of cropping system.

RÉSUMÉ

BUAH, J. N., CARSON, A.G., & HAIZEL, K.A. : *Le problème de mauvaises herbes sous les systèmes de la culture suivie dans la région végétative d' arbrisseau et fourré de la région centrale du Ghana.* Les effets à long terme de trois systémes de culture, la monoculture, l' assolement de deux cultures (le maïs/ la dolique ou la patate douce) et l' assolement de trois cultures (le maïs/la patate douce / le manioc), sur la quantité et la qualité de la flore de mauvaise herbe au-dessus du terrain et la partie non-dormante de la banque de graine de la mauvaise herbe du sol étaient à la fois étudiées au Champs d' Enseignement et de Recherche d' Ecole d' Agriculture de Cape Coast. Après 14 ans de culture suivie, il était constaté qu'il n'y avait pas de différences significatives dans le compositions des espèces de la flore de mauvaise herbe parmi les trois systèmes culturels alors que les assolements étaient considérablement moins couverts de mauvaise herbe que la monoculture. L' intensité de la assolement avait quelque influence sur la population de monocots qui étaient plus abondants en monoculture que dans les assolements de deux et de trois cultures, dans l'ordre de diminution en population. La crainte d' un changement des plantes annuelles facile-à-contrôler aux plantes annuelles difficile-à-contrôler, est dénuée de tout fondemet. La seule plante vivace problématique découverte en quantité appréciable était *Cyperus rotundus*. Seulement sept sur la totalité de 32 espéces de la flore de mauvaise herbe enregistrées se déeouvraient dans la portion non-dormante de la banque de graine. L' assolement de deux cultures avec fréquence de tillage relativement plus élevée avait la moindre quantité de graines non-dormantes, suivi par la monoculture et l'assolement de trois cultures, dans l' ordre d' accroissement de populations. Une moyenne de 82,539 de graines non-dormantes étaient enregistrée dans une superficie de 1 m^2 en 20 cm à partir du haut du sol humide de l' étude. La plus grande partie de graine était fournie surtout par les monocots annuels et touffe et à cycle court, y compris *Brachiaria lata, Dactyloctenium aegyptium* et *Eleusine indica*. Il était estimé qu' une seulement sur la totalité de 48, 821 de graines non-dormantes de *Dactyloctenium aegyptium* pourrait se développer et atteindre la maturité. Les chiffres corresponsdants respectivement à *Eleusine indica* et *Brachiaria lata* étaient un sur 32,240 et 2896 de graine non-dormantes. *Cyperus rotundus* était la seule espèces en quelle la quantité de tubercules dans la banque de graines était liée à et pourrait être utilisée à prédire le niveau d' infestation de la pousse sans regarder le systéme de culture.

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Introduction

Human population in Africa has grown to about 2.5 per cent per annum whilst corresponding growth in food production was 1.3 per cent per annum on the average. This disparity has resulted in serious food deficits and it is a source of concern for both policy makers and researchers (Cleave, 1974).

Ghana is not an exception with much of its food still produced on small holdings at subsistence level under the traditional shifting cultivation with its attendant bush fallowing. With the rising human population and pressure on arable land, the bush fallow period has become shortened to the point that it can no longer restore soil fertility and suppress acute weed infestation. Even though the introduction of mechanized tillage (ploughing and harrowing) has allowed for better control of pre-plant weeds over extensive areas and consequently a more permanent cultivation of the land, there still remains the problem of declining soil fertility and post-plant weed control. Solution to declining soil fertility may be found in the adoption of packages that include crop rotation (involving legumes), use of inorganic fertilizer, utilization of crop residues, ploughing of live mulch and application of organic manure. There is, however, limited knowledge of the effect of continuous cropping systems on the build up of weeds. It is most certain that cropping systems with associated variations in crop type, rotation intensity, tillage and direct weed control frequencies will influence the population dynamics of weeds (Swarbrick & Mercado, 1987) but as to what extent is a matter of conjecture in tropical agriculture.

Investigations were, therefore, carried out, as part of a general exercise in assessing the effects of three cropping systems in terms of productivity, maintenance of soil fertility, and sustainability.

The objectives of the investigations were:

1) To study the long-term effects of continuous monocropping,two-course and three-course rotations on the quality and quantity of both the above, ground flora and the non-dormant portion of the soil's weed seed bank; and
2) To establish relationship between quality and quantity of above-ground flora with that of the non-dormant portion of the seed bank and its potential in predicting future weed infestation in continuously-cropped fields.

Materials and methods

The investigations were carried out during the major growing season of 1991 at the Teaching and Research Farm of the University of Cape Coast, Cape Coast. The site has a climax vegetation described as Coastal Scrub and Thicket and a bimodally distributed annual rainfall with a mean range of 930-1200 mm per annum.

Soils at the site have been classified as belonging to the Benya series under the Edina-Benya-Atabadze-Udu compound association (Asamoah, 1973). The soils have from a depth of 0-20 cm, *p*H ranging from 5.5 to 6.6, organic matter content of 4.36-1.86 per cent, and total cation exchange capacity of 12.2-6.2 mg/100 g of soil.

Cropping systems

The investigations were superimposed on a 14-year-old rotation trial made up of three unreplicated treatments, i.e. cropping systems described as continuous monocropping, three-course rotation and two-course rotation.

Continuous monocropping. Maize was cultivated in the major season followed by bush fallowing in the minor season. The plot received one conventional tillage (ploughing plus two harrowings) per year..

Three-course rotation. Maize was cultivated in the major season followed by sweet potato in the minor season during the first year. In the 2nd year, cassava was planted in the major season and continued to the 3rd year. The cycle was repeated starting from the 4th year. The cropping sequence was thus maize/sweet potato/cassava. There were, therefore, two conventional tillages in the 1st year, a third in the 2nd year and no tillage in the 3rd year making a total of three tillages in 2 years.

Two-course rotation. Maize was grown in the major season followed by cowpea alternating with sweet potato in the minor season of each year. There were two conventional tillages per year.

Maize was usually planted in April in rows 75 cm apart and 40 cm between plants in a row. Cowpea was planted in 60 cm rows and 20 cm between stands in a row. Ridges were made 90 cm apart and vines of sweet potato planted 30 cm apart within the ridge. Spacing for cassava was 1 m apart and 60 cm between stands within the rows.

Sampling of above-ground weed flora

Sampling of the flora was carried out in May 1991. The 'running mean' method as described by Greig-Smith (1960) was used to determine the minimum number of quadrats (sample size) that must be counted in each treatment to provide a true reflection of the composition and population of the weed flora. The procedure was to identify a single weed species dominant in the three treatments which in this case was *Cyperus rotundus*. Counts of shoots were made in batches of increasing number of quadrats (size: 1 m × 1 m). Means of counts for the batches of variable number of quadrats were plotted against the number of quadrats counted in each batch. The number of samples (quadrats) to be counted in each treatment to give a true reflection of the quality and quantity of the weed flora was determined from the point where the curve levels off. In this case, the number of samples to be counted in continuous monocropping, three-course and two-course rotations were found to be 150, 100 and 120 quadrats, respectively.

Floral sampling was carried out by combining the line transect with the quadrat method which Brown (1954) and Greig-Smith (1960) referred to as a 'combination of systematic and random sampling'. The line transect was represented by the edge of a measuring tape stretched across the field. Positioning of the first transect was determined in a random manner and subsequent transects were fixed parallel to the first one at a spacing of 1 m apart. Siting of the quadrats along the transect was also determined in a random manner using a table of random numbers.

At each predetermined spot, the quadrat (1 m × 1 m) was placed firmly on the ground and the weed species and their respective numbers present in the enclosure of the quadrat were counted and recorded. The density of a weed species was determined by dividing the total number of the species recorded in all the quadrats by the total area of all the quadrats sited in the area (Brown, 1954), i.e. Density

$$= \frac{\text{Total number of a species in all quadrats}}{\text{Total area of quadrats sited}}$$

Analysis of variance was carried out on the eight most dominant species to determine whether densities were influenced by the cropping systems.

Sampling of the non-dormant portion of weed seed bank in the soil

An auger, of diameter 5 cm and column height 20 cm, was used to sample soil in the treatments in a random manner along same transects laid out for sampling of the above-ground vegetation. Three soil samples were taken along each alternate transect laid out at 1 m apart. Soil samples collected from each treatment were bulked and thoroughly mixed (Harper, 1977). From the bulk sample, 34 samples of 80 g each were taken. Each soil sample was washed under running tap through two steel sieves with mesh sizes of 212 and 200 μm for about 15 min. The 212-μm sieve was placed on top of the 200-μm one which was meant to trap seeds that escaped from the first sieve. The materials retained in the sieves after washing of each sample were emptied into a petri-dish.

The contents of the petri-dish were stirred and watered every 2 weeks to induce weed seeds to germinate. Emerged weed seedlings were identified, counted and removed at each counting. Those that could not be identified at the seedling stage were coded, counted and specimen were transplanted into poly-bag and nurtured to the flowering stage where they could be identified. Counts of seedlings were extrapolated to kilogram of soil basis.

To provide a common basis for comparing composition and size of the seed bank with that of above-ground weed flora, it was necessary to convert seedling counts per kg of soil to number of seedlings per m^2. This was done by first removing and weighing soil within an area of 1 m^2 and depth of 20 cm. Seedling counts per kg of soil were converted on *pro rata* basis to the weight of volume of soil, in an area of 1 $m^2 \times$ 20 cm. Analysis of variance was carried out on the seed of four weed species present in all the treatments.

Results

Above-ground weed flora

A total of 32 weed species belonging to 13 families were recorded in the three cropping systems. Of the species, 9 were monocotyledons (Family: Poaceae), 22 were dicotyledons and one was a sedge (Family : Cyperaceae).

Monocropping produced the highest total number of weeds, 237 per m^2 as against 125 and 122 per m^2 in the three-course (maize/sweet potato/cassava) and two-course (maize/cowpea or sweet potato) rotations, respectively (Table 1). It was also realized that monocropping had twice as many dicots (dicotyledons) and over 40 per cent more monocots (monocotyledons) than found in the rotations. Again, monocropping was more infested with the sedge *Cyperus rotundus* than the rotations.

Among the monocots, *Brachiaria lata* was the predominant species whilst *Boerhavia diffusa* was the most abundant dicot.

Results of statistical analyses of the densities of eight commonest species showed that there were significantly more weeds in monocropping that in the rotations. Difference in weed density between the two rotations was not significant. On the whole, density of each of the eight species was relatively higher in monocropping than in any of the rotations with the exception of *Cynodon dactylon* and *Ipomoea involucrata* (Table 1).

Size and composition of the non-dormant portion of the soil's weed seed bank

A total of seven weed species was recorded in the non-dormant portion of the soil's seed bank in the three cropping systems (Table 2).

Generally, the numbers of non-dormant seed of monocots far exceeded those of the dicots and sedges in all the three cropping systems. *Brachiaria lata* was relatively more abundant in the seed bank that *Dactyloctenium aegyptium* and *Eleusine indica*, with mean seed number/kg of soil values of 342, 293 and 248, respectively. The three-course rotation had the highest number of non-dormant seeds of 1,895 per kg soil as against 1,369 and 901 seeds per kg soil for monocropping and two-course rotation, respectively. There were also variations among the cropping systems in the numbers of non-dormant seed of the various weed species in the seed bank. *Brachiaria lata* seed in the three-course rotation was five times as numerous as in the monocropping and two-course rotation, whilst seed of *Dactyloctenium aegyptium* was four-fold and three-fold more numerous in monocropping than in the three-course and two-course rotations, respectively.

For the dicots, it was only *Tridax procumbense* seed that was present in all the three cropping systems. The only sedge *Cyperus rotundus* was

TABLE 1

Population of the Eight Common Weed Species and Others less important present in the Above-ground Flora of all Three Cropping Systems per 1 m²

Weed species	*Mono-cropping*	*Three-course rotation*	*Two-course rotation*	*Means*
DICOTS				
Tridax Procumbense L.	11.0	0.4	2.2	4.9
Centrosema pubescence L.	5.1	2.6	1.1	2.9
Ipomoea involucrata Beauv.	0.4	0.6	0.6	0.5
Boerhavia diffusa L.	32.7	11.4	10.0	18.0
SUB TOTAL (DICOTS)	49.2	15.0	13.9	
MONOCOTS				
Brachiaria lata Schumach	83.4	38.0	26.0	49.1
Cynodon dactylon (L.) Pers.	0.8	4.2	1.0	2.0
Commelina bengalensis L.	2.7	1.5	0.9	5.1
SUB TOTAL (MONOCOTS)	86.9	43.7	27.9	
CYPERACEAE				
Cyperus rotundus L.	65.5	27.3	40.9	44.6
TOTAL	201.5a*	86.0b	82.7b	
OTHER DICOTS				
Amaranthus spinosus L.	16.7	0.1	-	
Synedrella nodiflora Gaerth.	2.7	-	-	
Merremia aegyptia L.	8.4	-	-	
Crotolaris retusa L.	0.7	-	-	
Cassia mimosoides L.	0.3	-	-	
Sida erecta Burm.	0.1	1.9	-	
Sida acuta Burm.	-	0.2	-	
Cassia obtusifolia L.	1.5	1.3	-	
Sesamum undicum L.	0.5	-	-	
Acanthospermum hispidum DC.	0.8	0.4	-	
Acalyphaciliata forsk	-	12.0		
Phyllanthus amarus Schum.	-	1.8	5.8	
Craton lobatus L.	-	2.2	1.2	
Urena lobata L.	0.1	-	-	
Talinum triangulare Jacq.	1.9	0.1	-	
Mormodia charentia L.	-	-	0.6	
Stachytarpheta indica L.	-	-	1.2	
Desmodium scorpiurus L.	0.1	-	-	
SUB TOTAL	33.8	20.0	9.4	
OTHER MONOCOTS				
Dactyloctenium aegytium L.	-	-	7.6	
Eleucine indica L.	-	0.8	8.7	
Chloris pilosa Schumach	-	10.3	12.3	
Panicum maximum Jacq.	-	7.0	0.3	
Imperata cylindrica (L.) Raeuschel	0.4	0.4	-	
Sporobolus pyramidalis L.	1.8	0.5	-	
SUB TOTALS	2.2	19.0	28.9	
GRAND TOTAL	237.5	125.0	121.0	

*Means between columns and followed by similar letters are not significantly different at $P = 0.05$, according to Duncan's Multiple Range Test.

present in the seed banks of all the cropping systems, being more prevalent in monocropping than in the rotations.

Results of analysis of variance on quantities of the four weed species present in all the cropping systems showed that *Brachiaria lata* had significantly more seeds in the seed bank than *Tridax procumbense* and *Cyperus rotundus* (Table 2). The difference between *Brachiaria lata* and *Dactyloctenium aegyptium* was, however, not significant and likewise was the difference between *Dactyloctenium aegyptium* and *Tridax procumbense.*

Quantitative and qualitative relationship between above-ground flora and the non-dormant portion of soil's seed bank

It was evident that the quantities of non-dormant seeds of the weeds were far greater than their corresponding shoot numbers in the above-ground flora (Table 3). On the average, the shoot to seed ratio was 1:4,500 implying that only one out of a possible 4,500 non-dormant seeds in the seed bank succeeded in reaching the shoot stage. *Brachiaria lata, Tridax procumbense* and *Cyperus rotundus* were the only weeds found present in both above-ground flora and seed bank of all the cropping systems. The most abundant

TABLE 2

Total Number of Non-Dormant Weed Seeds per kg Soil in the Seed Banks of the Three Cropping Systems

Weed species	*Mono-cropping*	*Three-course rotation*	*Two-course rotation*	*Means*
DICOTS				
Tridax procumbense	286.1	167.6	126.2	193.3bc*
Amaranthus spinosus	-	-	124.5	41.5
Chromolaena odorata	264.8	285.6	-	183.5
MONOCOTS				
Brachiaria lata	157.6	744.1	123.9	341.9a
Dactylotenium aegyptium	558.8	138.9	182.5	293.4ab
Eleusine indica	-	491.2	252.8	248.0
CYPERACEAE				
Cyperus rotundus	102.6	68.0	90.7	87.1d
TOTAL	1369.9	1895.4	900.6	1388.6

*Means within column and followed by similar letters are not significantly different at $P = 0.05$, according to Duncan's Multiple Range Test.

weed species in both flora and seed bank was *Brachiaria lata*. Although *Tridax procumbense* had twice as many seeds as *Cyperus rotundus* in the seed bank, it was less abundant than *Cyperus rotundus* in the above-ground flora.

There was considerable variation and inconsistency in the distribution of non-dormant seed of some of the weeds in the three cropping systems (Fig. 1). For instance, whilst *Amaranthus spinosus* was present in an insignificant proportion in the above ground flora of the three-course rotation and totally absent in the flora of the two-course rotation, its non-dormant seed was only found in reasonable quantities in the two-course rotation. Similarly, even though *Dactyloctenium aegyptium* was only present in the flora of the two-course rotation, its non-dormant seed was present in relatively large numbers in seed banks of all the cropping systems.

Distribution of shoots and seeds of *Cyperus rotundus* and *Eleusine indica* was more consistent. *Cyperus rotundus* was found in large numbers in the flora and in relatively fewer numbers in the seed bank of the three cropping systems. *Eleusine indica* was present in both flora and seed banks of the rotations.

TABLE 3

Comparison between Population of Weed Species in Above-Ground Flora and their corresponding Number of Non-Dormant Seeds in the Seed Bank on per m² Basis

Weed species	*Above-ground flora*				*Weed seed bank*			
	Mono-cropping	*Three-course rotation*	*Two-course rotation*	*Means*	*Mono-cropping*	*Three-course*	*Two-course rotation*	*Means rotation*
Tridax procumbense	11.0	0.4	2.2	4.5	119017	69722	52499	80413
Amarathus spinosus	16.7	0.1	-	5.6	-	-	51792	17264
Brachiaria lata	83.4	38.0	26.0	49.1	65561	309545	51542	142217
Dactylotenium aegytium	-	-	7.6	2.5	232460	57782	75920	122054
Eleusine indica	-	0.8	8.7	3.2	-	204339	105165	103168
Cyperus rotundus	65.4	27.3	40.9	44.5	42682	28339	37731	36234
Chomolaena odorata	-	-	-	-	110157	118809	-	76322
Cropping system means	29.4	11.1	14.2		81411	112687	53521	

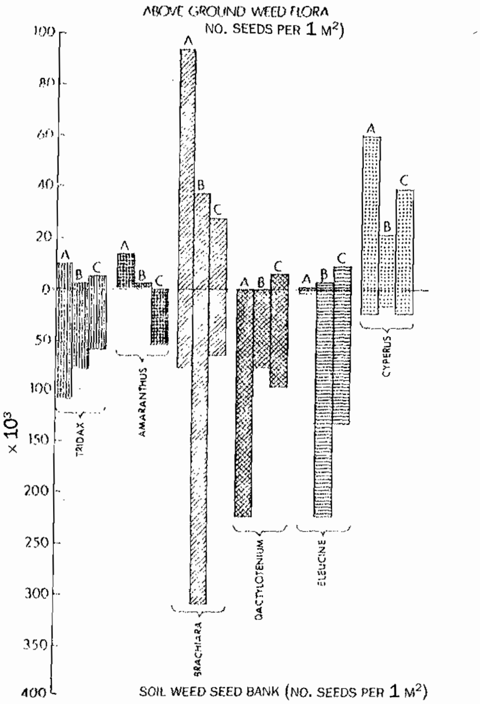

Fig. 1. Comparison between population of weed species in above-ground flora and their corresponding number of non-dormant seed in the seed bank on per m² basis.

Discussion

The quantity and quality of weed flora in arable land were known to be governed by two interdependent factors of 'Weed Seed Rain' and 'Weed Seed Bank'.

By definition, 'Weed Seed Rain' represents seeds shed by previous and existing weeds and those dispersed from other areas through the action of wind, water, human-beings and animals. The 'Weed Seed Bank' refers to a reservoir of very large number of viable weed seeds and vegetative propagules in the soil and it is derived from the 'Weed Seed Rain' (Swarbrick & Mercado, 1987). It was expected then that the three cropping systems with their associated varying crop types, frequencies of tillage, and direct weed control measures could influence the quality and quantity of the weed flora by controlling which species of weeds flowered and contributed to the 'Weed Seed Bank'.

Results have shown that in the long term (14 years), the three-course and two-course rotations were less significantly infested by weeds than monocropping. While these results were in agreement with those of Moody (1980) that intensive rotation systems decreased weed infestations, they contradicted his other claim that the species composition was equally affected by intensive rotations.

Four causes could account for the relative weediness in continuous monocropping. Firstly, the monocropping system was less intensively tilled (once a year) compared to the three-course rotation (three tillages in 2 years) and the two-course rotation (two tillages in 1 year). Consequently, the weeds in monocropping had more opportunity to mature and contribute seed to the seed bank. Frequent tillage was also supposed to induce more seeds in the soil to germinate thus depleting the seed bank as well as the quantity of seed being added to the seed rain (Koch & Beshir, 1982). Thirdly, the rotations were less infested with weeds because of their attendant frequent direct weed control measures that prevented most weeds from contributing to the seed bank. Finally, rotations in general with their succession of different crops were known to break the life cycles of some weeds and prevented them from contributing to the seed rain (Moody, 1980). Such effect was expected to be more pronounced in the case of the two rotations where the succeeding crops of cowpeas and sweet potato had spreading and prostrate growth habit and, therefore, could suppress weeds, reduce their reproductive capacity and subsequently reduce their seed bank populations (Evans, 1957; Pablo, 1983).

It was clearly evident that the intensity of rotation had some influence on the population of monocots in the flora. Monocots were more abundant in monocropping than in the two-course and three-course rotations, in the order of decreasing population. A plausible reason might be that part of their life cycles was similar to maize, which was cultivated once every year in both systems, and this helped the monocots to evade direct weed control measures such as slashing, hoeing and the use of herbicides (Pablo, 1983). Conversely, since maize was cultivated less frequently in the three-course rotation, the monocots were more often exposed to direct weed control action.

The only exceptions were *Cynodon dactylon* and *Ipomoea involcrata* whose populations were rather lower in monocropping than in the rotations. It was logical to expect these species which reproduce vegetatively by stolons to be more abundant in the rotations because of the more frequent tillage and, therefore, more fragmentation of stolons. This was not true of all species which rely on vegetative means of reproduction, such as *Cyperus rotundus*, which was rather more abundant in monocropping than in the rotations. It would seem as though frequent tillage reduced the populations of *Cyperus rotundus* by preventing the formation of fresh tubers through continuous depletion of the carbohydrate reserves of existing tubers, and by exposing others to dessication, as was reported by Swarbrick & Mercado (1987).

Fears of a shift from the easy-to-control annual weeds to the problematic perennials in soils under continuous cultivation were not justified. The only troublesome weed of note was the perennial *Cyperus rotundus* and that even constituted only 28, 22 and 33 per cent of the total weed population in monocropping, three-course and two-course rotations, respectively.

Only seven out of a total of 32 species recorded in the above-ground flora were found in the non-dormant or viable portion of the seed bank. Possible reasons for the absence of most of the weed species in the non-dormant portion of the seed bank were that the seeds and vegetative propagule of the absent species were either held in a state of dormancy by forces within and outside its immediate surroundings (Swarbrick & Mercado, 1987) and/or had not served a required after-ripening period. *Chromolaena odorata* was, on the other hand, recorded in the seed bank but found totally absent in the above-ground flora, suggesting that the seeds could have been brought in from outside the area by dispersal agents (Harper, 1977).

An average total of 82,539 non-dormant seeds were recorded in an area of 1 m^2 in the top 20 cm of moist soil in the present study. Comparative figures obtained in the Philippines and USA were 80,400 and 130,000 seeds, respectively (Swarbrick & Mercado, 1987). Estimates from the present study were, therefore, well within range of values obtained elsewhere in soils under continuous cultivation.

The quantity of seed in the seed bank appeared to depend on the frequency of tillage, with the more intensively tilled two-course rotation having less weed seeds than the less frequently tilled monocropping and three-course rotation. This was in line with the assertions by Brenchley & Warrington (1933) and Moody (1990) that intensive rotation could serve as weed control mechanism by preventing some weeds from reaching maturity.

Monocots were more numerous in all the seed banks comprising of 72, 62 and 53 per cent of the total seed numbers in the three-course, two-course rotations, and monocropping, respectively. The bulk of the seed was in each case contributed by mostly the short cycle and tufted annual monocots including *Brachiaria lata*, *Dactyloctenium aegyptium* and *Eleusine indica*. While the mean densities of shoots of these weeds ranged from 2.5 to 49.1 per m^2 in the above-ground flora, their corresponding numbers of non-dormant seeds in the seed bank were from 103,168 to 142,217. It was expected for instance in the case of *Dactylotenium aegyptium* that out of a total of 48,821 non-dormant seeds in the seed bank, only one cound develop and reach maturity. Corresponding figures for *Eleusine indica* and *Brachiaria lata* were one mature plant out of 32,240 and 2,896 seeds, respectively. The figures were not exceptionally high since a single plant of *Eleusine indica* was known to produce and add 50,000 seeds to the seed bank (Swarbrick & Mercado, 1987) while one

Amaranthus spinosus plant was estimated to add over 200,000 seeds to the seed bank (Holm *et al.*, 1977).

The general lack of positive relationship between the quantity of shoots in the flora and the quantity of non-dormant buds in the seed bank among most of the weeds meant that weed infestations could not be reliably predicted from the sizes of the non-dormant portion of the seed bank. One probable cause of this was that even after a seed had successfully germinated, its survival still depended on other variable factors such as suitability of the environment, competing plants, attacking insects, diseases, rodents and other natural causes.

Cyperus rotundus was the only exception in which the quantity of tubers in seed bank was related to and could be reliably used to predict level of shoot infestation, regardless of cropping system.

In conclusion, it could be stated that continuous cropping using conventional tillage practices could be done for long periods without causing undersirable shifts in the weed fauna. Crop rotations were on the whole more desirable than monocropping in terms of severity in weed infestation and the more intensive the rotation, the lower the level of weed infestation. Levels of non-dormant seeds in the soil's seed bank could not be reliably used in predicting weed infestations except in the case of *Cyperus rotundus*.

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