Effect of tillage and environment on weed population dynamics in the dry tropics[1]

Ian A. Zelaya[2], Micheal D.K. Owen[3], and Abelino Pitty[4]

Abstract: This investigation assessed the effects of two tillage systems and the seasonal distribution of precipitation and temperature on weed population dynamics in the dry tropics. A field that had been under either conventional tillage (CT) or no tillage (NT) for at least five years was used for the study. Weed populations were estimated every month from June 1995 to December 1996. Weed population heterogeneity was estimated with the Shannon and Wiener function and correlations between weed emergence and temperature or precipitation were calculated. The weed community consisted of 45 species distributed in 39 genera and 17 families. Higher weed populations occurred during the rainy season compared to the dry season and total weed emergence correlated well with the distribution of precipitation. *Cyperus rotundus* L., *Cynodon dactylon* (L.) Pers., *Commelina diffusa* Burn. f., *Ageratum conyzoides* L., *Crotalaria pallida* Aiton., *Nicandra physalodes* (L.) Gaertner, and total weed populations were higher in CT. *Aeschynomene americana* L., *Cenchrus echinatus* L., *Digitaria* spp., *Eleusine indica* (L.) Gaertner, *Euphorbia hirta* L., *Richardia scabra* L., *Kallstroemia maxima* (L.) Torr. & Gray., and total grass populations were higher in NT. In addition, NT had a more heterogeneous distribution of species thus suggesting that tillage reduces the diversity of weeds. Importantly, perennial weeds which require fragmentation for dissemination and establishment were more prevalent in CT.

Index words: Glyphosate, Hutcheson test, paraquat, seasonal distribution, Shannon and Wiener diversity index, weed emergence.

Resumen: Esta investigación evaluó el efecto de dos sistemas de labranza y la distribución estacional de la precipitación y temperatura en la dinámica poblacional de malezas en el trópico. Un campo de 6.5, manejado bajo labranza convencional (LCO) y labranza cero (LCE) por al menos cinco años fue usado para la investigación. Las poblaciones de malezas se estimaron mensualmente desde junio de 1995 hasta diciembre de 1996. La heterogeneidad de la población de malezas en LCO y LCE fue estimada mediante la función de Shannon y Wiener y se calcularon las correlaciones entre la emergencia de malezas y la temperatura o precipitación. La comunidad de malezas consistió de 45 especies distribuidas en 39 géneros y 17 familias. Más malezas existieron en la estación lluviosa comparado a la estación seca y la emergencia total de malezas correlacionó bien con la distribución de la precipitación. *Cyperus rotundus* L., *Cynodon dactylon* (L.) Pers., *Commelina diffusa* Burn. f., *Ageratum conyzoides* L., *Crotalaria pallida* Aiton., *Nicandra physalodes* (L.) Gaertner, y la población total de malezas fueron mayor en LCO. *Aeschynomene americana* L., *Cenchrus echinatus* L., *Digitaria* spp., *Eleusine indica* (L.) Gaertner, *Euphorbia hirta* L., *Richardia scabra* L., *Kallstroemia maxima* (L.) Torr. & Gray., y la población total de gramíneas fueron mayor en LCE. Adicionalmente, LCE tuvo una distribución más heterogénea de las especies sugiriendo que la labranza reduce la diversidad de malezas y favorece la reproducción de malezas perenes que requieren de fragmentación para su diseminación y establecimiento.

Palabras claves: Distribución estacional, emergencia de malezas, glifosato, índice de diversidad de Shannon y Wiener, paraquat, prueba de Hutcheson.

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INTRODUCTION

Weeds are an important agricultural pest complex that has coexisted with humankind for many centuries. In the tropics, humans spend more time removing weeds and weeds cause more yield reductions than in any other part of the world (Akobundu, 1987). Many farmers practice subsistence agriculture in the tropics and weed management consists of labor intensive practices that often result in only limited control, partially to the facts that tropical agriculture is technologically undeveloped compared to temperate regions and that professionals to conduct weed research are scarce (Young *et al.*, 1978; Doll, 1980). In addition, little is understood about the diverse aspects that govern the regenerative processes and emergence patterns of plants in the tropics (Kellman, 1974). Research investigating germination characteristics and emergence patterns of common weeds will improve our understanding of weed reproductive behavior and could help the development of alternative control tactics. The objective of this study was to assess the effect of precipitation, temperature, and tillage on weed population dynamics in a dry tropical environment.

Plant population dynamics. Tropical regions are characterized as having more abundant and varied plant life than other parts of the world (Krebs, 1985). Population dynamics refer to shifts in the plant community composition over time and these changes relate to the number of species and the relative abundance of each species in a habitat. Community heterogeneity refers to the relative variability of species in a particular area. Heterogeneity is higher in communities having a large number of species and an equivalent distribution of these species (Krebs, 1985).

The weed community is largely influenced by humans (Young and Evans, 1976). Agricultural production is oriented to monocropping and weeds increase the diversity of these agroecosystems by competing for, and using the environmental resources assigned for crop production. The composition of the weed flora in a particular agroecosystem reflects the climate, edaphic characteristics and past agronomic practices (Roberts, 1981; Froud-Williams *et al.*, 1983a; Zimdahl *et al.*, 1988). Agronomic practices that affect the weed flora include tillage and herbicide application (Wrucke and Arnold, 1985).

Effect of tillage on community heterogeneity. Tillage practices alter the agroecosystem and tend to change the weed community heterogeneity. Several experiments indicated that a reduction in tillage will increase species diversity. Cardina *et al.* (1991) found that the number of species in permanent grass sods was higher than in CT plots. NT may increase the diversity of annual grasses and small-seeded annual weeds but may also decrease the diversity of some annual dicotyledonous weeds (Pollard and Cussans, 1981; Pollard *et al.*, 1982). Large-seeded annual dicotyledonous species are more frequent in CT than in NT (Froud-Williams *et al.*, 1983b).

Some perennial species may also be a problem in reduced tillage because the root system is not disturbed and most herbicides are not effective on established perennial plants (Triplett, 1985). Froud-Williams *et al.* (1981) indicated that NT favors the establishment of some rhizomatous and stoloniferous perennials. Buhler *et al.* (1994) found greater and more diverse perennial weed populations in reduced tillage systems compared to a moldboard plow system.

Studies in Central America found higher diversity indices in NT weed communities than in CT (Monroy *et al.*, 1993; Godoy *et al.*, 1995). Monroy *et al.* (1993) concluded that broadleaf weed populations were more diverse in NT while grass populations were more diverse in CT. These investigations demonstrated that under tropical conditions, CT reduces the total number of species and favors the establishment of perennial species that require fragmentation for dissemination and establishment (Monroy *et al.*, 1993; Zelaya *et al.*, 1994; Godoy *et al.*, 1995).

Effect of tillage on seedling emergence and seed bank. The effect of tillage on weed emergence is not clear. Some studies indicate that more seedlings and faster emergence occurs in tilled plots (Roberts and Neilson, 1981; Bridges and Walker, 1985), whereas other studies found more emergence without tillage (Cardina *et al.*, 1991; Mohler and Callaway, 1992). Additionally, the effect of tillage varies among species (Buhler and Daniel, 1988), sites (Froud-Williams *et al.*, 1983a; Buhler and Mester, 1991) or between years of research (Wilson, 1981; Wilson, 1985). Dick and Daniel (1987) estimated that tillage systems require from four to ten years to reach weed population and soil characteristics equilibrium.

Weed emergence attributable to tillage practices represent a small percentage of the seed bank reserves (Roberts, 1963; Roberts and Potter, 1980). Cultivation two to four times a year promoted the emergence of 7% of the viable seeds in the top 23 cm of the soil (Roberts and Potter, 1980) and intensifying the frequency of cultivation increased weed emergence to only 10% (Roberts, 1963). Weed emergence attributed to tillage may be explained because of exposure of dormant seed to radiant energy, improved soil aeration, or loss of volatile soil germination inhibitors (Egley, 1986; Zimdahl *et al.*, 1988).

Roberts (1968) calculated that tillage reduced the seed bank 30% to 60% annually and predicted that the seed bank reserves could be depleted in 30 years. Replenishment of the seed bank is accelerated if weeds are not efficiently controlled (Moss, 1985; Burnside *et al.*, 1986) and if escaping weeds produce large numbers of seeds (Cavers and Benoit, 1989).

Seeds in NT are found near the surface (Pareja *et al.*, 1985; Triplett, 1986) and as depth increases, the concentration of weed seeds declines logarithmically. Yenish *et al.* (1992) indicated that more than 60% of all weed seed could be found in the top 1 cm of NT soils. This seed surface accumulation may favor the establishment of annual species because weed emergence from the soil surface is less difficult (Herr and Stroube, 1970; Aldrich, 1984).

CT practices mix the soil and tends to provide uniformity to the vertical distribution of the seed bank (Roberts, 1981; Cardina *et al.*, 1991). Tillage buries seeds, induces dormancy and increases seed longevity in the soil (Roberts and Dawkins, 1967; Stoller and Wax, 1974). Small seeded species with prolonged dormancy periods survive longer with deeper seed burial (Zimdahl *et al.*, 1988; Mester and Buhler, 1990). Hard seed coats may also enhance soil seed survival after burial (Stoller and Wax, 1974), however, subtle variations in soil environmental conditions may influence their survival period (Conn, 1990). Knowledge of seed survival can be used to predict the severity of future weed problems and to estimate the feasibility of eradicating a particular weed by eliminating seed production (Roberts and Feast, 1972; Dawson and Bruns, 1975).

MATERIALS AND METHODS

The experiment was located at El Zamorano, in the Yegüare Valley, Francisco Morazán, Honduras. This area has a mean elevation of 800 m above sea level, an average temperature range of 18 °C to 29° C and annual mean precipitation of 1100 mm. The region is characterized as a dry tropical environment where the dry season extends from December to May, and the rainy season from June to November. The mean accumulated precipitation for each month and maximum and minimum temperatures during 1995 and 1996 are presented in Figure 1. The research was conducted on San Nicolás, a maize (*Zea mays* L.) production field managed by the Department of Agronomy of Zamorano.

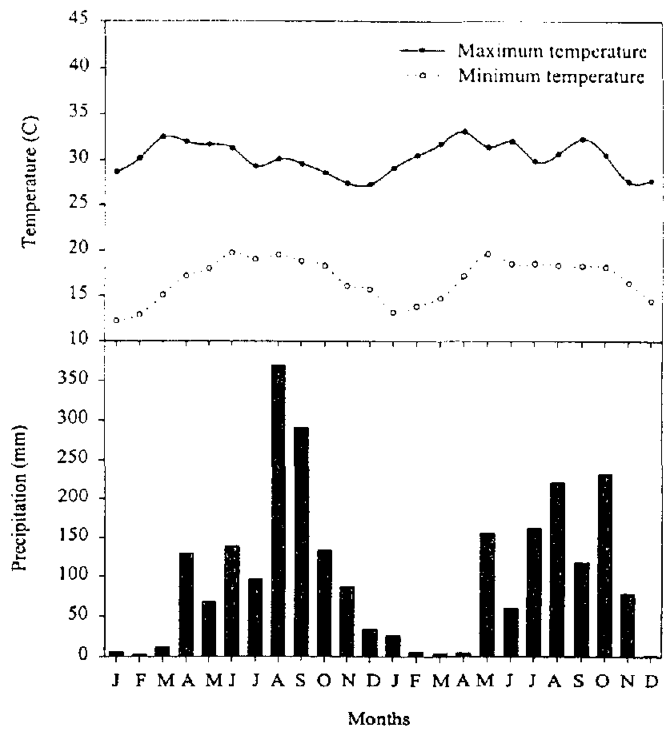

Figure 1. Monthly accumulated precipitation and maximum and minimum temperatures from January 1995 to December 1996 at El Zamorano, Honduras.

Previous management of San Nicolás. San Nicolás is a 6.5 ha field under CT for at least 30 years that has a loam to sandy loam soil type with 2.2% organic matter and 5.2 soil pH. In 1990, San Nicolás was divided in nine plots and three main treatments were replicated three times: CT, NT and a yearly CT:NT rotation (Dejud and Pitty, 1991). In 1991, the cover crop velvet bean (*Stizolobium deeringianum* (L.) Bort.) was intercropped with maize on half of all plots (Vega and Pitty, 1992). In 1992, the tillage rotation treatment was eliminated and changed to tillage equipment using water buffalos (*Bubalus bubalis* L.) (Zelaya, 1994).

Tillage evaluation. Weed population dynamics were monitored for 19 months in CT and NT systems. One 100 m^2 plot was assigned to each tillage system and replicated three times. Tillage was done on May 22 and May 23, 1995 and glyphosate (N-(phosphonomethyl) glycine) was applied on May 24, 1995. The CT treatment involved one moldboard plow pass and two disc passes, while NT was treated with 1.5 kg ai/ha of glyphosate. The first weed sampling was conducted one month after the treatments were applied. Weed populations were determined by counting the number of species and individuals per species that emerged from each plot. The sample area was 0.5 m^2 and for each plot, five arbitrarily assigned subsamples were taken. *Amaranthus*, *Ipomoea*, *Desmodium*, *Chloris*, and *Digitaria* species were not separated beyond the genus level due to difficulties in distinguishing seedlings under field conditions but mature plants were identified (Table 1). *Acalypha* and *Isocarpha* seedlings and mature plants could not be identified beyond the genus level.

After sampling, treatments were re-applied to eliminate existing vegetation and promote new seedling emergence. In CT, plots were prepared by manually hoeing and mixing the top 20 cm of the soil and NT plots received a uniform spray of paraquat (1,1'-dimethyl-4,4'-bipyridinium ion) at 1.0 kg ai/ha. Weed samples were taken every month from June 1995 to December 1996, except for October 1995 and 1996 when plots were flooded.

Data were analyzed as repeated measures with tillage system as the main plot and the sampling date as the repeated measure. Data analysis was conducted by analysis of variance (ANOVA) and means were separated with Fisher's least significant difference (LSD) test and reported ($P \leq 0.05$) significance level (SAS, 1987). Spearman's correlation coefficients were calculated to describe weed emergence as it related to mean monthly temperature and precipitation (SAS, 1979).

Population heterogeneity indexes were calculated for grasses, broadleaves, sedges, and total weed species. The Shannon and Wiener function was used to estimate the population diversity in both tillage systems (Krebs, 1985). This function measures the amount of uncertainty and estimates distribution of individuals between species. Population diversity measured by the Shannon and Wiener function is higher with greater and more equitable distribution of species (Krebs, 1985).

Statistical differences between the species diversity index obtained in CT and NT were determined by a Hutcheson test (Zar, 1996). This test evaluated the null hypothesis that the diversities in CT and NT were equal.

Table 1. Generic grouping of weed species at San Nicolás, El Zamorano, Honduras, 1995-1996.

Weed group	Family	Species
Broadleaves	Amaranthaceae	*Amaranthus hybridus*
		Amaranthus spinosus
		Amaranthus viridis
	Convolvulaceae	*Ipomoea nil*
		Ipomoea purpurea
	Fabaceae	*Desmodium canum*
		Desmodium tortuosum
Grasses	Poaceae	*Chloris radiata*
		Chloris virgata
		Digitaria horizontalis
		Digitaria sanguinalis

RESULTS AND DISCUSSION

Effect of tillage on weed population dynamics. The weed community consisted of 45 species distributed in 39 genera and 17 families. More sedges and total weed plants occurred in CT while grasses were prevalent in NT (Table 2). *Cyperus rotundus* L. was the only sedge species encountered but accounted for 74% of the total weeds found in CT. Stoller (1975) cited that *C. rotundus* propagation in cultivated fields was almost entirely by tubers. Pitty and Muñoz (1991) indicated that moist soil conditions and tillage promoted *C. rotundus* propagation. Tillage divides the tuber chain and eliminates the apical dominance exerted by the distal tuber thus promoting the germination of many tubers (Smith and Fick, 1937; Muzik and Cruzado, 1953). Compared to the dry season, greater *C. rotundus* population differences between CT and NT were obtained during the rainy season (Figure 2). *C. rotundus* emergence in CT was correlated to the distribution of precipitation suggesting that this species requires humid conditions to establish (Table 3). Rochecouste (1956) reported that *C. rotundus* was a more serious weed in sugar cane (*Saccharum officinarum* L.) fields when growing in wet soils.

CT had more total weeds than NT but this difference was a result of the higher *C. rotundus* populations found in CT (Table 2; Figure 2). Weed emergence was correlated to precipitation (Table 3). The availability of moisture has been reported to be an important resource for competition between crops and weeds (Everaarts, 1993). Zimdahl *et al.* (1988) reported that tillage favored weed emergence by exposing buried seeds to radiant energy that promoted germination.

Table 2. Plants per m^2 that emerged in conventional (CT) and no tillage (NT) systems from June 1995 to December 1996[1].

Family	Species	CT	NT
Sedges			
Cyperaceae	*Cyperus rotundus*	137.8 a[2]	2.2 b
	Total sedges	137.8 a	2.2 b
Grasses			
Poaceae	*Cenchrus echinatus*	0.1 b	5.3 a
	Chloris spp.	0.0 a	0.2 a
	Cynodon dactylon	1.7 a	0.1 b
	Digitaria spp.	1.5 b	14.6 a
	Eleusine indica	0.2 b	1.3 a
	Leptochloa filiformis	0.6 a	4.6 a
	Panicum maximum	0.0 a	0.1 a
	Sorghum halepense	1.6 a	2.7 a
	Total grasses	5.7 b	28.9 a

Table 2. Continuation.

Family	Species	CT	NT
Broadleaves			
Aizoaceae	*Mollugo verticillata*	0.2 a	0.1 a
Amaranthaceae	*Amaranthus* spp.	0.2 a	0.5 a
Asteraceae	*Ageratum conyzoides*	13.8 a	0.1 b
	Bidens pilosa	0.1 a	0.1 a
	Isocarpha spp.	0.0 a	0.1 a
	Melampodium divaricatum	0.1 a	0.1 a
	Sclerocarpus phyllocephalus	8.0 a	9.3 a
	Sonchus oleraceus	0.0 a	0.1 a
	Spilanthes ocymifolia	2.7 a	2.2 a
	Tithonia tubaeformis	11.6 a	19.2 a
Commelinaceae	*Commelina diffusa*	2.6 a	0.0 b
Convolvulaceae	*Ipomoea* spp.	0.1 a	0.1 a
	Merremia *quinquefolia*	0.0 a	0.2 a
	Quamoclit cholulensis	0.1 a	0.1 a
Euphorbiaceae	*Acalypha* spp.	0.1 a	0.1 a
	Euphorbia hirta	0.0 b	0.2 a
Fabaceae	*Aeschynomene americana*	0.0 b	0.1 a
	Crotalaria pallida	1.8 a	0.0 b
	Desmodium spp.	0.0 a	0.1 a
	Mimosa pudica	0.1 a	0.1 a
Malvaceae	*Sida acuta*	0.1 a	0.1 a
Oxalidaceae	*Oxalis corniculata*	0.0 a	0.1 a
Papaveraceae	*Argemone mexicana*	0.0 a	0.1 a
Portulacaceae	*Portulaca oleracea*	0.0 a	0.2 a
Rubiaceae	*Mitracarpus hirtus*	0.0 a	0.3 a
	Richardia scabra	0.2 b	1.8 a
Scrophulariaceae	*Scoparia dulcis*	0.6 a	0.2 a
Solanaceae	*Nicandra physalodes*	0.3 a	0.0 b
	Physalis ignota	0.1 a	0.1 a
Zygophyllaceae	*Kallstroemia maxima*	0.0 b	0.1 a
	Total broadleaves	42.4 a	35.1 a
	Total weeds	186.0 a	66.3 b

[1] Data are averaged from all sampling dates.
[2] Means in rows followed by the same letter are not significantly different at the P ≤ 0.05 level determined by Fisher's LSD test.

Grasses predominated in NT (Table 2; Figure 2) but emergence did not correlate well with the mean temperature and precipitation fluctuations (Table 3). Several investigations reported that NT favored the establishment of annual and perennial grass populations (Pleasant *et al.*, 1990; Godoy *et al.*, 1995). Froud-Williams *et al.*, (1983a) suggested that because most seeds in NT are near the surface, small-seeded grasses are exposed to light that promotes germination. Buhler and Pitty (1997) indicated that more annual grasses emerge from NT and seed burial as in CT, reduces seed survival.

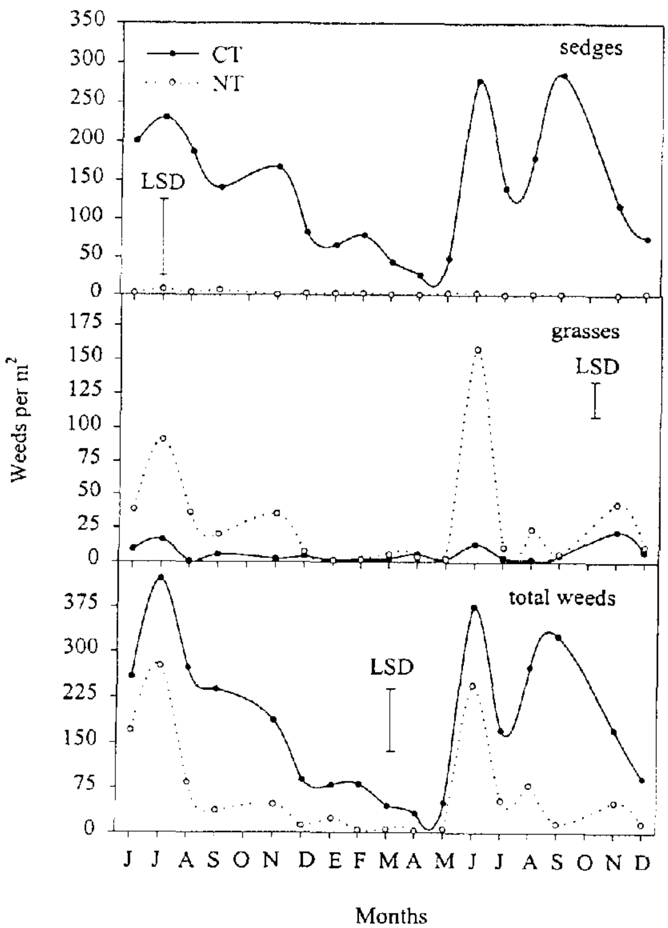

Figure 2. Sedges, grasses and total weeds emergence from June 1995 to December 1996 in conventional (CT) and no tillage (NT) systems in Zamorano, Honduras.

In the tropics, *Cynodon dactylon* (L) Pers. and *Commelina diffusa* Burm. f. are perennial weeds that reproduce by seeds or stolons (Pitty and Muñoz, 1991). *C. dactylon* and *C. diffusa* populations were higher in CT with greater fluctuations in emergence during the rainy season (Table 2; Figure 3). However, there were no significant interactions between *C. dactylon* or *C. diffusa* emergence with temperature or precipitation. Godoy *et al.* (1995) observed greater *C. diffusa* populations in CT and suggested that tillage segmented *C. diffusa* stems thus promoting dissemination and reproduction. Holm *et al.* (1977) reported that tillage enhanced *C. dactylon* dissemination in the field and suggested that cultivation segmented *C. diffusa* stems thus promoted root regrowth from the nodes. In addition, *C. diffusa* establishment was favored by wet soil conditions and was reported to be a greater competitor in heavily shaded habitats (Goldberg and Kigel, 1986; Pitty and Muñoz, 1991).

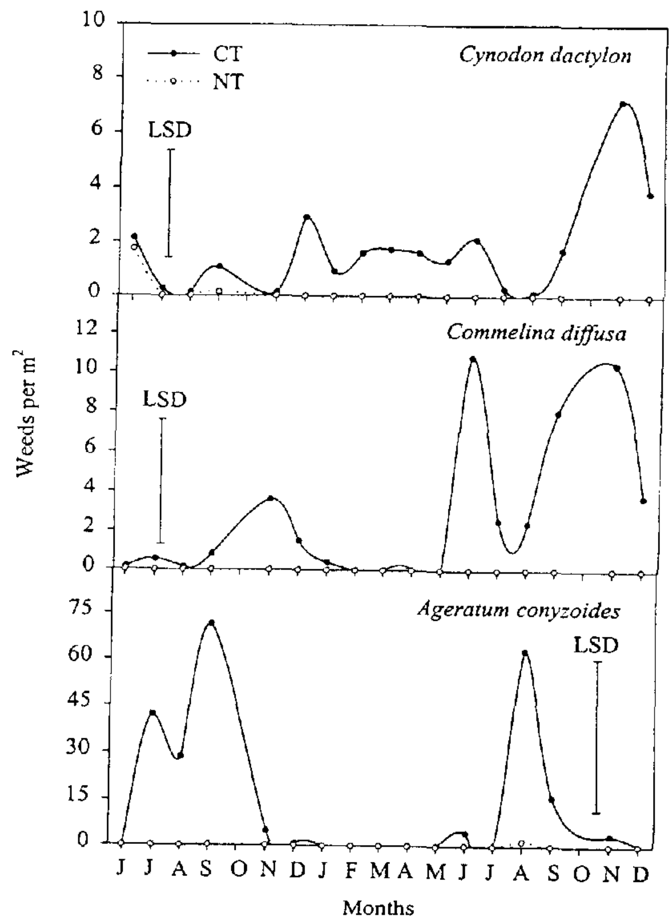

Figure 3. *Cynodon dactylon*, *Commelina diffusa* and *Ageratum conyzoides* emergence from June 1995 to December 1996 in conventional (CT) and no tillage (NT) systems in Zamorano, Honduras.

Ageratum conyzoides L. populations were more than 100 times greater in CT than in NT and emergence increased in July and ceased in November (Table 2; Figure 3). The emergence in CT correlated with precipitation (Table 3). This species is well adapted to tillage and water availability is important for growth (Maciel, 1980).

Crotalaria pallida Aiton. was found only in CT and significant differences in emergence ocurred during the rainy season (Table 2; Figure 4). The emergence in CT correlated with precipitation (Table 3). It is possible that under NT, seeds at the soil surface were exposed to greater predation. Moore (1978a; 1978b) reported 20% to 100% *C. pallida* seed predation by phytophagous insects.

Nicandra physalodes (L.) Gaertner was only found in CT and populations were higher in June, July and August of 1995 and 1996 (Table 2; Figure 4). Emergence correlated with the distribution of rain (Table 3). This species is well adapted to tillage (Kelly, 1964) and higher populations occur with high rainfall (Hawton, 1976).

Aeschynomene americana L. populations were higher in NT compared to CT, however, significant differences were only observed for June 1996 (Table 2; Figure 4). Precipitation and temperature did not effect the emergence pattern. The emergence of *A. americana* is epigeal thus cultivation can easily control germinated seedlings (Thro *et al.*, 1990) and may contribute to lower populations in CT.

Cenchrus echinatus L. populations in NT were 53 times greater than in CT but significant differences between NT and CT were only obtained in July 1995 and June 1996 (Table 2; Figure 5). The emergence in CT correlated with temperature (Table 3). Zelaya *et al.* (1994) found greater *C. echinatus* populations in NT than in CT.

Digitaria spp. populations in NT were almost 10 times higher than in CT and greater NT populations occurred during the rainy season (Table 2; Figure 5). Emergence correlated with fluctuations in rain (Table 3). Teasdale *et al.* (1991) found higher *Digitaria sanguinalis* (L.) Scop. populations in NT and indicated that crop residues did not affect populations. *D. sanguinalis* is normally an annual in temperate regions, but can behave as a perennial in the tropics. This is a prolific seed producer with short innate dormancy thus seed accumulation at the soil surface, typical in NT, may favor emergence. *D. sanguinalis* emergence is highly influenced by soil moisture (King and Oliver, 1994).

Table 3. Spearman's correlation and probability between weed emergence and mean monthly temperature and monthly accumulated precipitation in conventional (CT) and no tillage (NT) systems, El Zamorano, Honduras1995-1996.

Weed species or group	Tillage	Statistic	Temperature	Precipitation
Ageratum conyzoides	NT	correlation	0.00	0.15
		probability	0.98	0.57
	CT	correlation	0.01	0.52
		probability	0.96	0.03
Crotalaria pallida	NT	correlation	0.24	0.14
		probability	0.34	0.57
	CT	correlation	0.26	0.36
		probability	0.30	0.15
Nicandra physalodes	NT	correlation	0.31	0.13
		probability	0.23	0.61
	CT	correlation	0.30	0.53
		probability	0.23	0.02
Cenchrus echinatus	NT	correlation	0.24	0.40
		probability	0.36	0.11
	CT	correlation	0.44	0.21
		probability	0.07	0.42
Digitaria spp.	NT	correlation	0.11	0.47
		probability	0.66	0.06
	CT	correlation	0.02	0.17
		probability	0.93	0.50
Richardia scabra	NT	correlation	0.45	0.51
		probability	0.07	0.03
	CT	correlation	0.32	0.39
		probability	0.21	0.12
Total sedges	NT	correlation	0.23	0.34
		probability	0.38	0.17
	CT	correlation	0.35	0.56
		probability	0.16	0.02
Total grasses	NT	correlation	0.16	0.36
		probability	0.53	0.15
	CT	correlation	0.03	-0.16
		probability	0.89	0.44
Total weeds	NT	correlation	0.20	0.54
		probability	0.43	0.02
	CT	correlation	0.28	0.55
		probability	0.26	0.02

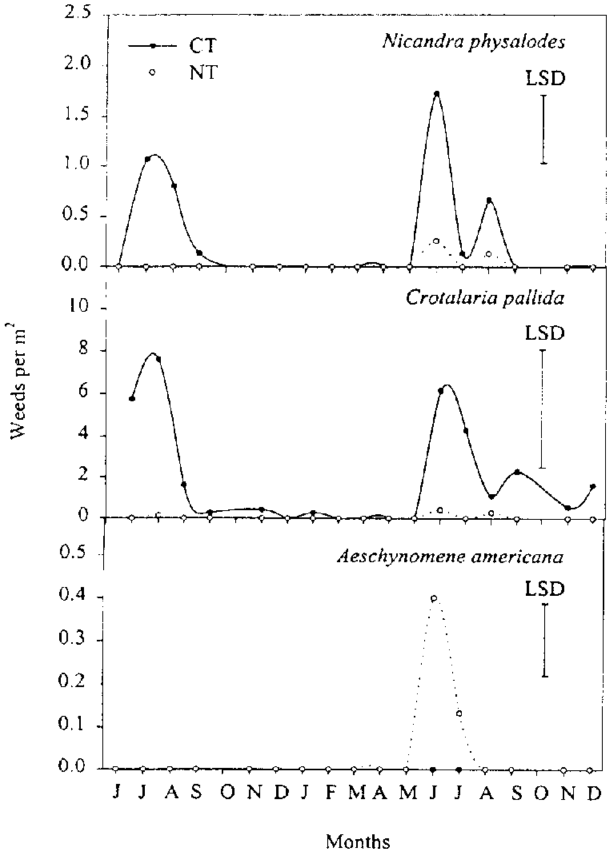

Figure 4. *Nicandra physalodes*, *Crotalaria pallida* and *Aeschynomene americana* emergence pattern from June 1995 to December 1996 in conventional (CT) and no tillage (NT) systems in Zamorano, Honduras.

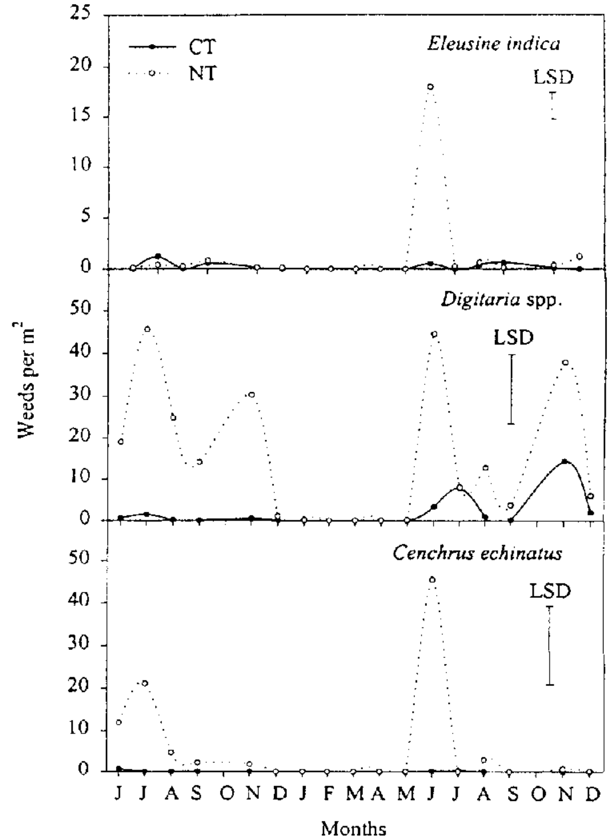

Figure 5. *Eleusine indica*, *Digitaria* spp. and *Cenchrus echinatus* emergence pattern from June 1995 to December 1996 in conventional (CT) and no tillage (NT) systems in Zamorano, Honduras.

Eleusine indica (L.) Gaertner populations were higher in NT but statistical differences were only obtained in June 1996 (Table 2; Figure 5). No significant interaction between emergence and precipitation or temperature were observed. Teasdale *et al.* (1991) reported higher *E. indica* populations in NT than in cultivated plots. Seeds at the surface on NT soils may have been exposed to light which promoted germination. Holm *et al.* (1977) indicated that *E. indica* germination was stimulated by light. Hawton and Dreennan (1980) found that burial beyond 8 cm was detrimental to *E. indica* emergence suggesting that CT created adverse conditions for seedling emergence.

Euphorbia hirta L. was only found in NT and populations were higher during the rainy season (Table 2; Figure 6). However, no significant interactions between emergence and precipitation or temperature were observed. Singh *et al.* (1937) obtained positive correlations between precipitation and *E. hirta* populations and concluded that weed density was determined by precipitation. In addition, Ramakrishnan (1960) reported that the occurrence of different *E. hirta* ecotypes depended on the edaphic conditions and indicated that erect ecotypes predominated during the rainy season.

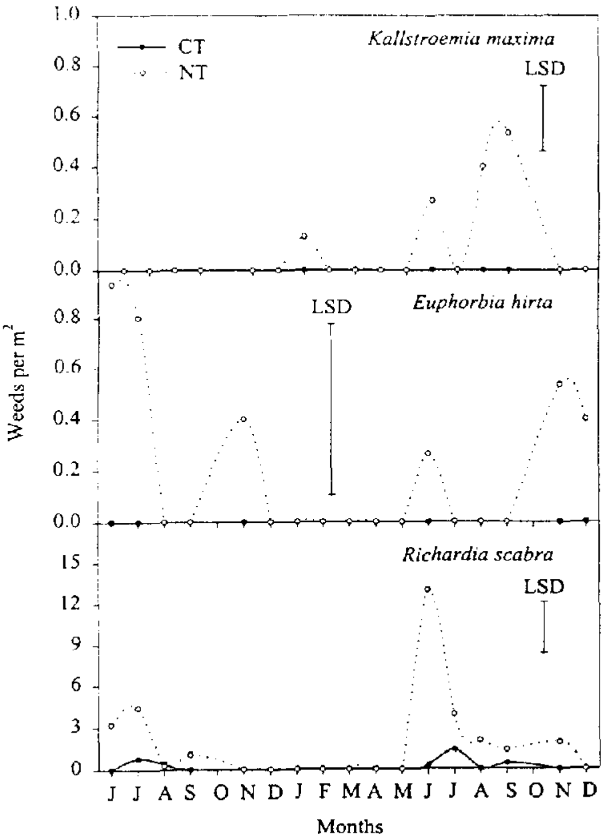

Figure 6. *Kallstroemia maxima*, *Euphorbia hirta* and *Richardia scabra* emergence from June 1995 to December 1996 in conventional (CT) and no tillage (NT) systems in Zamorano, Honduras.

Richardia scabra L. populations were nine times higher in NT when compared to CT and significant emergence differences were observed in July 1995 and June and July 1996 (Table 2; Figure 6). Population distribution correlated with precipitation and temperature (Table 3). Biswas *et al.* (1975) indicated that *R. scabra* emergence in the field was highly dependant on moisture conditions. Seeds in NT are found near the surface (Pareja *et al.*, 1985) and *R. scabra* germination may be enhanced because of exposure to light. Biswas *et al.* (1975) reported that little *R. scabra* emergence occurred when seeds were deeper than 1.5 cm thus suggesting that tillage may enforce dormancy.

Kallstroemia maxima (L.) Torr. & Gray populations were higher in NT, but significant differences were only observed for June, August, and September 1996 (Table 2; Figure 6). No significant interactions between emergence and precipitation or temperature were obtained. *K. maxima* is an annual weed with a deep root system that provides resistance to drought conditions. This species can grow throughout the year with adequate moisture conditions (Porter, 1969).

Weed population heterogeneity. No significant differences were obtained between the diversity index of sedges, grasses, and broadleaves in NT and CT (Table 4). Nevertheless, the diversity index for total weeds was higher in NT than in CT, indicating that NT had a more heterogeneous distribution of species. The equitability of the diversity index in CT was lower than in NT indicating that CT had reduced by almost 70%, the total possible diversity (Table 4). Lower equitable diversity index in CT may be attributable to the *C. rotundus* populations which accounted for more than 74% of the total weeds found in CT (Table 4). Several studies in Central America found higher diversity index for the total weed community and broadleaf weeds in NT thus suggesting that tillage reduces the diversity of weeds in the fields (Monroy *et al.*, 1993; Godoy *et al.*, 1995). In addition, studies in temperate regions report more diverse weed populations under NT (Cardina *et al.*, 1991; Buhler *et al.*, 1994). Repeated tillage practices tend to reduce the diversity of species.

CONCLUSIONS

Greater weed populations occurred in the rainy season compared to the dry season and the total weed emergence correlated better with the distribution of precipitation, thus indicating that moisture availability is an important determinant of weed emergence in the tropics. In the temperate regions weed emergence is promoted by warm temperature, however temperature had little effect of the emergence of tropical weed species. *C. rotundus*, *C. dactylon*, *C. diffusa*, *A. conyzoides*, *C. pallida*, *N. physalodes*, and the total weed population were higher in CT systems. Farmers with *C. rotundus*, *C. dactylon*, or *C. diffusa* infestations should manage their fields under NT to prevent further propagation and dissemination of these species. *A. conyzoides* emergence occurred in July thus represents a potential problem in traditional Honduran relay crops as dry beans (*Phaseolus vulgaris* L.). *A. americana*, *C. echinatus*, *Digitaria* spp., *E. indica*, *E. hirta*, *R. scabra*, *K. maxima*, and the total grass population were higher in NT systems. Grasses represent a greater weed problem and the accumulation of surface residue may reduce the efficacy of pre-emergence herbicides in NT.

NT had a more heterogeneous distribution of species thus suggesting that tillage reduces the diversity of weeds. Reproduction of perennials which require fragmentation for dissemination and establishment was favored in CT. Weed control should rely on herbicides but mechanical and cultural practices are to be considered as important components to the management of weeds in the tropics.

Table 4. Population heterogeneity comparisons in conventional (CT) and no tillage (NT) systems, El Zamorano, 1995-1996.

Tillage	Plants/m²	S [1]	H_{max} [3]	H [4]	E [5]	df [6]	t value
Sedges							
NT	279	1	0.00	0.00 a	0.00	355	0
CT	17579	1	0.00	0.00 a	0.00		
Grasses							
NT	3696	8	3.00	1.99 a	0.66	1329	-3.9
CT	727	7	2.81	2.15 a	0.76		
Broadleaves							
NT	4475	29	4.86	2.01 a	0.41	8105	-14.6
CT	5413	23	4.52	2.52 a	0.56		
Total weeds							
NT	8450	38	5.25	3.11 a	0.59	19085	66.3
CT	23719	31	4.95	1.60 b	0.32		

[1] Total number of species per tillage system

[3] Maximum species diversity index

[4] Shannon and Wiener diversity index. Indices in column within group followed by an equal letter are not significantly different at the $P \leq 0.05$ level determined by Hutcheson's test.

[5] Equitability of the Shannon and Wiener diversity index.

[6] Degrees of freedom.

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