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Comparison of Weed Populations in Conventional Till and No-till Experimental Agroecosystems

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경운 및 무경운 실험 농업생태계에서의 잡초개체군의 비교

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ABSTRACT

The weed population dynamics as affected by contrasting conventional tillage (CT) and no-tillage (NT) practices with a minimum herbicide application was studied in Athens, Georgia, U.S.A. Common chickweed (*Stellaria media*) was the most common spring weed while johnsongrass (*Sorghum halepense*), sicklepod (*Cassia obtusifolia*), and pigweed (*Amaranthus retroflexus*) accounted for 89~97% of net production during summers of 1983 and 1984. Total weed production in summer of 1984 was 2~5 times greater than that of 1983. Weed production was greater in NT plots than in CT plots in summer of 1983, but reverse was the case in summer of 1984. In spring, net production in NT plots was greater than that in CT plots, especially, in 1985. Species diversity was consistently higher in NT plots, but in the wet summer of 1984 the pattern was different, with higher diversity in CT plots. Weed species diversity was higher in the spring rye crop than in the summer grain sorghum crop. The larger but less diverse weed populations in summer of 1984 indicated that these populations experienced competitive exclusion. Under the favorable summer moisture conditions the three dominant species grew so vigorously and quickly as to exclude many less common species that were able to survive under the drier conditions in 1983. The three dominant species not only excluded other weeds in 1984 but also greatly reduced crop production. The perennial johnsongrass was equally successful, or even more so, in CT plots as in NT plots. Plowing did not kill johnsongrass rhizomes but tended to break them up, thus increasing the number of individual plants that appear after the plowing. It means that johnsongrass was not controlled by the plowing. In summer of 1983, a moderate amount of weedy growth was maintained with a minimum amount of herbicide application in NT and CT plots. It is possible that a small mixed weed population would be beneficial by providing cover for predatory and parasitic arthropods, and by reducing soil temperature and moisture losses.

Key words: Coventional tillage, Net production, No-tillage, Species diversity, Weed population

INTRODUCTION

A weed is a plant growing where it is not desired (Terminology Committee of the Weed Science Society of America, 1956). Crop yields may be greatly reduced by heavy growth of weeds. However, weeds if not too numerous may have beneficial effects on crops. For instance, they may have an important role in the cycling of crop nutrients. In areas of high rainfall such as the southern United States, weeds may function as biotic storage pools for crop nutrients that would be leached from the ecosystems if there were no weeds.

Historically, tillage has been applied in agroecosystem as a means of controlling weeds. Beginning in the 1940s, widespread availability of increasingly selective and effective herbicides has lessened the need for plowing to control weeds, and, accordingly, made reduced or conservation tillage feasible (Aldrich 1984). Reducing tillage lowers the needs for fossil fuel, equipment and labor, and reduces soil erosion which is a serious problem wherever annual row crops are grown. Despite availability of herbicides and reduced germination of buried seeds, problems with weeds are often cited as a disadvantage for no-tillage. Theoretically, when tillage is eliminated or reduced, the competitive ability of perennial weeds should allow them to increase and become increasingly dominant (Aldrich 1984). In order to manage and control weeds with a minimum use of herbicide, we need to research the interactions and relationships of weeds and crops in agroecosystems subject to different tillage practices. Such studies should also contribute to ecological concepts and principles.

In order to measure the character of a community we need to calculate species diversity (Begon *et al.* 1990). A number of species diversity indices have been derived by many scientists (Sorensen 1948, Simpson 1949, Pielou 1966, Hutcheson 1970, Lyons and Hutcheson 1978).

The present study was undertaken to investigate the seasonal change in abundance, productivity, dominance, and diversity of weed species in plots of no-tillage and conventional tillage agroecosystems that had been intensively studied by a team of staff and students of the Institute of Ecology, University of Georgia.

MATERIALS AND METHODS

The research area is located on the Horseshoe Bend Research Area in a band of the Oconee River on the Piedmont Region in Athens, Georgia. The two 1 acre (0.4 ha) experimental plots, are on an upper terrace of the river floodplain. The soil is a Hiwasee loam (Typic Rhodudults) as classified under the 1975 Soil Conservation Service system. Prior to 1966 the area was used for forage crop production. In 1966 a study of the effect of the insecticide, Sevin, on the whole commuity of a planted millet field was carried out (Barett 1968). Between 1967 and 1977 no crops were planted and the area allowed to undergo natural succession. A number of ecological studies on these "old-fields" were carried out (Odum *et al.* 1973, Bakelaar and Odum 1978).

In 1976 a series of agroecological studies that involved comparing no-tillage and conventional tillage cropping procedures were launched in the old-field study sites (House *et al.* 1984, Stinner *et al.* 1984, Groffman *et al.* 1986, Hendrix *et al.* 1986). During the 1983~1985 period a study of the weed population in both conventional tillage and no-tillage area was carried out by Park (1987). Complete site characteristics are given in Groffman *et al.* (1986).

During the 1983~1985 period when this study was being carried out there were eight 0.25 acre plots; 4 plots were plowed twice a year, hereafter designated CT plots, and 4 plots were not plowed, hereafter designated NT plots. Rye and sorghum were the winter crop and summer crop, respectively, during these years. All plots were fertilized each year with the same amount of N, P, and K, and all plots were last limed in 1980. Roundup (glyphosate) herbicide (6.5l/ha, 41%) was applied to all plots once a year, in May, prior to planting the summer crop. No insecticides were applied, or have been used in the area since 1966.

Weeds were randomly sampled on 48 0.5m×0.5m quadrats at approximately one month intervals, March and April for the winter-spring crop and June-October for the summer crop. The weeds were clipped to ground level and sorted by species. Samples were dried in an air forced oven at 60℃ for one week, then weighed. Representative whole plants were dug up in each plot to estimate root:shoot ratios of each species. Root:shoot ratios were used to calculate the total biomass of each species. Peak biomass of each species was summed to estimate net production. Since the litter fall of weeds and consumption of weeds by herbivores were not measured, net production figures are minimum estimates. Crop biomass and yield were routinely measured by the research team.

A number of diversity indices such as Simpson index, Shannon index, Pielou's evenness index, species richness index, and similarity indices were calculated for comparison of NT and CT agroecosystems. All indices were calculated on the basis of net production values for each species.

RESULTS

Rainfall for the winter-spring and the summer growing seasons is shown in Table 1. Rainfall in July, the month of most rapid growth of crops and weeds, was greater (about double) in 1984 than in 1983 when precipitation was near average for the region. The two

Table 1. Rainfall at Horseshoe Bend Experimental area during crop growing seasons 1983~1985

Year	Season	Month	Rainfall, cm
1983	Summer	June	15.7
		July	5.0
		August	7.4
		September	18.2
1984	Winter-spring	January	17.2
		February	16.8
		March	13.0
		April	11.8
1984	Summer	June	5.7
		July	23.5
		August	10.6
		September	0.0
1985	Winter-spring	January	6.5
		February	16.9
		March	2.9
		April	4.6

winter-spring seasons were not appreciably different and were near average.

Species composition and net production (maximum biomass) by species are displayed in Table 2. A completely different set of weeds was associated with the rye and the sorghum crop. Common chickweed (*Stellaria media*) was the most common spring weed while johnsongrass (*Sorghum halepense*), sicklepod (*Cassia obtusifolia*), and pigweed (*Amaranthus retroflexus*) accounted for 89~97% of net production during both summers. Johnsongrass was the major dominant except in the 1983 CT plots where sicklepod and pigweed were more productive. Total weed production in summer of 1984 was 2~5 times greater than that of 1983. Weed production was greater in NT plots in summer of 1983, but reverse was the case in summer of 1984. In spring, net production in NT plots was greater than that in CT plots, especially, in 1985.

Mean weed biomass by months is shown in Table 3. By late summer in 1983 there were more weeds in NT as compared to CT although differences were statistically significant only in August. In contrast, weed biomass in 1984 was significantly higher in CT plots in 3 out of 4 summer months. As would be expected weed biomass was very much smaller in the spring than in summer, and posed no threat to rye crop yield. Only in April 1985 was the difference between NT and CT statistically significant.

The seasonal growth of crops and weeds is compared in Figs. 1 and 2. The wet summer of 1984 was the first season in the ten year history of the Horseshoe Bend experiments that weeds "got out of hand", so to speak, and reduced drastically the crop biomass and grain yield in both NT and CT plots. By the end of the 1983 growing season weed biomass was 12% and 25% as large as crop biomass in CT and NT plots, respectively (Fig. 1), and grain yields were good. In contrast, the biomass of weeds at the end of the 1984 season equaled or exceeded crop biomass (Fig. 2), and grain yields were greatly reduced.

Species diversity indices based on the net production are compared in Table 4. Diversity was consistently higher in NT plots, but again the wet summer of 1984 was different, with higher diversity in CT plots. Weed species diversity was higher in the spring rye crop than in the summer grain sorghum crop. These results were confirmed by dominance-diversity profiles which contrast the 1983 and 1984 summer seasons (data not shown).

Table 2. Net production of weed species in no-till (NT) and conventional till (CT) plots

Spring weeds associated with rye crop net production (max. biomass), kg/ha		1984		1985	
		NT	CT	NT	CT
Stellaria media	(Common chickweed)	64.0	109.5	71.2	91.6
Lamium amplexicaule	(Henbit)	30.2	79.5	18.1	63.5
Veronica arvensis	(Corn speedwell)	44.7	4.3	30.2	7.4
Valerianelle spp.	(Corn salad)	32.4	0.6	14.0	1.6
Geranium carolinianum	(Carolina geranium)	25.8	1.5	25.8	0.4
Trifolium procumbens	(Big hopclover)	14.9	3.1	33.1	0.03
Vicia spp.	(Vetch)	3.5	–	97.8	4.9
Cerastium vulgatum	(Mouseear chickweed)	4.0	16.9	2.4	1.8
Cardamine hirsuta	(Hairy bittercress)	1.9	2.5	4.7	1.2
Viola spp.	(Violet)	4.6	0.5	5.6	1.0
Daucus carota	(Wild carrot)	0.8	–	–	1.0
Capsella bursa-pastoris	(Shepherd's purse)	–	–	–	–
Unidentified		46.6	38.2	9.3	2.2
Totals		273.4	256.6	312.4	176.9

Summer weeds associated with rye crop net production (max. biomass), kg/ha		1983		1984	
		NT	CT	NT	CT
Sorghum halepense	(Johnsongrass)	2202.0	98.6	5402.3	6158.7
Cassia obtusifolia	(Sicklepod)	844.2	940.3	1034.8	830.8
Amaranthus retroflexus	(Redroot pigweed)	710.8	662.2	422.9	2217.5
Amaranthus hybridus	(Hybrid pigweed)	–	–	18.9	154.6
Cyperus spp.	(Sedge)	148.7	29.5	8.9	25.7
Ipomoea spp.	(Morning glory)	3.0	–	13.9	38.2
Euphorbia spp.	(Spurge)	2.2	–	11.7	–
Campsis radicans	(Trumpet vine)	22.2	–	6.5	18.9
Acalypha virginica	(3-seeded sercury)	0.4	0.3	–	–
Croton monanthogynus	(Cronton)	77.8	2.5	–	–
Ranunculus spp.	(Buttercup)	0.8	–	–	–
Oxalis spp.	(Wood sorrel)	0.1	–	–	–
Rubus allegheniensis	(Blackberry)	20.6	–	–	–
Xanthium pensylvanicum	(Cocklebur)	3.2	–	–	–
Solanum carolinense	(Horse-nettle)	8.3	3.3	–	–
Malva spp.	(Mallow)	11.9	–	–	–
Mollugo verticillata	(Carpetweed)	0.1	0.3	–	–
Trifolium procumbens	(Big hopclover)	0.2	–	–	–
Vicia spp.	(Vetch)	0.5	–	–	–
Total		4238.7	1750.8	6919.8	9445.1

Species composition in NT and CT plots was more similar in summer of 1984 than in summer of 1983. Sorensen's indices of similarity for summer of 1984 were as follows: qualitative index - 93% and quantitative index - 86%. In contrast, these indices were 62 and 48, respectively, in summer of 1983. Species composition in NT and CT plots was similar in

Table 3. Comparison of mean monthly biomass (±one standard error) of weeds in CT and NT plots

Year	Month	Mean biomass, kg/ha	
		NT	CT
1983	June	125.8±66.6	131.8±61.2
	July	976.9±393.9	1137.7±548.7
	August	**2488.1±524.6***	1118.3±234.1
	September	2793.2±1861.4	1572.5±579.0
1984	March	247.4±33.9	242.2±30.9
	April	96.7±25.3	68.9±17.0
1984	June	281.9±35.2	**521.1±70.4***
	July	1837.4±432.2	**2897.6±444.2***
	August	6350.5±697.5	6503.9±1092.9
	September	6196.2±782.1	9273.7±952.2
1985	March	169.0±20.7	168.0±21.5
	April	**259.5±30.9***	73.7±12.2

* Number in bold face are significantly larger than comparable numbers in the alternative tillage

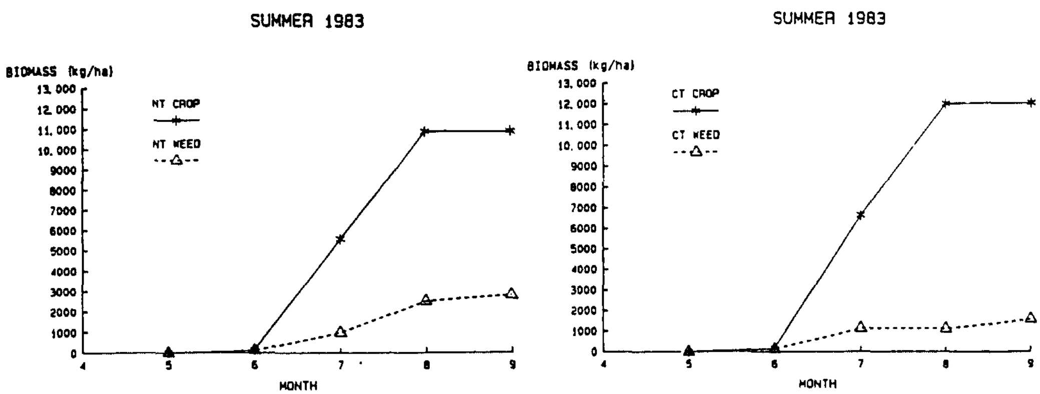

Fig. 1. Growth of crop and weed in summer of 1983.

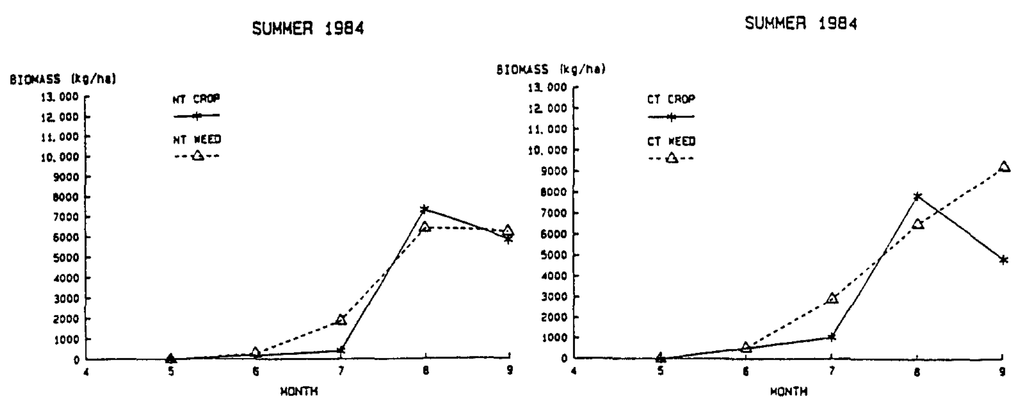

Fig. 2. Growth of crop and weed in summer of 1984.

Table 4. Species diversity indices calculated on the basis of net production. H: Shannon index, d: Simpson index, e: Pielou's evenness index, D: species richness index, S-number of species. H and d were statistically analyzed by t-test

Year	Season	plots	H*	d*	e	D	S
1983	Summer	NT	1.265a	0.623a	0.438	2.035	18
		CT	0.956	0.558a	0.460	0.937	8
1984	Spring	NT	1.923	0.829	0.802	2.603	11
		CT	1.163	0.612	0.529	2.186	10
	Summer	NT	0.703a	0.365a	0.338	0.792	8
		CT	0.951	0.512a	0.489	0.656	7
1985	Spring	NT	1.876	0.808	0.782	1.741	11
		CT	1.151	0.593	0.463	2.125	12

*: all pairs of diversity indices between NT plots and CT plots were significantly different at $\alpha = 0.01$

a: diversity of same seasons between 1983 and 1984, and between 1984 and 1985 were significantly different by t-test at $\alpha = 0.01$

spring of 1984 and 1985. Sorensen's indices of similarity for spring of 1984 and 1985 were 90 and 96%, respectively. However, quantitative indices showed greater differences in species composition (low similarity indices): 54 and 52% in spring of 1984 and 1985, respectively.

DISCUSSION

The larger but less diverse weed populations in 1984 can be explained on the basis of competitive exclusion. Under the favorable summer moisture conditions the three dominant species grew so vigorously and quickly that they excluded many less common species that were able to survive under the drier conditions in 1983. The three dominant species not only excluded other weeds in 1984 but also greatly reduced crop production (compare Figs. 1 and 2). The greater 1984 weed population in CT plots as compared to NT plots was largely the result of greater abundance of pigweed and johnsongrass (Table 2).

The perennial johnsongrass is known far and wide as "one of the world's worst weeds" (Holm *et al.* 1977). In our experience it is equally successful, or even more so, in CT plots as in NT plots. The biomass of johnsongrass in NT and CT plots in September of 1984 was 5,402 kg / ha and 6,159 kg / ha, respectively. Plowing did not kill johnsongrass rhizomes but tends to break them up, thus increasing the number of individual plants that appear after the plowing. This might cause greater reduction of biomass of crop in CT plots than in NT plots at the end of 1984 season (Fig. 2). Bridges and Chandler (1987) have reported an inverse sigmoid relationship between johnsongrass density and yield of seed cotton in Texas. That is, low densities had little effect, but yield reduction increased very rapidly once the density exceeded a sort of threshold.

Over the ten years span of our experiments weed biomass in NT plots at harvest time has been on the average about the same, sometimes larger, sometimes smaller, as in CT plots (personal observation). In other words, no-tillage in our experience has not exacerbated the weed problem when the same amount of herbicide is applied as in conventional tillage. Thus, we may conclude that growing a crop under no-tillage does not necessarily result in weed problems. Odum *et al.* (1994) suggested that a crop-fallow rotation could be a good practice for maintaining soil quality over the long term. As fallow field natural vegetation (Odum *et al.* 1994) and no-tillage vegetation enrich the soil and reduce soil erosion, a serious problem in southeastern United States, a crop- fallow rotation under no-tillage should be advantageous for long term sustainability of soil. In summer of 1983, moderate weedy growth was maintained with a minimum amount of herbicide application in NT and CT plots. Thus, it is possible that a small mixed weed population would be beneficial by providing cover from predatory and parasitic arthropods, and by reducing soil temperature and moisture losses. This conclusion is supported by a number of ecologists (Crossley *et al.* 1984, Kingsley *et al.* 1986). Additionally, control weeds with a minimum amount of herbicide application (roundup (glyphosate) herbicide: 6.5*l* /ha, 41%) is beneficial because herbicides at moderate rates that allow a low level of weeds are believed to slow down the development of resistance to herbicides (Gould 1991). As a result, farmers can save money with a small amount of herbicide application and moderate price of herbicides. Ware (1983) reported that to register a new active pesticide required, on the average, 7 years and $10 million and such expenses were passed on to the consumer.

적 요

미국 죠지아주 Athens에 있는, 최소한의 제초제만을 뿌린, 경운한 밭(CT plots)과 경운하지 않은 밭(NT plots)에 있어서의 잡초의 다양성이 연구되었다. 봄에는 *Stellaria media*가 가장 많았고 1983년과 1984년 여름에는 *Sorghum halepense, Cassia obtusifolia,* 그리고 *Amaranthus retroflexus*가 총생산량의 89~97%를 차지하였다. 1984년 여름에 있어서의 총잡초생산량이 1983년에 비해 2~5배였다. 1983년에는 NT plots에서의 잡초 생산량이 CT plots보다 많았고, 1984년에는 정반대의 결과였다. 특히 1985년 봄에는 NT plots에서의 총 생산량이 CT plots보다 더 많았다. 종의 다양성이 지속적으로 NT plots에서 더 높았다. 그러나, 비가 많이 온 1984년에는 CT plots에서 더 높았다. 잡초의 종류는 수수가 자란 곳보다 봄귀리가 자랐던 곳에서 더 활발하였다. 1984년 여름에는 잡초의 양이 더 많았고 또 잡초의 종류가 덜 다양했으며 이 사실은 이 군집들이 서로를 경쟁적으로 제거했다는 것을 보여준다. 습기가 많아 적절한 환경조건하에서 세가지 우세한 잡초는 매우 강하고 빨리 자람으로써 1983년과 같이 건조한 조건에서 자랄 수 있었던 열세인 잡초들을 자라지 못하게 하였다. 이 세가지 잡초는 다른 잡초 뿐만 아니라 작물의 생산량도 감소시켰다. 다년생 *S. halepense*는 CT plots에서 NT plots에서보다 비슷하거나 더 많이 자랐다. 밭을 가는 것이 *S. halepense*의 지하경을 죽이지 못했고 오히려 지하경의 숫자를 늘려주었다. 이것은 *S. halepense*가 밭을 가는 것에 의해 조절되어지지 않았다는 것을 의미한다. 1983년 여름에는 NT plots과 CT plots 모두에 최소한의 제초제 사용으로써 적절한 양의 잡초가 유지되었다. 이것은 여러 종류의 잡초가 약간씩 섞인 잡초의 군집이 식물을 먹거나 기생하는 절지동물로부터 보호 역할을 하거나, 토양온도나 토양습도가 낮아지는 것을 막아줌으로써 생긴 결과일 수 있다.

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APPENDIX

1. Simpson Index (diversity form)

$$d= \frac{N}{N-1} (1-\sum(n_i / N)^2)$$

$$Var(d)= \frac{2}{N(N-1)} (2(N-2) \sum P_i^3 + \sum P_i^2 - (2N-3)(\sum P_i^2)^2)$$

$$Z_d = \frac{d_1 - d_2}{(var\ d_1 + var\ d_2)^{1/2}}$$

2. Shannon Index

$$H = -\sum(n_i / N) \ln (n_i / N)$$

$$Var\ h = (\sum P_i \ln^2 P_i - (\sum P_i \ln P_i)^2) / N + (s-1) / 2N^2$$

$$t = \frac{h_1 - h_2}{(var\ h_1 + var\ h_2)^{1/2}}$$

3. Pielou's Evenness Index

$e = H / \ln s$

n_i: the biomass of species i

N: the total biomass of the sample

s: the number of species

$P_i = ni / N$

4. The qualititative index of Sorensen

$IS_s = 100(2C / (A + B))$

C: number of species common to two stand (till and no-till)

A: total number of species in NT plots

B: total number of species in CT plots

5. The quantitative index of Sorensen

$ISM_o = 100(2Mw / (MA+MB))$

Mw: the sum of the smaller quantitative values of the speciescommon to two stands

MA: the sum of the quantitative values of all the species in NT plots

MB: the sum of the quantitative values of all the species in CT plots

6. Species richness index

$D = (s-1) / \ln N$

s: number of species

N: biomass of all species